RADIANT Platform - Administrator Guide

Complete guide for managing the RADIANT AI Platform via the Admin Dashboard

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Compliance Frameworks: HIPAA, SOC 2 Type II, GDPR, FDA 21 CFR Part 11

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1. Introduction

1.1 What is RADIANT?

RADIANT is a multi-tenant AWS SaaS platform providing unified access to 106+ AI models through:

- **50 External Provider Models**: OpenAI, Anthropic, Google, xAI, DeepSeek, and more
- **56 Self-Hosted Models**: Running on AWS SageMaker for cost control and privacy
- **Intelligent Routing**: Cognitive Router for optimal model selection
- **Preference Engine**: Personalization learning from user interactions

1.2 Administrator Roles

Role	Permissions	Use Case
Super Admin	Full access to all features	Platform owner
Admin	Tenant management, billing, models	Operations team
Operator	Read access, limited actions	Support team
Auditor	Read-only access to logs	Compliance team

Role Details **Super Admin** - The highest privilege level with unrestricted access:

- Create and delete tenants
- Manage all administrators
- Access all billing and financial data
- Modify system-wide configuration
- Approve production database migrations
- Impersonate any tenant for debugging
- Access compliance and audit reports
- Typically limited to 1-3 people (CTO, lead engineer)

Admin - Day-to-day operations management:

- Create and modify tenants (cannot delete)
- Manage users within tenants
- Configure AI models and providers
- View billing data (cannot modify pricing)
- Monitor system health
- Cannot access other admin accounts
- Typically assigned to operations team members

Operator - Limited support and monitoring:

- View tenant information (read-only)
- View user issues and support tickets
- Monitor system health dashboards
- Cannot modify any configuration
- Cannot access billing or sensitive data
- Typically assigned to support staff

Auditor - Compliance and security review:

- Full read access to audit logs
- Access to compliance reports
- Cannot modify anything
- Cannot view sensitive data (API keys, passwords)
- Access is logged for compliance
- Typically assigned to compliance officers or external auditors

1.3 Key Concepts

Concept	Description
Tenant	Organization with isolated data
User	End-user within a tenant
Subscription	Billing tier (1-7)
Credits	Currency for AI usage
API Key	Authentication for API access
App	Consumer application (Think Tank, etc.)

Tenant Architecture Explained A **Tenant** represents a complete organization using RADIANT. Each tenant has:

- **Complete Data Isolation**: All data is stored with tenant IDs and protected by PostgreSQL Row-Level Security (RLS). One tenant can never access another tenant's data, even if there's a bug in application code.
- **Separate Billing**: Each tenant has its own subscription, credit balance, and usage tracking. Costs are attributed to the correct tenant automatically.
- **Custom Configuration**: Tenants can customize model access, rate limits, and feature flags without affecting other tenants.
- **User Management**: Each tenant manages their own users, roles, and permissions independently.

User vs Administrator **Users** are end-users who interact with RADIANT-powered applications like Think Tank. They:

- Sign up and log in via Cognito
- Use AI models through the API or applications
- Have credits deducted for usage
- Cannot access the Admin Dashboard

Administrators manage the RADIANT platform itself. They:

- Access the Admin Dashboard
- Manage tenants, users, and billing
- Configure AI models and providers
- Have no credits (administrative access is separate)

Credit System Explained Credits are RADIANT's universal currency for AI usage:

- **1 credit = $0.01 USD** (configurable per deployment)
- Different models cost different amounts based on their API pricing
- Credits are deducted in real-time as requests complete
- Tenants can purchase credits or receive them through subscriptions
- Credits can be tracked, audited, and reported on

Example Credit Costs: | Model | Cost per 1K tokens | |-------|------------------| | GPT-4o | 5 credits input, 15 credits output | | GPT-4o-mini | 0.5 credits input, 1.5 credits output | | Claude 3.5 Sonnet | 3 credits input, 15 credits output | | Self-hosted Llama | 0.2 credits (all) |

API Key Types RADIANT supports multiple API key types:

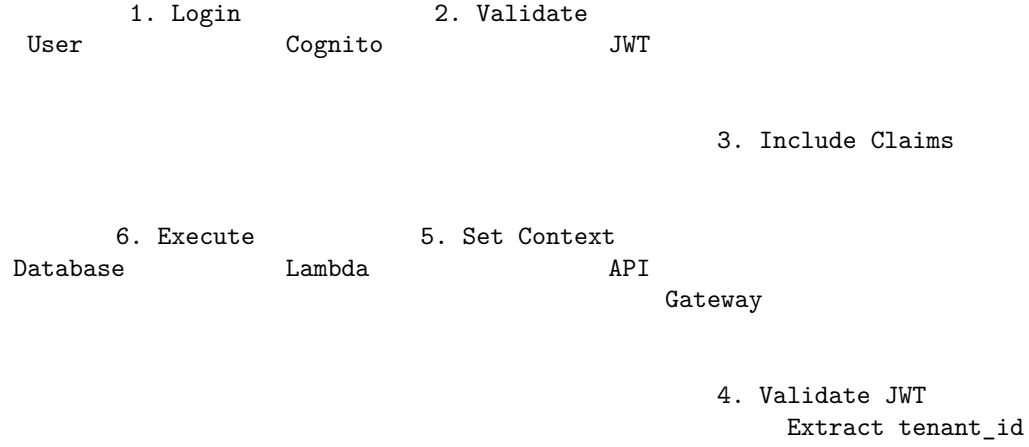
- **User API Keys**: Tied to a specific user, inherit user's permissions
- **Service API Keys**: For server-to-server communication, not tied to a user
- **Admin API Keys**: For administrative operations, require elevated permissions
- **Scoped Keys**: Limited to specific models, endpoints, or rate limits

1.4 Authentication Flow & Security

Detailed Documentation: For comprehensive authentication guides, see:

- Authentication Overview - Architecture and feature matrix
- Platform Admin Guide - Cognito management, global policies
- Security Architecture - Threat models, compliance
- Authentication API Reference - All auth endpoints

JWT-Based Authentication All authentication flows through Amazon Cognito with JWT tokens:



Authentication Steps:

1. **Authentication:** Users authenticate via Amazon Cognito. Upon success, they receive a JSON Web Token (JWT).
2. **Token Validation:** The API Gateway Custom Authorizer validates the JWT signature using Cognito's public keys.
3. **Context Injection:** The Authorizer extracts the immutable `tenant_id` from the JWT claims and injects it into the request context.
4. **Lambda Context Setting:** The Lambda function sets PostgreSQL session variables before any database operation.
5. **RLS Enforcement:** All queries are automatically filtered by the database engine.

JWT Claims Structure

```
{
  "sub": "user-uuid-here",
  "email": "user@example.com",
  "custom:tenant_id": "tenant-uuid-here",
  "custom:app_id": "thinktank",
  "custom:user_role": "member",
  "custom:tenant_role": "admin",
  "iat": 1735570000,
  "exp": 1735573600,
  "iss": "https://cognito-idp.us-east-1.amazonaws.com/us-east-1_XXXXX"
}
```

Critical Security Invariant

> **CRITICAL:** Application code **NEVER** accepts a `tenant_id` from the request body, query parameters, or custom headers. It **ONLY** trusts the ID injected by the API Gateway Authorizer from the cryptographically signed JWT.

This is the single most important security rule in the RADIANT architecture. Violation of this rule creates a critical vulnerability allowing tenant impersonation.

Conditional Access Policies

Condition	Action
New device detected	Require MFA re-authentication
Unusual location	Challenge with security questions
After-hours access	Alert + additional logging
Multiple failed attempts	Temporary lockout + notification
API key from new IP	Rate limit + alert
Tenant status = suspended	Reject all requests
Tenant status = pending_deletion	Reject all requests

1.5 Compute Isolation (Lambda Tenant Isolation Mode)

RADIANT leverages **AWS Lambda Tenant Isolation Mode** (released 2025) to enforce strict boundaries between tenants sharing the same function code.

How It Works

1. **Request Arrival** - Request arrives at Lambda with tenant identifier in event payload
2. **Tenant Detection** - Lambda service inspects the `tenant_id` field from the authorizer context
3. **Environment Binding** - Request routed to execution environment dedicated to that tenant
4. **Isolation Guarantee** - Warm environments are tenant-specific and never reused across tenants
5. **Resource Isolation** - `/tmp` directory and memory are cryptographically isolated per tenant

Security Guarantees

Threat	Without Isolation Mode	With Isolation Mode
`/tmp` data leakage	Possible (shared container)	**Eliminated** (separate microVM)
Memory scraping	Possible (shared memory)	**Eliminated** (isolated memory)
Global variable pollution	Possible	**Eliminated**
Cold start timing attacks	Reduced	**Eliminated**

Threat	Without Isolation Mode	With Isolation Mode
Environment variable exposure	Possible	**Eliminated**

Administrator Verification To verify Tenant Isolation Mode is enabled:

1. AWS Console → Lambda → Function → Configuration → Concurrency
2. Check for "Tenant Isolation: Enabled" badge
3. Or via AWS CLI: `aws lambda get-function-configuration --function-name <name>`

1.6 Three-Layer Authentication Architecture (v5.1.1)

RADIANT implements a comprehensive three-layer authentication system for complete security coverage:

Layer 1: End-User Authentication End users authenticate via AWS Cognito User Pool with support for:

Feature	Description
Email/Password	Standard authentication with strong password policies
MFA	Optional or required TOTP, SMS, or email verification
SSO Federation	SAML 2.0 and OIDC integration for enterprise customers
Domain Enforcement	Force SSO for specific email domains

Database Table: `tenant_users`

- RLS-protected tenant isolation
- Role-based access (standard_user, tenant_admin, tenant_owner)
- Feature flags for app access (Think Tank, Curator, Tenant Admin)

Layer 2: Platform Administrator Authentication Platform admins use a separate Cognito Admin Pool with mandatory MFA:

Role	Permissions
super_admin	Full access, can delete tenants, manage other admins
admin	Tenant/user management, model configuration
operator	Read-only monitoring and support
auditor	Compliance logs and reports only

Database Table: `platform_admins`

- No RLS (cross-tenant access required)
- Permission-based authorization
- Full audit trail of admin actions

Layer 3: Service/Machine Authentication API keys for server-to-server and automated integrations:

Feature	Description
Scoped Access	Fine-grained permissions (chat:read, embeddings:write, etc.)
Rate Limiting	Per-key and global rate limits
IP Restrictions	Whitelist allowed IP addresses
Expiration	Optional key expiration dates

Feature	Description
Audit Logging	All key usage tracked in `service_api_key_audit`

API Key Scopes:

- `chat:read`, `chat:write` - Conversation access
- `models:read` - Model information
- `embeddings:write` - Vector embedding generation
- `files:read`, `files:write` - File upload/download
- `knowledge:read`, `knowledge:write` - Knowledge graph access
- `admin:read`, `admin:write` - Administrative operations

Enterprise SSO Configuration Navigate to **Settings → SSO Connections** to configure:

1. **SAML 2.0**
   - Upload IdP metadata XML or URL
   - Configure attribute mapping
   - Set up group-to-role mapping
2. **OIDC**
   - Enter issuer URL and client credentials
   - Configure claim mapping
   - Test connection before enabling
3. **Domain Enforcement**
   - Specify email domains requiring SSO
   - Users from enforced domains cannot use password auth

1.7 Two-Factor Authentication (MFA) - v5.52.28

RADIANT enforces role-based Multi-Factor Authentication (MFA) using industry-standard TOTP (RFC 6238).

MFA Enforcement by Role

Role	MFA Required	Can Disable
`super_admin`	**Yes**	No
`admin`	**Yes**	No
`operator`	**Yes**	No
`auditor`	**Yes**	No
`tenant_admin`	**Yes**	No
`tenant_owner`	**Yes**	No
`standard_user`	No (future)	N/A

Critical Security Rules:

- Admin roles **cannot bypass** MFA enrollment
- Admin roles **cannot disable** MFA once enrolled
- MFA enrollment is enforced at login via full-screen gate

MFA Enrollment Flow

1. **Login** - User enters email/password
2. **MFA Check** - System checks if role requires MFA
3. **Enrollment Gate** - If not enrolled, full-screen enrollment UI appears
4. **QR Code** - Scan with authenticator app (Google Authenticator, 1Password, Authy)
5. **Verification** - Enter 6-digit code to confirm
6. **Backup Codes** - Receive 10 one-time recovery codes
7. **Complete** - User can now access the dashboard

Supported Authenticator Apps

- Google Authenticator
- Microsoft Authenticator
- 1Password
- Authy
- Any RFC 6238 compliant TOTP app

Backup Codes Each user receives 10 backup codes during enrollment:

- Format: `XXXX-XXXX` (8 alphanumeric characters)
- Each code can only be used **once**
- Warning displayed when < 3 codes remain
- Regenerate codes from **Settings → Security**

Device Trust Users can opt to "Trust this device for 30 days":

- Reduces MFA prompts on trusted devices
- Maximum 5 trusted devices per user
- Devices can be revoked from Settings
- Trust expires automatically after 30 days

Lockout Policy

Condition	Action
3 failed MFA attempts	5-minute lockout
Lockout expires	Attempts reset
Successful verification	Attempts reset

MFA Settings Page Access MFA configuration at **Settings → Security**:

- **Status** - View MFA enabled/disabled status
- **Backup Codes** - View remaining count, regenerate codes
- **Trusted Devices** - List and revoke trusted devices
- **Audit Log** - View MFA-related events

Database Tables

Table	Purpose
`tenant_users.mfa_*`	MFA columns for tenant users
`platform_admins.mfa_*`	MFA columns for platform admins
`mfa_backup_codes`	Hashed one-time recovery codes
`mfa_trusted_devices`	30-day device trust tokens
`mfa_audit_log`	Partitioned audit log for MFA events

Table	Purpose

MFA API Endpoints

Endpoint	Method	Purpose
`/api/v2/mfa/status`	GET	Get MFA status
`/api/v2/mfa/check`	GET	Check if MFA required
`/api/v2/mfa/enroll/start`	POST	Start enrollment
`/api/v2/mfa/enroll/verify`	POST	Verify enrollment
`/api/v2/mfa/verify`	POST	Verify code during login
`/api/v2/mfa/backup-codes/regenerate`	POST	Regenerate backup codes
`/api/v2/mfa/devices`	GET	List trusted devices
`/api/v2/mfa/devices/:id`	DELETE	Revoke device

1.8 Internationalization & Multi-Language Search (v5.52.29)

RADIANT supports 18 languages for authentication UI and full-text search across all content.

Supported Languages

Language	Code	Direction	Search Method
English	`en`	LTR	PostgreSQL `english`
Spanish	`es`	LTR	PostgreSQL `spanish`
French	`fr`	LTR	PostgreSQL `french`
German	`de`	LTR	PostgreSQL `german`
Portuguese	`pt`	LTR	PostgreSQL `portuguese`
Italian	`it`	LTR	PostgreSQL `italian`
Dutch	`nl`	LTR	PostgreSQL `dutch`
Polish	`pl`	LTR	PostgreSQL `simple`
Russian	`ru`	LTR	PostgreSQL `russian`
Turkish	`tr`	LTR	PostgreSQL `turkish`
Japanese	`ja`	LTR	`pg_bigm` bi-gram
Korean	`ko`	LTR	`pg_bigm` bi-gram
Chinese (Simplified)	`zh-CN`	LTR	`pg_bigm` bi-gram
Chinese (Traditional)	`zh-TW`	LTR	`pg_bigm` bi-gram
Arabic	`ar`	**RTL**	PostgreSQL `simple`
Hindi	`hi`	LTR	PostgreSQL `simple`
Thai	`th`	LTR	PostgreSQL `simple`
Vietnamese	`vi`	LTR	PostgreSQL `simple`

CJK Search (Chinese, Japanese, Korean) CJK languages require special handling because they don't use word boundaries:

- **pg_bigm** extension provides bi-gram indexing
- Automatic language detection on content ingestion
- `search_content()` function routes queries to appropriate search method
- GIN indexes on all searchable text columns

RTL Support (Arabic) Arabic users see proper right-to-left layouts:

- Automatic `dir="rtl"` on auth containers
- Flipped margins, paddings, and flex directions
- LTR preservation for emails, codes, passwords

Database Migration 071

Column/Index	Table	Purpose
`detected_language`	`uds_conversations`	Auto-detected content language
`search_vector_simple`	`uds_conversations`	Fallback tsvector
`search_vector_english`	`uds_conversations`	Language-specific tsvector
`idx_*_bigm_*`	Multiple	GIN bi-gram indexes for CJK

1.9 System Overview Dashboard

Access real-time platform health at **System → Overview**:

Component Health Monitoring

Component	Metrics Tracked
LiteLLM Gateway	Tasks, CPU, memory, requests/min
Aurora PostgreSQL	ACU, connections, IOPS
ElastiCache Redis	Memory, connections, cache hit rate
Lambda Functions	Invocations, concurrent executions, throttles
API Gateway	Requests/sec, error rates
Cognito Pools	Active users, sign-ins, failed logins

Dashboard Features

- **Auto-Refresh**: Real-time updates every 30 seconds
- **Capacity Planning**: Utilization percentages with headroom alerts
- **Alert Management**: Active alerts with severity levels
- **Trend Analysis**: Up/down/stable indicators for all metrics

1.8 LiteLLM Gateway Configuration

Access gateway settings at **System → Gateway**:

Auto-Scaling Parameters

Parameter	Description	Default
Min Tasks	Minimum running ECS tasks	2
Max Tasks	Maximum scaling limit	50
Desired Tasks	Initial task count	2
Task CPU	vCPU units per task (256=0.25 vCPU)	2048
Task Memory	Memory per task in MB	4096

Scaling Thresholds

Threshold	Description	Default
Target CPU Utilization	Scale out when exceeded	70%
Target Memory Utilization	Scale out when exceeded	80%
Target Requests/Target	Requests per task before scaling	1000
Scale Out Cooldown	Wait between scale-out events	60s
Scale In Cooldown	Wait between scale-in events	300s

Rate Limiting

Setting	Description	Default
Global Rate Limit	Max requests/second (all tenants)	10,000
Per-Tenant Limit	Max requests/minute per tenant	1,000
Response Caching	Cache identical requests	Enabled
Cache TTL	How long to cache responses	3600s

Health Check Settings

Setting	Description	Default
Health Check Path	Endpoint for health checks	`/health`
Check Interval	Time between checks	30s
Timeout	Max wait for response	10s
Unhealthy Threshold	Failed checks before unhealthy	3

1.9 SSO Connections Management

Access SSO settings at **Settings → SSO**:

Supported Protocols

Protocol	Use Case
SAML 2.0	Enterprise IdPs (Okta, Azure AD, OneLogin)
OIDC	Modern IdPs with OpenID Connect support

Creating a SAML Connection

1. Navigate to **Settings → SSO**
2. Click **Add Connection**
3. Select **SAML 2.0** protocol
4. Enter:
   - **Connection Name**: Human-readable identifier
   - **Tenant ID**: UUID of the target tenant
   - **IdP Entity ID**: From your IdP metadata
   - **IdP SSO URL**: Login endpoint URL
   - **IdP Certificate**: X.509 certificate (PEM format)
5. Configure domain enforcement (optional)
6. Set default user role
7. Click **Create Connection**

Creating an OIDC Connection

1. Navigate to **Settings → SSO**
2. Click **Add Connection**
3. Select **OIDC** protocol
4. Enter:
   - **Connection Name**: Human-readable identifier
   - **Tenant ID**: UUID of the target tenant
   - **Issuer URL**: Your IdP's issuer URL
   - **Client ID**: From your IdP
   - **Client Secret**: From your IdP
5. Configure domain enforcement (optional)
6. Set default user role
7. Click **Create Connection**

Domain Enforcement Force users with specific email domains to use SSO:

```
Enforced Domains: example.com, corp.example.com
```

Users with `@example.com` or `@corp.example.com` emails cannot use password authentication.

Testing Connections

1. Find the connection in the list
2. Click → **Test Connection**
3. Verify the result:
   - **Success**: IdP is reachable and responding
   - **Failure**: Check configuration and IdP status

---

2. Accessing the Admin Dashboard

2.1 URL and Login

1. Navigate to: `https://admin.your-domain.com`
2. Enter your email address
3. Enter your password
4. Complete MFA verification (required)

2.2 First Login

On first login:

1. You'll receive a temporary password via email
2. Enter the temporary password
3. Set a new password (12+ characters, mixed case, numbers, symbols)
4. Set up MFA using an authenticator app
5. You'll be redirected to the dashboard

2.3 Session Management

Setting	Value
Session Duration	8 hours
Idle Timeout	30 minutes
Concurrent Sessions	3 maximum
Remember Device	30 days

Setting	Value

2.4 Password Requirements

- Minimum 12 characters
- At least one uppercase letter
- At least one lowercase letter
- At least one number
- At least one special character
- Cannot reuse last 10 passwords

---

3. Dashboard Overview

3.1 Main Dashboard

The dashboard displays key metrics at a glance:

```
RADIANT Admin Dashboard                          Welcome, Admin


  Tenants          Users          Requests        Revenue
    142            8,456           2.3M           $45,230
   +12%            +8%             +23%            +15%


                    Request Volume (7 days)

  Mon     Tue     Wed     Thu     Fri     Sat     Sun


Recent Activity:
• New tenant: Acme Corp (2 minutes ago)
• Model enabled: claude-3-opus (15 minutes ago)
• Alert: High API error rate (1 hour ago)
```

3.2 Navigation Menu

Section	Description
Dashboard	Overview and metrics
Tenants	Tenant management
Users	User management
Models	AI model configuration
Providers	Provider management
Billing	Subscriptions and credits
Storage	Storage usage
Orchestration	Preference Engine settings
Localization	Translation management

Section	Description
Configuration	System settings
Security	Security monitoring
Compliance	Compliance reports
Experiments	A/B testing
Cost	Cost analytics
Audit	Audit logs
Migrations	Database migrations
Notifications	System alerts
Settings	Personal settings

---

4. Tenant Management

New in v4.18.55: Complete Tenant Management System (TMS) with lifecycle management, multi-tenant users, soft delete/restore, and compliance features.

4.1 Viewing Tenants

Navigate to **Tenants** to see all organizations:

Column	Description
Name	Organization display name and internal identifier
Type	Organization or Individual (phantom tenant)
Tier	Service tier (1-5: SEED, SPROUT, GROWTH, SCALE, ENTERPRISE)
Status	Active, Suspended, Pending, Pending Deletion, Deleted
Compliance	HIPAA, SOC2, GDPR badges if enabled
Users	Active user count with invited/suspended breakdown
Created	Creation date with relative time

Tenant Types

Type	Description	Use Case
Organization	Company or team workspace	B2B customers
Individual	Personal workspace (phantom tenant)	B2C users, free tier

Tenant Tiers

Tier	Name	Features
1	SEED	Basic features, standard support
2	SPROUT	Advanced features, email support
3	GROWTH	Premium features, dedicated KMS key
4	SCALE	Enterprise features, priority support
5	ENTERPRISE	Full features, custom SLA, dedicated resources

4.2 Creating a Tenant

1. Click **"+ Create Tenant"** button

2. Fill in **Basic Information**:
   - **Internal Name**: URL-friendly identifier (e.g., `acme-corp`)
   - **Display Name**: Human-readable name (e.g., `Acme Corporation`)
   - **Type**: Organization or Individual
   - **Tier**: Select service tier (1-5)
3. Configure **Region & Compliance**:
   - **Primary Region**: us-east-1, us-west-2, eu-west-1, eu-central-1, ap-southeast-1
   - **Compliance Frameworks**: Check HIPAA, SOC2, GDPR as needed
   - **Domain** (optional): Custom domain for SSO
4. Set up **Initial Admin**:
   - **Admin Email**: Primary administrator email
   - **Admin Name**: Administrator display name
5. Click **"Create Tenant"**

Note: HIPAA-enabled tenants automatically have a minimum 90-day retention period.

4.3 Tenant Statuses

Status	Description	Actions Available
Active	Normal operation	Edit, Suspend, Delete
Suspended	Temporarily disabled	Edit, Activate, Delete
Pending	Awaiting setup	Edit, Activate, Delete
Pending Deletion	Scheduled for deletion	Restore only
Deleted	Hard deleted	None (audit only)

4.3 Tenant Details

View comprehensive tenant information:

```
Tenant: Acme Corporation

Overview          Users          Billing          Settings

Tenant ID:        tn_abc123xyz
Status:            Active
Plan:             Professional (Tier 4)
Created:          2024-01-15
Last Active:      2 minutes ago

Usage This Month:
   API Requests:     145,234
   Tokens Used:      12.5M
   Storage:          2.3 GB
   Credits Used:     $1,234.56

[Edit]  [Suspend]  [Delete]  [Impersonate]
```

4.4 Soft Delete & Restore

Tenants are never immediately deleted. Instead, they go through a **retention period**:

Deleting a Tenant

1. Navigate to **Tenants** → **[Tenant]**
2. Click the **Delete** button (or use dropdown menu)
3. Enter a **reason** for deletion (required)
4. Choose whether to **notify users**
5. Click **"Delete Tenant"**

The tenant will be marked as **"Pending Deletion"** with a scheduled hard-delete date.

Retention Periods

Compliance	Minimum Retention	Default
None	7 days	30 days
GDPR	30 days	30 days
SOC2	30 days	30 days
HIPAA	90 days	90 days

Restoring a Tenant

1. Find the tenant in the **Pending Deletions** section
2. Click **"Restore"**
3. Click **"Send Verification Code"**
4. Check your email for the 6-digit code
5. Enter the code and click **"Restore Tenant"**

Security: Verification codes expire after 15 minutes and allow only 3 attempts.

Automatic Hard Delete A scheduled job runs daily at **3:00 AM UTC** to:

- Process all tenants past their retention period
- Delete all S3 data for the tenant
- Schedule KMS key deletion (7-day pending window)
- Mark user records as deleted
- Send deletion confirmation emails

4.5 Multi-Tenant Users

Users can belong to **multiple tenants** with different roles:

Membership Roles

Role	Permissions
Owner	Full access, can delete tenant, cannot be removed
Admin	Full access, can manage users
Member	Standard access to tenant resources
Viewer	Read-only access

Adding Users to a Tenant

1. Navigate to **Tenants** → **[Tenant]** → **Users**
2. Click **"+ Add User"**
3. Enter the user's email address
4. Select their role

5. Choose to send an invitation email (optional)
6. Click **"Add User"**

No Orphan Users The system **prevents orphan users** through a database trigger. When a user's last membership is removed, they are automatically soft-deleted. This ensures:

- Every active user has at least one tenant
- Billing is always attributed correctly
- No abandoned accounts consuming resources

4.6 Phantom Tenants

When a new user signs up without an invitation:

1. System creates an **Individual** type tenant automatically
2. User becomes the **Owner** of their phantom tenant
3. Tenant is named "[User's Name]'s Workspace"
4. User can later be invited to Organization tenants

This enables both **B2C** (individual users) and **B2B** (organizations) use cases.

4.7 Deletion Notifications

Users receive automatic emails when their tenant is scheduled for deletion:

Notification	Timing
7-day warning	7 days before deletion
3-day warning	3 days before deletion
1-day warning	1 day before deletion
Deletion confirmation	After hard delete

4.8 Compliance Features

Risk Acceptances For compliance frameworks, document risk acceptances:

1. Navigate to **Tenants** → **[Tenant]** → **Compliance**
2. View required controls for enabled frameworks
3. For controls that cannot be fully implemented:
   - Click **"Accept Risk"**
   - Enter risk description and mitigating controls
   - Provide business justification
   - Set expiration date
   - Submit for approval (if required)

Compliance Reports A scheduled job runs **monthly on the 1st at 4:00 AM UTC** generating:

- Tenant compliance breakdown (HIPAA, SOC2, GDPR)
- Risk acceptance status (pending, approved, expired)
- Retention compliance status
- Alerts for non-compliant tenants

4.9 Tenant Actions

Action	Description	Permission
Edit	Modify tenant settings	Admin

Action	Description	Permission
Suspend	Temporarily disable	Admin
Delete	Soft delete with retention	Admin
Restore	Restore from pending deletion	Admin + 2FA
Manage Users	Add/remove/modify memberships	Admin
View Audit Log	See tenant activity	Admin

4.10 Data Isolation Architecture

RADIANT implements **six layers of tenant isolation** providing defense in depth:

```
                    TENANT ISOLATION LAYERS


LAYER 1: COMPUTE ISOLATION

   AWS Lambda Tenant Isolation Mode (2025)
   • Separate Firecracker microVM per tenant
   • /tmp and memory NEVER shared between tenants
   • Warm environments dedicated to specific tenant_id


LAYER 2: NETWORK ISOLATION

   API Gateway
   • Per-tenant usage plans (rate limits by tier)
   • AWS WAF rules (SQL injection, XSS, rate limiting)
   • VPC endpoints for private connectivity (Enterprise tier)


LAYER 3: DATA ISOLATION (Polyglot Persistence)

   Aurora PostgreSQL: Row-Level Security (RLS)
     SET app.current_tenant_id = 'tenant-uuid';
     POLICY: tenant_id = current_setting('app.current_tenant_id')::UUID

   DynamoDB: IAM Leading Keys Condition
     "dynamodb:LeadingKeys": ["TENANT#${tenant_id}#*"]

   S3: Bucket Policy + Prefix Isolation
     s3://bucket/tenants/${tenant_id}/

   ElastiCache Redis: Key Prefix Namespacing
     tenant:${tenant_id}:session:*


LAYER 4: ENCRYPTION ISOLATION

   Tier 1-2: AWS-owned KMS key (shared, automatic rotation)
   Tier 3:   Customer Managed Key (CMK) per tenant
   Tier 4-5: CMK with BYOK option (customer-controlled)
   • Separate key for data at rest encryption
   • Key deletion scheduled on tenant termination
```

```
LAYER 5: IDENTITY ISOLATION

   JWT Claims: tenant_id extracted by API Gateway Authorizer
   NEVER trust tenant_id from request body, headers, or query params
   Cognito User Pool with custom attributes per tenant
   Session tokens scoped to specific tenant context


LAYER 6: CONTROL PLANE ISOLATION

   Tenant Management Service (TMS) - Separate from Admin Dashboard
   • Independent deployment and release cycle
   • Higher security controls and MFA requirements
   • Reduced blast radius from application compromise
   • Internal-only API (not exposed to public internet)
```

Storage Layer Isolation Summary

Data Type	Storage	Isolation Mechanism	Use Case
Users, Tenants, Conversations, Messages	Aurora PostgreSQL	Row-Level Security (RLS)	Complex queries, transaction
Sessions, Real-time presence	DynamoDB	Leading Keys + IAM	High velocity, TTL, global ta
Cache, Rate limiting	ElastiCache Redis	Key prefix namespacing	Sub-millisecond access
Media files, Exports	S3	Bucket policy + prefix	Large objects, CDN integrati
Audit logs	S3 + Athena	Object Lock + prefix	Immutable compliance record

4.11 Tenant Metadata Reference

Field	Type	Description
`tenant_id`	UUID	Primary key, system-generated (never user-provided)
`name`	VARCHAR(255)	Internal identifier (URL-friendly)
`display_name`	VARCHAR(255)	Human-readable name
`type`	ENUM	`'organization'` or `'individual'`
`status`	ENUM	`'active'`, `'suspended'`, `'pending'`, `'pending_deletion'`, `'deleted'`
`tier`	INTEGER	Subscription tier (1-5): SEED, SPROUT, GROWTH, SCALE, ENTERPRI
`primary_region`	VARCHAR(20)	AWS region for data residency (e.g., `us-east-1`)
`compliance_mode`	JSONB	Array: `['hipaa', 'soc2', 'gdpr']`
`retention_days`	INTEGER	Custom retention period override (7-730 days)
`deletion_scheduled_at`	TIMESTAMPTZ	When hard delete will occur (if pending_deletion)
`deletion_requested_by`	UUID	User/admin who initiated deletion
`stripe_customer_id`	VARCHAR(255)	Billing integration identifier
`kms_key_arn`	VARCHAR(500)	Per-tenant encryption key (Tier 3+)
`metadata`	JSONB	Custom tenant metadata
`settings`	JSONB	Tenant-specific settings
`created_at`	TIMESTAMPTZ	Creation timestamp
`updated_at`	TIMESTAMPTZ	Last modification timestamp

4.12 API Gateway Rate Limits by Tier

Tier	Requests/Second	Burst	Monthly Quota	Price Point
Tier 1 (SEED)	10	50	100,000	$200/month
Tier 2 (SPROUT)	50	200	1,000,000	$1,000/month
Tier 3 (GROWTH)	200	500	10,000,000	$5,000/month
Tier 4 (SCALE)	1,000	2,000	100,000,000	$25,000/month
Tier 5 (ENTERPRISE)	Custom	Custom	Unlimited	$150,000+/month

Administrator Action: Usage plan assignment happens automatically based on tenant tier. Override via Admin Dashboard → Tenant → API Settings.

4.13 TMS API Endpoints Reference

Tenant CRUD

Method	Path	Description	Auth
POST	`/internal/tms/tenants`	Create tenant	Internal Service Token
GET	`/internal/tms/tenants/{id}`	Get tenant	Internal Service Token
PUT	`/internal/tms/tenants/{id}`	Update tenant	Internal Service Token
DELETE	`/internal/tms/tenants/{id}`	Soft delete tenant	Internal Service Token
POST	`/internal/tms/tenants/{id}/restore`	Restore tenant	Internal Service Token + 2FA
POST	`/internal/tms/phantom-tenant`	Create phantom tenant	Internal Service Token

User Membership

Method	Path	Description	Auth
GET	`/internal/tms/tenants/{id}/users`	List tenant users	Internal Service Token
POST	`/internal/tms/tenants/{id}/users`	Add user to tenant	Internal Service Token
PUT	`/internal/tms/tenants/{id}/users/{userId}`	Update membership	Internal Service Token
DELETE	`/internal/tms/tenants/{id}/users/{userId}`	Remove user	Internal Service Token

Request/Response Examples Create Tenant Request:

```
{
  "name": "acme-corp",
  "displayName": "Acme Corporation",
  "type": "organization",
  "tier": 3,
  "primaryRegion": "us-east-1",
  "complianceMode": ["hipaa", "soc2"],
  "adminEmail": "admin@acme.com",
  "adminName": "John Smith"
}
```

Create Tenant Response:

```
{
  "success": true,
  "data": {
    "tenant": {
```

```
      "id": "550e8400-e29b-41d4-a716-446655440000",
      "name": "acme-corp",
      "displayName": "Acme Corporation",
      "type": "organization",
      "status": "active",
      "tier": 3,
      "kmsKeyArn": "arn:aws:kms:us-east-1:123456789012:key/..."
    },
    "adminUser": {
      "id": "user-uuid-here",
      "email": "admin@acme.com"
    },
    "membership": {
      "role": "owner",
      "status": "active"
    }
  }
}
```


Soft Delete Request:


```
{
  "initiatedBy": "admin-uuid",
  "reason": "Customer requested account closure",
  "notifyUsers": true
}
```


Soft Delete Response:


```
{
  "success": true,
  "data": {
    "tenantId": "550e8400-e29b-41d4-a716-446655440000",
    "status": "pending_deletion",
    "deletionScheduledAt": "2025-01-30T03:00:00Z",
    "retentionDays": 30,
    "affectedUsers": {
      "total": 47,
      "willBeDeleted": 42,
      "willRemain": 5
    },
    "notificationsSent": true
  }
}
```


4.14 Scheduled Jobs

Job	Schedule	Description
Hard Delete	Daily 3:00 AM UTC	Processes tenants past retention period
Deletion Notifications	Daily 9:00 AM UTC	Sends 7/3/1 day warnings
Orphan Check	Weekly Sunday 2:00 AM UTC	Safety net for orphan user cleanup
Compliance Report	Monthly 1st 4:00 AM UTC	Generates compliance status report

Hard Delete Job Details Process:

1. Query tenants where `status = 'pending_deletion'` AND `deletion_scheduled_at < NOW()`
2. For each tenant (up to 10 per run to avoid Lambda timeout):
   - Count users that will be deleted vs retained (multi-tenant users)
   - Delete all tenant memberships (triggers orphan user check)
   - Delete S3 data under `tenants/{tenant_id}/` prefix
   - Schedule KMS key for deletion (7-30 day AWS delay)
   - Update tenant status to `'deleted'`
   - Send deletion confirmation emails
   - Log to immutable audit trail

Administrator Note: Hard deletes cannot be reversed. Monitor the audit log for any unexpected deletions.

4.15 Database Schema (Migration 126)

tenant_user_memberships Table

```
CREATE TABLE tenant_user_memberships (
    id UUID PRIMARY KEY DEFAULT gen_random_uuid(),
    tenant_id UUID NOT NULL REFERENCES tenants(id) ON DELETE CASCADE,
    user_id UUID NOT NULL REFERENCES users(id) ON DELETE CASCADE,
    role VARCHAR(50) DEFAULT 'member'
        CHECK (role IN ('owner', 'admin', 'member', 'viewer')),
    status VARCHAR(20) DEFAULT 'active'
        CHECK (status IN ('active', 'suspended', 'invited')),
    joined_at TIMESTAMPTZ DEFAULT NOW(),
    invited_by UUID REFERENCES users(id),
    invitation_token VARCHAR(255),
    invitation_expires_at TIMESTAMPTZ,
    last_active_at TIMESTAMPTZ,
    created_at TIMESTAMPTZ DEFAULT NOW(),
    updated_at TIMESTAMPTZ DEFAULT NOW(),
    UNIQUE(tenant_id, user_id)
);
```

tms_audit_log Table

```
CREATE TABLE tms_audit_log (
    id UUID PRIMARY KEY DEFAULT gen_random_uuid(),
    tenant_id UUID REFERENCES tenants(id) ON DELETE SET NULL,
    user_id UUID REFERENCES users(id) ON DELETE SET NULL,
    admin_id UUID REFERENCES administrators(id) ON DELETE SET NULL,
    action VARCHAR(100) NOT NULL,
    resource_type VARCHAR(50),
    resource_id VARCHAR(255),
    old_value JSONB,
    new_value JSONB,
    ip_address INET,
    user_agent TEXT,
    trace_id VARCHAR(100),
    created_at TIMESTAMPTZ DEFAULT NOW()
);
```

tms_verification_codes Table

```
CREATE TABLE tms_verification_codes (
    id UUID PRIMARY KEY DEFAULT gen_random_uuid(),
```

```
    user_id UUID REFERENCES users(id) ON DELETE CASCADE,
    admin_id UUID REFERENCES administrators(id) ON DELETE CASCADE,
    operation VARCHAR(50) NOT NULL
        CHECK (operation IN ('restore_tenant', 'hard_delete', 'transfer_ownership', 'compliance_overrid
    resource_id UUID NOT NULL,
    code_hash VARCHAR(64) NOT NULL,
    attempts INTEGER DEFAULT 0,
    max_attempts INTEGER DEFAULT 3,
    expires_at TIMESTAMPTZ NOT NULL,
    verified_at TIMESTAMPTZ,
    created_at TIMESTAMPTZ DEFAULT NOW(),
    CONSTRAINT chk_user_or_admin CHECK (user_id IS NOT NULL OR admin_id IS NOT NULL)
);
```

Orphan Prevention Trigger

```
CREATE OR REPLACE FUNCTION tms_prevent_orphan_users()
RETURNS TRIGGER AS $$
DECLARE
    remaining_memberships INTEGER;
BEGIN
    SELECT COUNT(*) INTO remaining_memberships
    FROM tenant_user_memberships
    WHERE user_id = OLD.user_id
    AND id != OLD.id
    AND status != 'invited';

    IF remaining_memberships = 0 THEN
        UPDATE users SET status = 'deleted', updated_at = NOW()
        WHERE id = OLD.user_id;

        INSERT INTO tms_audit_log (tenant_id, user_id, action, resource_type, resource_id)
        VALUES (OLD.tenant_id, OLD.user_id, 'user_auto_deleted_orphan', 'user', OLD.user_id::text);
    END IF;

    RETURN OLD;
END;
$$ LANGUAGE plpgsql;

CREATE TRIGGER tms_check_orphan_on_membership_delete
AFTER DELETE ON tenant_user_memberships
FOR EACH ROW EXECUTE FUNCTION tms_prevent_orphan_users();
```

4.16 Troubleshooting

Issue	Cause	Resolution
Cannot delete tenant	Tenant has HIPAA compliance	Verify 90-day minimum retention is met
Restore code not received	Email delivery failed	Check spam folder, verify email address, resend code
Restore code invalid	Code expired or max attempts	Request new code (3 attempt limit, 15 min expiry)
User not deleted with tenant	User has other tenant memberships	Expected behavior - user retained for other tenants
Phantom tenant not created	User email already exists	User will be associated with existing account
KMS key not created	Tenant tier below 3	Upgrade to Tier 3+ for dedicated KMS key
Cannot remove last owner	Business rule enforcement	Transfer ownership first or delete tenant

5. User & Administrator Management

5.1 Administrator Roles

Role	Dashboard Access	API Access	Billing	Audit
Super Admin	Full	Full	Full	Full
Admin	Full	Full	Read	Read
Operator	Read	Read	None	Read
Auditor	Logs only	None	None	Full

5.2 Managing Administrators

Navigate to **Administrators** to:

1. **Invite New Admin**:
   - Click **"+ Invite Administrator"**
   - Enter email address
   - Select role
   - Click **"Send Invitation"**
2. **Modify Admin**:
   - Click on administrator row
   - Edit role or permissions
   - Click **"Save Changes"**
3. **Remove Admin**:
   - Click **"Remove"** button
   - Confirm removal
   - Admin's sessions are invalidated immediately

5.3 Viewing Tenant Users

Navigate to **Tenants** → [**Tenant**] → **Users** to see:

Field	Description
Email	User email
Name	Display name
Role	Tenant role
Status	Active/Invited/Disabled
Last Login	Last authentication
API Keys	Number of active keys

5.4 User Actions

Action	Description
Reset Password	Send password reset email
Disable	Prevent login
Enable	Restore access
Delete	Remove user data

Action	Description
View Sessions	See active sessions

6. AI Model Configuration

6.1 Model Registry

Navigate to **Models** to see all available models:

```
AI Models                                          106 Total


Filter: [All ]  Category: [All ]  Status: [Enabled ]

Model               Provider    Category   Tier   Status

gpt-4o              OpenAI      Chat       1        Enabled
gpt-4o-mini         OpenAI      Chat       1        Enabled
claude-3-opus       Anthropic   Chat       2        Enabled
claude-3-sonnet     Anthropic   Chat       1        Enabled
gemini-pro          Google      Chat       1        Enabled
llama-3.1-70b       Self-Host   Chat       3        Enabled
whisper-large       Self-Host   Audio      3        Disabled

[+ Add Model]  [Import Models]  [Export Config]
```

6.2 Model Categories

Category	Description	Example Models
Chat/LLM	Text generation	GPT-4o, Claude 3, Gemini
Embedding	Vector embeddings	text-embedding-3-large
Vision	Image understanding	GPT-4V, Claude Vision
Audio	Speech-to-text	Whisper, Deepgram
Image	Image generation	DALL-E 3, Stable Diffusion
Code	Code generation	Codestral, DeepSeek Coder
Scientific	Research models	BioGPT, ChemLLM

Category Details **Chat/LLM (Large Language Models)**: The core of RADIANT. These models handle conversational AI, content generation, summarization, and general-purpose text tasks. They're the most commonly used and include flagship models from OpenAI, Anthropic, Google, and open-source alternatives.

Embedding Models: Convert text into numerical vectors for semantic search, similarity matching, and retrieval-augmented generation (RAG). Essential for building knowledge bases and search functionality. Vectors are typically 1536-3072 dimensions.

Vision Models: Analyze images, extract text (OCR), describe visual content, and answer questions about images. Increasingly important for document processing, accessibility, and multimodal applications.

Audio Models: Transcribe speech to text, translate audio, and identify speakers. Whisper is the most popular, offering excellent accuracy across 99 languages. Used for meeting transcription, accessibility, and voice interfaces.

Image Generation: Create images from text descriptions. DALL-E 3 offers the best prompt following, while Stable Diffusion provides more customization options. Consider content policies when enabling these.

Code Models: Specialized for programming tasks including code generation, explanation, debugging, and refactoring. Some are fine-tuned on specific languages or frameworks.

Scientific Models: Domain-specific models trained on scientific literature. Useful for research applications but require careful evaluation for accuracy.

6.3 Model Configuration

Click on a model to configure:

Setting	Description
Enabled	Available for use
Min Tier	Minimum subscription tier
Rate Limits	Requests per minute
Max Tokens	Maximum context/output
Temperature Range	Allowed temperature values
Price Override	Custom pricing

Configuration Settings Explained **Enabled**: When disabled, the model is hidden from users and API requests return "model not found". Use this to temporarily remove models during maintenance or to restrict access to specific models.

Min Tier: Sets the minimum subscription tier required to access this model. For example, setting GPT-4 to Tier 2 means Free tier users cannot use it. This helps control costs and create upgrade incentives.

Rate Limits: Controls requests per minute per user for this model. Prevents abuse and ensures fair access. Set based on the provider's rate limits and your capacity:

- Conservative: 10-20 requests/minute
- Standard: 50-100 requests/minute
- High: 200+ requests/minute (requires provider rate limit increases)

Max Tokens: Limits context window and output length. Useful for controlling costs since longer contexts cost more. Set based on use case:

- Short tasks (Q&A): 4,096 tokens
- Medium tasks (writing): 16,384 tokens
- Long tasks (analysis): 32,768+ tokens

Temperature Range: Restricts the temperature parameter users can set. Temperature controls randomness:

- 0.0: Deterministic, consistent outputs
- 0.7: Balanced creativity and consistency
- 1.0+: More creative, less predictable

Restricting range (e.g., 0.0-1.0) prevents users from setting extreme values that produce poor results.

Price Override: Allows custom pricing different from the default. Useful for:

- Offering discounts on specific models
- Increasing prices for premium models

- Matching competitor pricing
- A/B testing pricing strategies

6.4 Self-Hosted Models

For Tier 3+ deployments:

1. Navigate to **Models → Self-Hosted**
2. Click **"+ Add Self-Hosted Model"**
3. Configure:
   - **Model ID**: Unique identifier
   - **SageMaker Endpoint**: Endpoint name
   - **Instance Type**: ml.g5.xlarge, etc.
   - **Auto-Scaling**: Min/max instances
4. Deploy model to SageMaker

6.5 Thermal States (Self-Hosted)

State	Description	Response Time
HOT	Always running	<100ms
WARM	Scaled down	<5s
COLD	Stopped	30-60s
OFF	Disabled	N/A

---

7. Provider Management

7.1 External Providers

Navigate to **Providers** to manage API integrations:

Provider	Models	Status	Health
OpenAI	12	Configured	99.9%
Anthropic	6	Configured	99.8%
Google AI	8	Configured	99.7%
xAI	2	Configured	99.5%
DeepSeek	4	Not configured	-

7.2 Adding Provider Credentials

1. Click on provider name
2. Click **"Configure"**
3. Enter API credentials:
   - **API Key**: Provider API key
   - **Organization ID**: (if applicable)
   - **Base URL**: (for custom endpoints)
4. Click **"Test Connection"**
5. Click **"Save"**

7.3 Provider Health Monitoring

View real-time provider health:

```
Provider Health: OpenAI


Status:             Healthy
Uptime (30d):     99.94%
Avg Latency:      245ms
P95 Latency:      520ms
Error Rate:       0.02%

Last 24 Hours:

12am        6am         12pm         6pm         12am
```

7.4 Fallback Configuration

Configure provider fallbacks:

1. Navigate to **Providers → Fallbacks**
2. Set priority order for each model category
3. Configure automatic failover rules
4. Set retry policies

---

8. Billing & Subscriptions

8.1 Subscription Tiers

Tier	Name	Monthly	Features
1	Free	$0	Basic models, 1K requests
2	Starter	$29	More models, 10K requests
3	Professional	$99	All external models, 100K requests
4	Business	$299	Priority support, 500K requests
5	Enterprise	$999	Self-hosted, unlimited
6	Enterprise+	Custom	Custom SLAs, dedicated support
7	Ultimate	Custom	On-premise options

8.2 Credit System

Credits are the universal currency for AI usage:

Model Type	Cost per 1M Tokens
GPT-4o	500 credits
GPT-4o-mini	50 credits
Claude 3 Opus	600 credits
Claude 3 Sonnet	150 credits
Self-hosted	20 credits

8.3 Managing Subscriptions

Navigate to **Billing → Subscriptions**:

1. View current subscription
2. Upgrade/downgrade tier
3. Add credit packages
4. View invoices
5. Update payment method

8.4 Usage Reports

Generate usage reports:

1. Navigate to **Billing → Reports**
2. Select date range
3. Choose grouping (by tenant/model/user)
4. Export as CSV/PDF

8.5 Billing Alerts

Configure alerts for:

- Credit balance low
- Usage spike
- Approaching quota
- Failed payments

---

9. Storage Management

9.1 Storage Overview

Navigate to **Storage** to monitor:

```
Storage Overview


Total Used:       234.5 GB of 500 GB (47%)


By Type:
   Documents:     120.3 GB (51%)
   Images:        45.2 GB (19%)
   Audio:         38.7 GB (17%)
   Video:         22.1 GB (9%)
   Other:         8.2 GB (4%)

Top Tenants:
1. Acme Corp       45.2 GB
2. TechStart       32.1 GB
3. DataCo          28.4 GB
```

9.2 Storage Tiers

Tier	Included	Additional
Free	1 GB	N/A
Starter	10 GB	$0.10/GB
Professional	100 GB	$0.08/GB
Business	500 GB	$0.05/GB
Enterprise	2 TB	$0.03/GB

9.3 File Management

Manage uploaded files:

- View file metadata
- Download files
- Delete files
- Set retention policies

---

10. Orchestration & Preference Engine

10.1 Cognitive Router (formerly Brain Router)

The Cognitive Router automatically selects optimal models:

Factor	Weight	Description
Cost	30%	Price optimization
Quality	30%	Output quality
Speed	20%	Response latency
Availability	20%	Provider health

10.2 Neural Patterns

Configure orchestration patterns:

Pattern	Description	Use Case
Single	One model	Simple requests
Fallback	Primary + backup	High availability
Parallel	Multiple simultaneous	Consensus
Chain	Sequential models	Complex tasks

10.3 Workflow Templates

Create reusable workflows:

1. Navigate to **Orchestration → Workflows**
2. Click **"+ New Workflow"**
3. Define steps and conditions
4. Set triggers and parameters
5. Save and activate

10.4 Orchestration Methods

Location: Admin Dashboard → Orchestration → Methods

Manage the 70+ built-in orchestration methods that power workflow steps.

Method Categories

Category	Count	Examples
Generation	3	Chain-of-Thought, Iterative Refinement
Evaluation	6	Multi-Judge Panel, G-Eval, Pairwise
Synthesis	5	Mixture of Agents, LLM-Blender
Verification	8	SelfCheckGPT, CiteFix, PRM
Debate	5	Sparse Debate, HAH-Delphi
Aggregation	4	Self-Consistency, GEDI Electoral
Routing	7	RouteLLM, FrugalGPT, Pareto, C3PO, AutoMix
Uncertainty	6	Semantic Entropy, SE Probes, Kernel Entropy
Hallucination	3	Multi-Method Detection, MetaQA
Human-in-Loop	3	HITL Review, Active Learning

System vs User Methods

Type	Editable	Description
System	Parameters only	Built-in methods with locked definitions
User	Full (future)	Custom tenant methods (planned feature)

System methods show a "System" badge in the UI. Only `defaultParameters` and `isEnabled` can be modified.

Setting Default Parameters

1. Navigate to **Orchestration → Methods**
2. Select a method from the list
3. Adjust parameters in the right panel
4. Click **Save** to update defaults

Example Parameters (vary by method):

Parameter	Type	Used By	Description
`sample_count`	integer	Entropy, Consistency	Number of response samples
`threshold`	number	Routing, Detection	Decision threshold
`temperature`	number	Generation, Debate	Sampling temperature
`confidence_threshold`	number	Cascade, HITL	Escalation trigger
`budget_cents`	number	Pareto Routing	Cost constraint
`kernel`	enum	Kernel Entropy	RBF, linear, polynomial
`topology`	enum	Sparse Debate	ring, star, tree, full

See `THINKTANK-ADMIN-GUIDE.md` Section 34.5 for complete parameter reference by method.

Parameter Inheritance

```
Admin Default → Workflow Step → User Template Override
     ↓               ↓                  ↓
  Tenant-wide    Per-workflow      Per-user template
```

Parameters set at the Admin level apply to all workflows. User workflow templates can override these per-template.

10.5 Orchestration Security (RLS)

All orchestration tables are protected by PostgreSQL Row-Level Security (RLS) with tenant isolation.

Security Model Summary

Table	Read Access	Write Access
`orchestration_methods`	All authenticated users	Super admin only
`orchestration_workflows`	System: all users; User-created: own tenant only	Own tenant only
`workflow_method_bindings`	Follows parent workflow	Follows parent workflow
`workflow_customizations`	Own tenant only	Own tenant only
`orchestration_executions`	Own tenant (+ super admin)	Own tenant only
`orchestration_step_executions`	Follows parent execution	Follows parent execution
`user_workflow_templates`	Own + shared + approved public	Own only (tenant admin can mana

Session Variables The API sets these PostgreSQL session variables before any database operation:

Variable	Purpose	Set By
`app.current_tenant_id`	Current tenant UUID	JWT claims
`app.current_user_id`	Current user UUID	JWT claims
`app.is_tenant_admin`	Tenant admin flag	JWT claims
`app.is_super_admin`	Super admin flag	JWT claims
`app.client_ip`	Client IP address	Request context
`app.user_agent`	Browser user agent	Request headers

Helper Functions Three helper functions are available for workflow access control:

```
-- Check if current user can view a workflow
SELECT can_access_workflow('workflow-uuid');

-- Check if current user can modify a workflow
SELECT can_modify_workflow('workflow-uuid');

-- Get all accessible workflows with permissions
SELECT * FROM get_accessible_workflows();
```

Audit Trail All modifications to workflows are logged to `orchestration_audit_log`:

Column	Description
`table_name`	Which table was modified
`record_id`	UUID of the modified record
`action`	INSERT, UPDATE, or DELETE
`old_data`	Previous state (JSONB)
`new_data`	New state (JSONB)
`tenant_id`	Tenant making the change
`user_id`	User making the change
`ip_address`	Client IP address
`user_agent`	Browser user agent
`changed_at`	Timestamp of change

User Workflow Template Sharing Users can share their workflow templates at three levels:

1. **Private** (default): Only the creator can see/use the template
2. **Shared within Tenant** (`is_shared = true`): All users in the tenant can see/use
3. **Public** (`is_public = true`): Visible to all tenants after super admin approval

To approve a public template (super admin only):

```
UPDATE user_workflow_templates
SET share_approved_at = NOW(), share_approved_by = 'admin-uuid'
WHERE template_id = 'template-uuid' AND is_public = true;
```

Migration: `V2026_01_10_003__orchestration_rls_security.sql`

---

11. Pre-Prompt Learning

Location: Admin Dashboard → Orchestration → Pre-Prompts

The Pre-Prompt Learning system tracks and learns from the effectiveness of pre-prompts (system prompts) used by the AGI Brain. It uses **attribution analysis** to determine what factor actually caused issues - not just the pre-prompt.

11.1 Overview Dashboard

The dashboard shows key metrics:

Metric	Description
Templates	Active/total pre-prompt templates
Total Uses	Pre-prompt instances used
Avg Rating	Average user rating (1-5)
Thumbs Up Rate	Percentage of positive feedback
Exploration Rate	Rate of trying non-optimal templates to learn

11.2 Attribution Analysis

When users report issues, the system analyzes which factor was responsible:

Factor	When Blamed
Pre-prompt	System instructions wrong
Model	Model selection inappropriate
Mode	Orchestration mode wrong
Workflow	Pattern did not fit task
Domain	Domain detection incorrect
Other	External factors

The attribution pie chart shows the distribution of blame across factors.

11.3 Template Management

Navigate to the **Templates** tab to:

- View all pre-prompt templates
- See usage statistics and success rates
- Check which orchestration modes each template supports
- View average feedback scores

11.4 Adjusting Weights

Click the **sliders icon** on any template to adjust weights:

Weight	Default	Description
Base Effectiveness	0.5	Starting score before bonuses
Domain Weight	0.2	Bonus for matching domain
Mode Weight	0.2	Bonus for matching mode
Model Weight	0.2	Bonus for compatible model
Complexity Weight	0.15	Bonus for complexity match
Task Type Weight	0.15	Bonus for task type match
Feedback Weight	0.1	Historical feedback influence

Score Formula:

```
Final Score = Base + (Domain × DomainWeight) + (Mode × ModeWeight) +
              (Model × ModelWeight) + (Complexity × ComplexityWeight) +
              (TaskType × TaskTypeWeight) + FeedbackAdjustment
```

11.5 Learning Configuration

Configure learning behavior:

- **Learning Enabled**: Toggle on/off
- **Exploration Rate**: Percentage of requests using non-optimal templates to gather data (default: 10%)
- **Exploration Decay**: How quickly exploration decreases (default: 0.99)
- **Minimum Exploration**: Floor for exploration rate (default: 1%)

11.6 Recent Feedback

The **Feedback** tab shows recent user feedback with:

- Rating (1-5 stars)
- Attribution label (what got blamed)
- User comments
- Timestamp

See Pre-Prompt Learning System Documentation for full details.

---

12. Localization

12.1 Translation Registry

Location: Admin Dashboard → Localization → Translation Registry

The Translation Registry provides comprehensive management of all UI strings across RADIANT applications with tenant-specific override capabilities.

Key Features:

- **100+ Pre-Seeded Strings**: Common UI elements, errors, dialogs, validation messages
- **App-Scoped Categories**: radiant_admin, thinktank_admin, thinktank, curator, common
- **Tenant Overrides**: Custom text per tenant with protection from auto-updates
- **18 Language Support**: Full coverage across all supported languages

12.2 Supported Languages

Language	Code	Flag	RTL
English	en		No
Spanish	es		No
French	fr		No
German	de		No
Portuguese	pt		No
Italian	it		No
Dutch	nl		No
Polish	pl		No
Russian	ru		No
Turkish	tr		No
Japanese	ja		No
Korean	ko		No
Chinese (Simplified)	zh-CN		No
Chinese (Traditional)	zh-TW		No
Arabic	ar		**Yes**
Hindi	hi		No
Thai	th		No
Vietnamese	vi		No

12.3 Tenant Translation Overrides

Tenant administrators can override any system string with custom text:

Override Workflow:

1. Navigate to **Localization → Translation Registry**
2. Select target language from dropdown
3. Browse or search for strings to customize
4. Click **Edit** to create an override
5. Enter custom text and save

Protection System:

- **Protected Overrides** (default): Won't be updated by automatic translation
- **Unprotected Overrides**: May be updated when system translations improve
- **Revert**: Delete override to return to system translation

Admin UI Tabs: | Tab | Purpose | |-----|---------| | **Registry** | Browse all strings, create overrides | | **Your Overrides** | Manage existing overrides, toggle protection | | **Coverage** | View translation coverage by language |

12.4 Translation Override API

Base URL: `/api/admin/localization`

List Registry Entries

```
GET /api/admin/localization/registry?app_id=thinktank&category=chat&search=error&page=1&limit=50
```

Get Entry with All Translations

```
GET /api/admin/localization/registry/:id
```

List Tenant Overrides

```
GET /api/admin/localization/overrides?language_code=es&protected=true
```

Create/Update Override

```
POST /api/admin/localization/overrides
Content-Type: application/json

{
  "registry_id": 42,
  "language_code": "es",
  "override_text": "Texto personalizado",
  "is_protected": true
}
```

Delete Override (Revert to System)

```
DELETE /api/admin/localization/overrides/:id
```

Toggle Protection

```
PATCH /api/admin/localization/overrides/:id/protection
Content-Type: application/json

{
  "is_protected": false
}
```

Get Translation Bundle (with Overrides Applied)

```
GET /api/admin/localization/bundle/es?app_id=thinktank
```

Response:

```
{
  "languageCode": "es",
  "translations": {
    "thinktank.chat.placeholder": "Escribe tu mensaje...",
    "common.buttons.save": "Guardar"
  },
  "overrideCount": 5,
  "overrideKeys": ["thinktank.chat.placeholder"]
}
```

12.5 Tenant Localization Config

Configure language settings per tenant:

```
GET /api/admin/localization/config
PUT /api/admin/localization/config
```

Configuration Options: | Setting | Default | Description | |---------|---------|-------------| | `default_language` | `en` | Default language for new users | | `enabled_languages` | `['en']` | Languages available to users | | `allow_user_language_selection` | `true` | Let users choose their language | | `enable_ai_translation` | `true` | Use AI for missing translations | | `brand_name` | `null` | Custom brand name for strings |

12.6 Database Schema

Table	Purpose
`localization_registry`	Source strings with keys, context, category
`localization_translations`	System translations per language
`tenant_translation_overrides`	Tenant-specific overrides with protection
`tenant_localization_config`	Per-tenant language configuration
`translation_audit_log`	Change history for compliance

12.7 String Categories

Category	Examples
`buttons`	Save, Cancel, Delete, Edit, Submit
`errors`	Network error, Session expired, Validation
`dialogs`	Confirm, Delete confirmation, Unsaved changes
`validation`	Required field, Invalid email, Min/max length
`toasts`	Success messages, Error messages
`time`	Relative time (minutes ago, hours ago)
`pagination`	Showing X to Y, Previous, Next
`tables`	No data, Loading, Search
`upload`	Drag and drop, Max size, Allowed types
`auth`	Sign in, Sign out, Forgot password
`navigation`	Dashboard, Settings, Users
`chat`	Placeholder, Send, Thinking

12.8 Think Tank Admin Localization

Tenant administrators access a simplified localization UI at **Administration → Localization**:

- **Your Overrides**: View and manage custom translations
- **Browse Strings**: Search Think Tank-specific strings
- **Configuration**: Set default language and enabled languages

---

12. Configuration Management

12.1 System Configuration

Navigate to **Configuration** to manage:

Category	Settings
General	Platform name, domain, timezone
Email	SMTP settings, templates
Security	Password policy, MFA settings
API	Rate limits, CORS settings
Features	Feature flags

12.2 Tenant Overrides

Allow tenant-specific configuration:

1. Navigate to **Configuration → Tenant Overrides**

2. Select tenant
3. Override specific settings
4. Save changes

12.3 SSM Parameters

System configuration is stored in AWS SSM:

Parameter	Description
`/radiant/prod/database/url`	Database connection
`/radiant/prod/api/rate-limit`	API rate limits
`/radiant/prod/features/*`	Feature flags

---

13. AI Ethics & Standards

Location: Admin Dashboard → Ethics

The Ethics module provides transparency into the ethical principles guiding AI behavior and their source standards.

13.1 Standards Tab

View all industry AI ethics frameworks that inform RADIANT's ethical principles:

Standard	Organization	Type	Required
NIST AI RMF 1.0	National Institute of Standards and Technology	Government	
ISO/IEC 42001:2023	International Organization for Standardization	ISO	
EU AI Act	European Union	Government	
IEEE 7000-2021	IEEE	Industry	
OECD AI Principles	OECD	Government	
UNESCO AI Ethics	UNESCO	Government	
ISO/IEC 23894:2023	ISO	ISO	
ISO/IEC 38507:2022	ISO	ISO	

Each standard shows:

- **Full Name**: Complete standard title with version
- **Organization**: Issuing body
- **Type**: Government, ISO, Industry, Academic, Religious
- **Required Badge**: Mandatory for compliance
- **Description**: Summary of the standard's purpose
- **Publication Date**: When the standard was issued
- **External Link**: Direct link to official standard

13.2 Principles Tab

View ethical principles with their standard sources:

Principle	Category	Source Standards
Love Others	Love	NIST GOVERN 1.2, ISO 42001 Clause 5.2, Matthew 22:39
Golden Rule	Love	NIST MAP 1.1, EU AI Act Article 9, Matthew 7:12

Principle	Category	Source Standards
Speak Truth	Truth	NIST GOVERN 4.1, ISO 42001 Clause 7.4, EU AI Act Article 13, John 8:32
Show Mercy	Mercy	NIST MEASURE 2.6, EU AI Act Article 14, Matthew 5:7
Serve Humbly	Service	NIST GOVERN 1.1, ISO 42001 Clause 5.1, Mark 10:45
Avoid Judgment	Mercy	NIST MAP 2.3, EU AI Act Article 10, Matthew 7:1
Care for Vulnerable	Service	NIST MAP 1.5, EU AI Act Article 7, ISO 42001 Clause 8.4, Matthew 25:40

Each principle displays:

- **Teaching**: The principle text
- **Category Badge**: love, mercy, truth, service, humility, peace, forgiveness
- **Derived from / Aligned with**: Standard badges with section references

13.3 Violations Tab

Monitor ethical violations in AI responses:

- **Action**: What was evaluated
- **Score**: Ethical score percentage
- **Concerns**: Specific violations detected
- **Guidance**: Recommended corrections
- **Reasoning**: Explanation of the evaluation

13.4 Statistics

Summary cards showing:

- **Total Evaluations**: All ethical checks performed
- **Approved**: Passed evaluations
- **Violations**: Failed evaluations
- **Average Score**: Mean ethical score
- **Today**: Evaluations in the last 24 hours

13.5 Standard Alignment Levels

Principles map to standards with different alignment levels:

Level	Meaning
derived	Principle was directly derived from this standard
aligned	Principle aligns with this standard's requirements
supports	Principle supports this standard's goals
extends	Principle extends beyond this standard

See AI Ethics Standards Documentation for full details.

---

14. Provider Rejection Handling

Location: Think Tank → Notifications (Bell icon)

When AI providers reject prompts based on their policies (not RADIANT's), the system automatically attempts fallback to alternative models.

14.1 How It Works

```
User Prompt → Model Rejects → Check RADIANT Ethics
     Our ethics block → Reject with explanation
     Our ethics pass → Try fallback models (up to 3 attempts)
           Fallback succeeds → Return response (user notified)
           All fail → Reject with full explanation
```

14.2 Rejection Types

Type	Description	Auto-Fallback
content_policy	Provider's content policy violation	Yes
safety_filter	Safety/moderation filter triggered	Yes
provider_ethics	Provider's ethical guidelines differ	Yes
capability_mismatch	Model can't handle request type	Yes
context_length	Prompt too long for model	Yes
moderation	Pre-flight moderation blocked	Yes
rate_limit	Rate limiting	Retry

14.3 User Notifications

Users see rejection notifications via the bell icon in Think Tank:

- **Unread count badge** - Number of unread notifications
- **Notification panel** - Slides out showing all rejections
- **Suggested actions** - Rephrase, simplify, contact admin
- **Resolution status** - Whether fallback succeeded

14.4 Fallback Model Selection

Models are selected for fallback based on:

1. **Rejection rate** - Models with lowest historical rejection rates preferred
2. **Required capabilities** - Must match original model's capabilities
3. **Provider diversity** - Prefer different providers

14.5 Model Rejection Statistics

Location: Admin Dashboard → Analytics → Model Stats

View per-model:

- Total requests and rejections
- Rejection rate percentage
- Breakdown by rejection type
- Fallback success rate

14.6 Database Tables

Table	Purpose
`provider_rejections`	Track all rejections with fallback chain
`rejection_patterns`	Learn patterns for smarter fallback
`user_rejection_notifications`	User-facing notifications
`model_rejection_stats`	Per-model statistics

14.7 Configuration

Setting	Default	Description
`MAX_FALLBACK_ATTEMPTS`	3	Maximum fallback tries per request
`MIN_MODELS_FOR_TASK`	2	Minimum capable models required

See Provider Rejection Handling Documentation for full details.

14.8 Rejection Analytics

Location: Admin Dashboard → Analytics → Rejections

Comprehensive analytics on AI provider rejections to inform ethics policy updates.

Summary Cards

- **Total Rejections (30d)** - All rejections in last 30 days
- **Fallback Success Rate** - Percentage resolved by fallback models
- **Rejected to User** - Requests that couldn't be completed
- **Flagged Keywords** - Keywords marked for policy review

By Provider Tab

Column	Description
Provider	Provider ID (openai, anthropic, google, etc.)
Rejections	Total rejections in period
Models	Number of models affected
Unique Prompts	Distinct prompts rejected
Fallback Rate	Success rate of fallback attempts
Rejected to User	Requests that failed all fallbacks
Types	Rejection types (content_policy, safety_filter, etc.)

Violation Keywords Tab Track which keywords trigger rejections:

Column	Description
Keyword	The triggering keyword
Category	violence, security, controlled, etc.
Occurrences	Times keyword appeared in rejected prompts
Provider Breakdown	Rejections per provider for this keyword
Status	Flagged, Pre-filter added, or Monitoring

Actions:

- **Flag for Review** - Mark keyword for policy consideration
- **Add Pre-Filter** - Block prompts containing keyword before sending to AI

Flagged Prompts Tab View full content of rejected prompts for investigation:

- Full prompt text (for policy review only)
- Detected violation keywords
- Model and provider that rejected
- Number of times this prompt pattern was rejected
- Suggested actions: Add Pre-Filter, Dismiss

Policy Review Tab Recommendations based on rejection patterns:

- High-frequency rejection patterns
- Suggested pre-filters to add
- Keywords to consider blocking

Database Tables

Table	Purpose
`rejection_analytics`	Daily aggregated stats by model/provider/mode
`rejection_keyword_stats`	Per-keyword occurrence and rejection counts
`rejected_prompt_archive`	Full prompt content for flagged reviews

Using Analytics to Update Ethics Policy

1. **Monitor** → Watch the Keywords tab for high-occurrence terms
2. **Flag** → Mark suspicious keywords for review
3. **Investigate** → View full prompts in Flagged Prompts tab
4. **Decide** → Add pre-filter, add warning, or dismiss
5. **Implement** → Update RADIANT ethics policy to pre-filter prompts

---

15. Security & Compliance

15.1 Security Dashboard

Navigate to **Security** to monitor:

```
Security Dashboard                    Threat Level: Low


Active Threats:     0
Failed Logins:      23 (last 24h)
Suspicious IPs:     2 blocked
MFA Adoption:       94%

Recent Alerts:

   Unusual login location - user@acme.com (2h ago)
   Resolved: Brute force attempt blocked (5h ago)
   Resolved: API key rotated - tenant xyz (1d ago)
```

13.2 Anomaly Detection

Automatic detection of:

- Impossible travel (geographic anomalies)
- Session hijacking attempts
- Brute force attacks
- Unusual API patterns

15.3 Compliance Dashboard

Navigate to **Compliance** to access five tabs:

Tab	Purpose
Reports	SOC 2, HIPAA, GDPR, ISO 27001 compliance reports
GDPR	Data subject requests and consent management
HIPAA	PHI protection and access controls
Breaches	Data breach incident tracking
Retention	Data retention policy configuration

15.4 GDPR Management

The GDPR tab provides:

Data Subject Requests (Articles 15-22): | Request Type | Description | Deadline | |--------------|-------------|----------| | Access | Export all user data | 30 days | | Rectification | Correct personal data | 30 days | | Erasure | Right to be forgotten | 30 days | | Restriction | Limit processing | 30 days | | Portability | Machine-readable export | 30 days | | Objection | Object to processing | 30 days |

Processing Requests:

1. Navigate to **Compliance → GDPR**
2. View pending requests with deadlines
3. Click **"Process"** to fulfill request
4. System automatically exports/deletes data
5. Request marked complete with audit trail

15.5 HIPAA Configuration

The HIPAA tab provides per-tenant settings:

Setting	Default	Description
HIPAA Mode	Off	Enable all HIPAA features
PHI Detection	On	Auto-detect PHI in requests
PHI Encryption	On	Column-level encryption
Enhanced Logging	On	Detailed PHI access logs
MFA Required	On	Require MFA for all users
Session Timeout	15 min	Auto-logout after inactivity
Access Review	90 days	Periodic access review period
PHI Retention	2190 days	6 years per HIPAA
Audit Retention	2555 days	7 years recommended

15.6 Data Breach Management

The Breaches tab tracks security incidents:

Incident Types:

- Unauthorized access
- Data theft
- Ransomware
- Accidental disclosure
- System breach
- Insider threat

Notification Requirements: | Regulation | Notify | Timeline | |------------|--------|----------| | GDPR | DPA + affected users | 72 hours | | HIPAA | HHS + affected individuals | 60 days |

15.7 Data Retention Policies

Default retention periods:

Data Type	Retention	Legal Basis	Action
Session Data	90 days	Legitimate Interest	Delete
Usage Analytics	2 years	Legitimate Interest	Anonymize
Audit Logs	7 years	Legal Obligation	Archive
PHI Data	6 years	Legal Obligation	Archive
Billing Records	7 years	Legal Obligation	Archive
GDPR Requests	3 years	Legal Obligation	Archive
Consent Records	7 years	Legal Obligation	Archive

15.8 Generating Compliance Reports

1. Navigate to **Compliance → Reports**
2. Select framework (SOC 2, HIPAA, GDPR, ISO 27001)
3. Click **"Generate Report"**
4. View compliance score and findings
5. Export to PDF for auditors

15.9 Regulatory Standards Registry

Location: Admin Dashboard → Security → Reg Standards

Comprehensive registry of all regulatory standards Radiant must comply with.

Supported Standards (35 Frameworks)

Category	Standards
Data Privacy	GDPR, CCPA, CPRA, LGPD, PIPEDA, APPI, PDPA
Healthcare	HIPAA, HITECH, HITRUST CSF
Security	SOC 2, SOC 1, ISO 27001, ISO 27017, ISO 27018, ISO 27701, CSA STAR, NIST CSF, NIST 800-53, C
Financial	PCI-DSS, SOX, GLBA
Government	FedRAMP, StateRAMP, ITAR, CMMC
AI Governance	EU AI Act, NIST AI RMF, ISO 42001, IEEE 7000
Accessibility	WCAG 2.1, ADA, Section 508
Industry	FERPA, COPPA

Overview Tab The Overview tab provides:

- **Summary Cards**: Total standards, requirements, implementation progress
- **Categories Grid**: Standards organized by domain with mandatory counts
- **Priority Standards**: Mandatory frameworks requiring immediate attention
- **Requirements Status**: Not started, in progress, implemented, verified

Standards Tab Browse all regulatory frameworks with:

- **Search**: Find standards by code, name, or description
- **Category Filter**: Filter by Data Privacy, Security, Healthcare, etc.

- **Mandatory Filter**: Show only required standards
- **Standard Details**: Click any standard to view full requirements

My Compliance Tab Track your tenant's compliance status:

- **Enable/Disable**: Toggle which standards apply to your organization
- **Compliance Score**: Track progress per standard (0-100%)
- **Status**: Not Assessed → Non-Compliant → Partial → Compliant → Certified
- **Audit Tracking**: Last audit date and next scheduled audit

Requirements Tracker For each standard, track individual requirements:

Field	Description
Requirement Code	Unique identifier (e.g., GDPR-32, PCI-7)
Title	Short description of the requirement
Control Type	Technical, Administrative, Physical, Procedural
Status	Not Started → In Progress → Implemented → Verified
Owner	Person responsible for implementation
Evidence	Link to compliance evidence
Due Date	Implementation deadline

Updating Requirement Status

1. Navigate to **Reg Standards → Standards**
2. Click on a standard to open details sheet
3. Find the requirement to update
4. Use the status dropdown to change implementation status
5. Changes are automatically saved

15.10 Self-Audit & Regulatory Reporting

Location: Admin Dashboard → Security → Self-Audit

Automated compliance self-auditing with timestamped pass/fail results for regulatory reporting.

Running an Audit

1. Navigate to **Security → Self-Audit**
2. Click **"Run Audit"** button
3. Select framework (SOC 2, HIPAA, GDPR, ISO 27001, PCI-DSS, or All)
4. Audit executes automatically (~5-30 seconds depending on scope)
5. Results appear in dashboard with pass/fail breakdown

Dashboard Overview The dashboard displays:

- **Overall Pass Rate**: Aggregate compliance score across all frameworks
- **Total Checks**: Number of automated compliance checks (45+)
- **Critical Issues**: Failed checks with critical severity requiring immediate attention
- **Framework Scores**: Individual compliance scores per framework with trend indicators

Framework Compliance Checks

Framework	Checks	Categories
SOC 2	12	Access Control, Data Protection, Audit Logging, Incident Response, Change Management
HIPAA	8	PHI Protection, Access Control, Audit Trail, Data Retention
GDPR	8	Consent Management, Data Subject Rights, Data Processing, Data Transfer, Breach Response
ISO 27001	9	Security Policy, Organization, Access Control, Cryptography, Operations, Incident Management, Co
PCI-DSS	8	Network Security, Data Protection, Encryption, Access Control, Authentication, Monitoring, Testin

Audit History View historical audit runs with:

- **Timestamp**: Exact date/time of audit execution
- **Framework**: Which standard was audited
- **Type**: Manual, Scheduled, or Triggered
- **Score**: Overall compliance percentage
- **Pass/Fail/Skip**: Breakdown of check results
- **Triggered By**: Admin who initiated the audit

Viewing Audit Details Click any audit run to see:

- **Score Overview**: Large score display with pass/fail/skip counts
- **Critical Failures**: Red panel highlighting checks requiring immediate action
- **By Category**: Progress bars showing compliance per category
- **All Results**: Expandable list of every check with status and remediation steps

Generating Reports From an audit run details view:

1. Click **"Export PDF Report"** for auditor-ready documentation
2. Click **"View Evidence"** to see raw query results and execution details

Scheduling Audits Configure automated audit schedules:

1. Navigate to **Self-Audit → Checks Registry**
2. Select framework to schedule
3. Choose frequency: Daily, Weekly, Monthly, or Quarterly
4. Set notification preferences for failures
5. Audits run automatically at configured times

API Integration Integrate audit results with external systems:

```
# Run audit programmatically
POST /api/admin/self-audit/run
{ "framework": "soc2" }

# Fetch latest results
GET /api/admin/self-audit/runs/{runId}

# Generate report
GET /api/admin/self-audit/runs/{runId}/report
```

15.11 Compliance Framework Reference

Comprehensive reference for all supported compliance frameworks with implementation details.

SOC 2 Type II Trust Services Criteria Implementation:

Control	Radiant Implementation	Evidence
CC1.1 - COSO Integrity	Ethics pipeline with content screening	Ethics audit logs
CC2.1 - Security Policy	Tenant-level security configuration	`dynamic_config` table
CC3.1 - Risk Assessment	Security anomaly detection	`security_anomalies` table
CC4.1 - Monitoring	Real-time audit logging	DynamoDB + PostgreSQL audit trails
CC5.1 - Logical Access	Cognito User Pools with MFA	AWS CloudTrail
CC5.2 - Authentication	JWT tokens with session management	Token validation logs
CC6.1 - Encryption	AES-256 at rest, TLS 1.3 in transit	AWS KMS key policies
CC6.6 - Change Management	Dual-approval for production changes	`approval_requests` table
CC7.1 - System Operations	CloudWatch monitoring, automated alerts	AWS CloudWatch dashboards
CC7.2 - Incident Response	Security anomaly alerting	SNS notifications
CC8.1 - Change Management	Database migration approvals	Migration audit logs
CC9.1 - Business Continuity	Multi-AZ deployment, automated backups	Aurora automated backups

Automated Audit Checks:

- MFA enforcement for administrators
- Password policy configuration
- Session timeout settings (30 minutes)
- RBAC implementation verification
- Encryption at rest confirmation
- Audit log retention (7 years)
- Change management process validation

HIPAA / HITECH Administrative Safeguards (45 CFR §164.308):

Requirement	Implementation	Configuration
Security Officer	Designated in tenant config	`hipaa_config.security_officer`
Workforce Training	User acknowledgment tracking	Onboarding audit logs
Access Management	Role-based access with MFA	Cognito + RLS policies
Contingency Plan	Multi-AZ, automated backups	Aurora + S3 replication
Evaluation	Self-audit system	Quarterly compliance audits

Technical Safeguards (45 CFR §164.312):

Requirement	Implementation	Evidence
Access Control	Unique user IDs, automatic logoff	Cognito user management
Audit Controls	PHI access logging	`phi_access_logs` table
Integrity Controls	Column-level encryption	AWS KMS + application encryption
Transmission Security	TLS 1.3 enforced	API Gateway + ALB policies

PHI Detection & Protection:

```
PHI Detection Pipeline

Request → PHI Scanner → [PHI Detected?]
                              ↓ Yes
                        Encrypt + Log → Sanitize → Continue
                              ↓ No
```

```
Continue Processing
```

Retention Requirements:

- PHI Data: 6 years (2,190 days)
- Audit Logs: 7 years (2,555 days)
- BAA Records: 6 years from termination

GDPR (General Data Protection Regulation) Lawful Bases Supported:

Basis	Use Case	Configuration
Consent (Art. 6(1)(a))	Marketing, analytics	Consent tracking UI
Contract (Art. 6(1)(b))	Service delivery	Terms acceptance
Legal Obligation (Art. 6(1)(c))	Audit retention	Automatic retention
Legitimate Interest (Art. 6(1)(f))	Security, fraud prevention	Documented in DPA

Data Subject Rights Implementation:

Right	Article	API Endpoint	SLA
Access	Art. 15	`POST /gdpr/request/access`	30 days
Rectification	Art. 16	`PATCH /users/{id}`	30 days
Erasure	Art. 17	`POST /gdpr/request/erasure`	30 days
Restriction	Art. 18	`POST /gdpr/request/restriction`	30 days
Portability	Art. 20	`POST /gdpr/request/portability`	30 days
Objection	Art. 21	`POST /gdpr/request/objection`	30 days

Cross-Border Transfers:

- Standard Contractual Clauses (SCCs) for non-EU transfers
- AWS regions: `eu-west-1`, `eu-central-1` for EU data residency
- Region restrictions configurable per tenant

Breach Notification:

- 72-hour notification to supervisory authority
- Affected user notification without undue delay
- Breach tracking in `data_breaches` table

ISO 27001:2022 Annex A Controls Implementation:

Control	Title	Radiant Implementation
A.5.1	Policies for information security	`dynamic_config` security policies
A.5.15	Access control	Cognito + RLS + RBAC
A.5.23	Information security for cloud services	AWS security configurations
A.6.1	Screening	Admin approval workflow
A.8.2	Privileged access rights	Super Admin role restrictions
A.8.3	Information access restriction	Tenant isolation (RLS)
A.8.5	Secure authentication	MFA, JWT, session management
A.8.9	Configuration management	Infrastructure as Code (CDK)
A.8.10	Information deletion	Automated retention + deletion
A.8.12	Data leakage prevention	PHI detection, ethics pipeline

Control	Title	Radiant Implementation
A.8.15	Logging	Comprehensive audit logging
A.8.16	Monitoring activities	CloudWatch + anomaly detection
A.8.24	Use of cryptography	AWS KMS, AES-256, TLS 1.3

PCI-DSS v4.0 Requirements Mapping:

Req	Description	Implementation
1	Network security controls	VPC security groups, NACLs
2	Secure configurations	CDK hardened templates
3	Protect stored data	AES-256 encryption, tokenization
4	Protect data in transit	TLS 1.3, certificate pinning
5	Malware protection	AWS WAF, Shield
6	Secure systems	Automated patching, code review
7	Restrict access	RBAC, least privilege
8	Identify users	Unique IDs, MFA, password policies
9	Physical access	AWS data center controls
10	Logging & monitoring	CloudTrail, audit logs
11	Security testing	Automated scanning, pen testing
12	Security policies	Documented in admin guide

Note: Full PCI-DSS certification requires additional controls beyond Radiant's scope (physical security, organizational policies). Radiant provides the technical controls for SAQ-A or SAQ-D compliance.

FedRAMP / StateRAMP Control Families Addressed:

Family	Controls	Radiant Coverage
AC	Access Control	Full
AU	Audit & Accountability	Full
CM	Configuration Management	Full
IA	Identification & Authentication	Full
SC	System & Communications Protection	Full
SI	System & Information Integrity	Full

FedRAMP Boundaries:

- Authorization Boundary: AWS GovCloud available
- Data Flow: Documented in System Security Plan
- Interconnections: API Gateway with mutual TLS

EU AI Act Compliance Risk Classification:

Category	AI Systems	Radiant Controls
Unacceptable	Social scoring, subliminal manipulation	Blocked by ethics pipeline
High-Risk	Healthcare, legal, employment	Enhanced logging, human oversight
Limited	Chatbots, emotion recognition	Transparency disclosures
Minimal	Spam filters, games	Standard controls

Article 9 - Risk Management:

- Domain detection for high-risk use cases
- Ethics screening with configurable policies
- Human-in-the-loop for sensitive decisions

Article 13 - Transparency:

- Model disclosure in API responses
- Training data documentation
- Capability limitations documented

Article 14 - Human Oversight:

- Admin approval workflows
- Escalation triggers
- Override capabilities

15.12 Compliance Checklist Registry

Location: Admin Dashboard → Security → Compliance Checklists

The Compliance Checklist Registry provides versioned, interactive checklists linked to regulatory standards with auto-update support.

Key Features

- **Versioned Checklists** - Each regulatory standard has versioned checklists
- **Regulatory Linking** - Checklists are linked to `regulatory_standards` registry
- **Auto-Update** - Service automatically checks for regulatory version updates
- **Per-Tenant Configuration** - Choose version selection mode per standard
- **Progress Tracking** - Track item completion across teams
- **Audit Runs** - Schedule and run formal checklist audits

Version Selection Modes

Mode	Behavior
Auto (default)	Automatically uses latest active checklist version
Specific	Use a specific version, updates when newer available
Pinned	Locked to exact version, no automatic updates

Dashboard Overview Navigate to **Security → Compliance Checklists** to see:

- All regulatory standards with completion progress
- Per-standard checklist status and version info
- Pending regulatory version updates
- Recent audit run history

Checklist Items Each checklist item includes:

Field	Description
Item Code	Unique identifier (e.g., `SOC2-PRE-001`)
Priority	Critical, High, Medium, Low
Evidence Types	Required evidence (document, screenshot, config, log)
API Endpoint	Optional endpoint for automated evidence collection
Automated Check	Link to `system_audit_checks` for auto-validation
Estimated Time	Minutes to complete the item

Field	Description
Guidance	Detailed instructions for completing the item

Item Status Tracking

Status	Description
Not Started	Item has not been addressed
In Progress	Work is underway
Completed	Item is done with evidence attached
Not Applicable	Item doesn't apply to this tenant
Blocked	Item cannot proceed (reason required)

Pre-Built Checklists Initial checklists are seeded for:

Standard	Version	Categories
SOC 2 Type II	2024.1	Pre-Audit, Documentation, Evidence, Access Control, Change Mgmt, Risk Mgmt, Monitorin
HIPAA	2024.1	Administrative Safeguards, Technical Safeguards, Physical Safeguards
GDPR	2024.1	Data Subject Rights, Processing Records, Security Measures
ISO 27001:2022	2022.1	Organizational, People, Physical, Technological (93 controls)
PCI-DSS	4.0	12 requirement categories

Auto-Update Service The checklist registry can automatically check for regulatory updates:

1. **Update Sources** - Configure RSS feeds, APIs, or webhooks per standard
2. **Check Frequency** - Default 24 hours, configurable per source
3. **Update Detection** - Records detected version changes
4. **Processing** - Admin reviews and approves new checklist versions
5. **Notification** - Tenants notified when their effective version changes

Audit Runs Start formal checklist reviews:

Run Type	Purpose
Manual	Ad-hoc review
Scheduled	Periodic compliance check
Pre-Audit	Preparation before external audit
Certification	Formal certification attempt

API Endpoints Base Path: `/api/admin/compliance/checklists`

Dashboard & Configuration:

Endpoint	Method	Description
`/dashboard`	GET	Full dashboard with progress per standard
`/config`	GET	All tenant checklist configurations
`/config/:standardId`	GET/PUT	Get/set version selection for a standard
`/config/:standardId/effective-version`	GET	Get effective version for tenant

Versions & Items:

Endpoint	Method	Description
`/versions`	GET/POST	List versions for standard / Create version
`/versions/latest`	GET	Get latest version for standard code
`/versions/:id`	GET	Get specific version details
`/versions/:id/set-latest`	POST	Set version as latest
`/versions/:id/categories`	GET/POST	List/create categories
`/versions/:id/items`	GET/POST	List/create checklist items

Progress & Audit:

Endpoint	Method	Description
`/progress/:versionId`	GET	Get tenant progress for version
`/progress/items/:itemId`	PUT	Update item progress/status
`/audit-runs`	GET/POST	List history / Start new audit run
`/audit-runs/:id/complete`	PUT	Complete an audit run

Auto-Updates:

Endpoint	Method	Description
`/updates/pending`	GET	Get pending regulatory updates
`/updates`	POST	Record a version update
`/updates/:id/process`	PUT	Process (approve/reject) an update
`/updates/check/:standardId`	POST	Check sources for updates

Database Tables

Table	Purpose
`compliance_checklist_versions`	Versioned checklists per standard
`compliance_checklist_categories`	Categories within a checklist
`compliance_checklist_items`	Individual checklist items
`tenant_checklist_config`	Per-tenant version selection
`tenant_checklist_progress`	Item completion tracking
`checklist_audit_runs`	Audit run history
`regulatory_version_updates`	Detected regulatory updates
`checklist_update_sources`	Auto-update source configuration

Quick Reference Checklist For quick pre-audit preparation:

- ☐ Run self-audit for all frameworks (`/compliance/self-audit`)
- ☐ Export audit logs for review period
- ☐ Generate compliance reports (PDF)
- ☐ Review critical findings and remediation status
- ☐ Verify all evidence artifacts are accessible
- ☐ Confirm data retention policies are enforced

Documentation Required

Document	Location	Purpose
System Security Plan	`/docs/SYSTEM-SECURITY-PLAN.md`	Architecture overview
Data Flow Diagram	Admin Dashboard → Compliance	Data processing flows
Access Control Matrix	`/docs/ACCESS-CONTROL-MATRIX.md`	Role permissions
Incident Response Plan	`/docs/INCIDENT-RESPONSE.md`	Breach procedures
Business Continuity Plan	`/docs/BUSINESS-CONTINUITY.md`	Disaster recovery

API Request/Response Examples Get Dashboard Data:

```
GET /api/admin/compliance/checklists/dashboard
Headers: x-tenant-id: your-tenant-id

Response:
{
  "standards": [
    {
      "id": "standard-123",
      "code": "SOC2",
      "name": "SOC 2 Type II",
      "latestVersion": "2024.1",
      "effectiveVersionId": "version-abc",
      "completionPercentage": 66.7,
      "itemsCompleted": 12,
      "totalItems": 18
    }
  ],
  "pendingUpdates": 0,
  "recentAuditRuns": []
}
```

Get Versions for Standard:

```
GET /api/admin/compliance/checklists/versions?standardId=standard-123

Response:
{
  "versions": [
    {
      "id": "version-abc",
      "version": "2024.1",
      "title": "SOC 2 Type II Pre-Audit Checklist",
      "versionDate": "2024-01-01",
      "isLatest": true,
      "isActive": true,
      "categoriesCount": 7,
      "itemsCount": 18
    }
  ]
}
```

Create Checklist Version:

```
POST /api/admin/compliance/checklists/versions
Content-Type: application/json
```

```
{
  "standardId": "standard-123",
  "version": "2025.1",
  "title": "SOC 2 Type II Pre-Audit Checklist 2025",
  "description": "Updated for 2025 AICPA guidance",
  "versionDate": "2025-01-01"
}

Response: 201 Created
{
  "id": "new-version-id",
  "version": "2025.1",
  "title": "SOC 2 Type II Pre-Audit Checklist 2025",
  "isLatest": false,
  "isActive": true
}
```

Get Items with Progress:

```
GET /api/admin/compliance/checklists/versions/{versionId}/items
Headers: x-tenant-id: your-tenant-id

Response:
{
  "items": [
    {
      "id": "item-001",
      "itemCode": "SOC2-PRE-001",
      "title": "Confirm audit dates",
      "description": "Schedule dates with external auditor",
      "categoryCode": "pre_audit",
      "priority": "critical",
      "isRequired": true,
      "estimatedMinutes": 15,
      "evidenceTypes": ["document", "attestation"],
      "status": "completed",
      "completedAt": "2024-01-15T10:30:00Z",
      "completedBy": "user-123"
    }
  ]
}
```

Update Item Progress:

```
PUT /api/admin/compliance/checklists/progress/items/{itemId}
Content-Type: application/json
Headers: x-tenant-id: your-tenant-id

{
  "status": "completed",
  "notes": "Verified with auditor on call",
  "evidenceUrls": [
    "https://storage.example.com/evidence/audit-confirmation.pdf"
  ]
}
```

Response:

```
{ "success": true }
```

Set Tenant Version Configuration:

```
PUT /api/admin/compliance/checklists/config/{standardId}
Content-Type: application/json
Headers: x-tenant-id: your-tenant-id

{
  "versionSelection": "specific",
  "selectedVersionId": "version-abc",
  "autoUpdateEnabled": false,
  "notificationOnUpdate": true
}

Response:
{
  "tenantId": "your-tenant-id",
  "standardId": "standard-123",
  "versionSelection": "specific",
  "selectedVersionId": "version-abc",
  "autoUpdateEnabled": false,
  "notificationOnUpdate": true
}
```

Start Audit Run:

```
POST /api/admin/compliance/checklists/audit-runs
Content-Type: application/json
Headers: x-tenant-id: your-tenant-id

{
  "versionId": "version-abc",
  "runType": "pre_audit",
  "notes": "Preparing for Q1 external audit"
}

Response: 201 Created
{
  "id": "run-123",
  "tenantId": "your-tenant-id",
  "versionId": "version-abc",
  "runType": "pre_audit",
  "status": "in_progress",
  "startedAt": "2024-01-15T10:00:00Z",
  "triggeredBy": "user-123"
}
```

Complete Audit Run:

```
PUT /api/admin/compliance/checklists/audit-runs/{runId}/complete
Content-Type: application/json

{
  "status": "completed",
  "score": 95,
```

```
  "findings": [
    "Minor documentation gap in CC5.2 - recommend update before external audit"
  ],
  "recommendations": [
    "Schedule follow-up review for access control documentation"
  ]
}
```

Response:

```
{
  "id": "run-123",
  "status": "completed",
  "completedAt": "2024-01-16T14:30:00Z",
  "score": 95,
  "findings": ["..."]
}
```

Query Parameters Reference

Endpoint	Parameter	Type	Description
`/versions`	`standardId`	UUID	Required. Filter by standard
`/versions/latest`	`standardCode`	String	Required. Standard code (e.g., `SOC2`)
`/versions/:id/items`	`categoryCode`	String	Optional. Filter by category
`/audit-runs`	`limit`	Integer	Max results (default: 20)
`/config`	-	-	Returns all configs for tenant

Error Responses

Status	Error	Description
400	Bad Request	Missing required field or invalid format
401	Unauthorized	Missing or invalid authentication
403	Forbidden	Tenant ID mismatch or insufficient permissions
404	Not Found	Resource doesn't exist
500	Server Error	Internal error (check logs)

Example error response:

```
{
  "error": "standardId, version, and title required"
}
```

Evidence Collection API

```
# Export audit logs for date range
GET /api/admin/audit-logs/export?start=2024-01-01&end=2024-12-31

# Export compliance report
GET /api/admin/self-audit/runs/{runId}/report

# Export user access logs
GET /api/admin/users/access-logs/export
```

```
# Get checklist progress
GET /api/admin/compliance/checklists/progress/{versionId}

# Start pre-audit checklist run
POST /api/admin/compliance/checklists/audit-runs
Body: { "versionId": "...", "runType": "pre_audit" }
```

15.13 Administrator Emergency Protocols

Critical procedures for security incidents and platform emergencies.

Emergency Tenant Suspension **Scenario:** GuardDuty detects malicious activity originating from a specific tenant (e.g., launching an outbound DDoS attack, data exfiltration attempt).

Procedure:

1. **Do NOT** shut down the entire system
2. Access **Admin Dashboard → Tenants**
3. Locate the tenant by ID or name
4. Click **"Suspend Tenant"** (requires MFA confirmation)
5. Enter suspension reason for audit log

System Response:

- API Gateway Authorizer immediately rejects all JWTs containing that `tenant_id`
- Tenant is effectively quarantined from compute layer immediately
- All active sessions are invalidated
- Scheduled jobs for that tenant are paused
- Alert sent to security team via SNS

Post-Incident:

1. Investigate root cause using X-Ray traces filtered by `tenant_id`
2. Collect forensic evidence from CloudWatch Logs
3. Determine if data breach occurred (breach notification may be required)
4. Decide: remediate and restore, or permanent termination
5. Document incident in compliance system

Key Rotation Emergency **Scenario:** Compromise of an administrative credential or API key.

Procedure:

Compromise Type	Action
IAM User Keys	Rotate immediately via AWS Console
Database Credentials	Trigger Aurora Master Password Rotation via Secrets Manager
Tenant API Keys	Revoke all API keys via Admin Dashboard → Tenant → API Keys
KMS Key Suspected	Schedule key rotation (cannot immediately delete due to data access)

System Response:

- Secrets Manager automatically updates the secret
- Database connections automatically restart with new credentials
- No code deployment required
- Audit trail recorded in CloudTrail

Mass Incident Response Scenario: Platform-wide security incident (e.g., zero-day vulnerability exploitation).

Procedure:

1. **Activate Incident Response Team** - PagerDuty escalation
2. **Enable WAF Emergency Rules** - Block suspicious patterns
3. **Freeze Deployments** - Halt all CI/CD pipelines
4. **Capture Evidence** - Export CloudTrail, CloudWatch, GuardDuty findings
5. **Patch/Mitigate** - Apply hotfix or WAF rule
6. **Gradual Restoration** - Enable services tenant by tenant
7. **Post-Mortem** - Root cause analysis within 72 hours
8. **Communication** - Status page updates, customer notification if data affected

Data Breach Response Timeline

Regulation	Notification Deadline	Recipient
GDPR	72 hours	Supervisory Authority
HIPAA	60 days	HHS, affected individuals
State Laws	Varies (often 72 hours)	State AG, affected individuals

Breach Response Steps:

1. **Contain** - Suspend affected tenant(s), revoke compromised credentials
2. **Assess** - Determine scope: which tenants, which data, how many records
3. **Preserve** - Forensic copy of affected systems
4. **Report** - Legal team notified within 4 hours
5. **Notify** - Regulatory notifications per timeline
6. **Remediate** - Fix vulnerability, rotate credentials
7. **Document** - Complete incident report for compliance

Recovery Objectives

Data Class	RPO (Recovery Point)	RTO (Recovery Time)	Backup Strategy
Critical (User accounts, tenant config)	1 hour	1 hour	Continuous replication + hourl
High (Conversations, messages)	4 hours	4 hours	4-hour snapshots
Medium (Preferences, cached data)	24 hours	8 hours	Daily snapshots
Low (Analytics, aggregates)	7 days	24 hours	Weekly snapshots
Audit Logs	0 (immutable)	4 hours	S3 Object Lock + cross-region

15.14 Security Monitoring Schedules

Location: Admin Dashboard → Security → Schedules

Full-featured EventBridge schedule management with templates, notifications, and webhooks.

Available Schedules

Schedule	Default	Purpose
Drift Detection	Daily 00:00 UTC	Monitors model output distribution changes
Anomaly Detection	Hourly	Behavioral scans for suspicious patterns
Classification Review	Every 6 hours	Aggregates classification statistics

Schedule	Default	Purpose
Weekly Security Scan	Sunday 02:00 UTC	Comprehensive security audit
Weekly Benchmark	Saturday 03:00 UTC	TruthfulQA and factual accuracy tests

Managing Schedules

1. Navigate to **Security → Schedules**
2. View all schedules with current configuration and next execution time
3. Toggle **Enable/Disable** to control schedule
4. Click **Configure** to modify cron expression (with real-time preview)
5. Click **Run Now** to trigger immediate execution
6. Click **Test Run** for dry-run validation without affecting data

Bulk Operations

- **Enable All**: Enable all schedules at once
- **Disable All**: Disable all schedules (e.g., for maintenance)

Schedule Templates Apply pre-configured schedule sets:

Template	Description
Production (Conservative)	Fewer checks, less resource usage
Development (Aggressive)	Frequent checks for dev environments
Minimal	Weekly only, for low-traffic tenants

To apply a template:

1. Go to **Templates** tab
2. Review template settings
3. Click **Apply** to update all schedules

Notifications Configure alerts for schedule executions:

1. Go to **Notifications** tab
2. Enable notifications
3. Configure:
   - **SNS Topic ARN**: For AWS SNS notifications
   - **Slack Webhook URL**: For Slack channel alerts
   - **Notify on Success**: Alert when schedules complete
   - **Notify on Failure**: Alert when schedules fail (recommended)

Webhooks Send execution results to external services:

1. Go to **Webhooks** tab
2. Enter webhook URL
3. Click **Add Webhook**

Webhook events:

- `execution.completed` - Schedule finished successfully
- `execution.failed` - Schedule encountered errors

Webhook payload:

```
{
  "event": "execution.completed",
  "payload": {
    "scheduleType": "drift_detection",
    "status": "completed",
    "itemsProcessed": 150,
    "itemsFlagged": 3,
    "executionTimeMs": 4523
  },
  "timestamp": "2024-12-29T12:00:00Z"
}
```

Cron Expression Format Uses AWS EventBridge cron format: `Minutes Hours Day-of-month Month Day-of-week Year`

Common Presets: | Preset | Cron Expression | Description | |--------|-----------------|-------------| | Hourly | `0 * * * ? *` | Every hour | | Every 6 hours | `0 0,6,12,18 * * ? *` | 4 times daily | | Daily midnight | `0 0 * * ? *` | Once per day | | Weekly Sunday 2AM | `0 2 ? * SUN *` | Weekly on Sunday |

The UI shows human-readable descriptions and next 5 execution times for any cron expression.

Execution History View past execution results including:

- **Status**: Running, Completed, Failed
- **Duration**: Execution time in seconds
- **Items Processed**: Number of items checked
- **Items Flagged**: Security issues found
- **Errors**: Any errors encountered

Audit Log All schedule changes are logged with:

- Timestamp and user who made change
- Previous and new cron expression
- Enable/disable actions
- Reason for change (optional)

API Endpoints **Core:** | Endpoint | Method | Description | |----------|--------|-------------| | `/api/admin/security/schedules` | GET | Get all schedule config | | `/api/admin/security/schedules/dashboard` | GET | Dashboard with stats | | `/api/admin/security/schedules/{type}` | PUT | Update schedule | | `/api/admin/security/schedules/{type}/en` | POST | Enable schedule | | `/api/admin/security/schedules/{type}/disable` | POST | Disable schedule | | `/api/admin/security/schedules/{type}/run-now` | POST | Trigger manual run (with optional dryRun) |

Templates: | Endpoint | Method | Description | |----------|--------|-------------| | `/api/admin/security/schedules/templates` | GET | List templates | | `/api/admin/security/schedules/templates` | POST | Create template | | `/api/admin/security/schedules/templates/{id}/apply` | POST | Apply template | | `/api/admin/security/schedules/templates/{id}` | DELETE | Delete template |

Notifications & Webhooks: | Endpoint | Method | Description | |----------|--------|-------------| | `/api/admin/security/schedules/notifications` | GET/PUT | Notification config | | `/api/admin/security/schedules/w` | GET/POST | Webhook management | | `/api/admin/security/schedules/webhooks/{id}` | DELETE | Delete webhook |

Utilities: | Endpoint | Method | Description | |----------|--------|-------------| | `/api/admin/security/schedules/parse-cron` | POST | Parse cron with preview | | `/api/admin/security/schedules/bulk/enable` | POST | Enable all schedules | | `/api/admin/security/schedules/bulk/disable` | POST | Disable all schedules | |

`/api/admin/security/schedules/presets` | GET | Get cron presets | | `/api/admin/security/schedules/executions` | GET | Get execution history | | `/api/admin/security/schedules/audit` | GET | Get audit log |

---

14. Cost Analytics

14.1 Cost Dashboard

Navigate to **Cost** to view:

```
Cost Analytics                          Period: Last 30 Days


Total Spend:       $12,456.78           (+12% vs last month)
Projected:         $14,200.00           (this month)

By Provider:
   OpenAI:        $6,234.56 (50%)
   Anthropic:     $3,456.78 (28%)
   Self-hosted:   $1,234.56 (10%)
   Other:         $1,530.88 (12%)

AI Recommendations:
  Switch 23% of GPT-4 calls to GPT-4-mini (save $890/mo)
  Enable caching for repeated queries (save $340/mo)
```

14.2 Cost Alerts

Configure alerts:

- Daily budget exceeded
- Weekly spend spike
- Per-tenant limits
- Per-model thresholds

14.3 Cost Optimization

Review AI-powered recommendations:

1. Navigate to **Cost → Insights**
2. Review suggestions
3. Click **"Apply"** to implement (requires approval)
4. Track savings over time

---

15. Revenue Analytics

15.1 Revenue Dashboard

Navigate to **Revenue** to view gross revenue, COGS, and profit:

```
Revenue Analytics                       Period: Last 30 Days
```

```
Gross Revenue:     $29,450.00          (+12.5% vs last period)
Total COGS:        $14,150.00
Gross Profit:      $15,300.00          (+15.2% vs last period)
Gross Margin:      51.95%

Revenue Breakdown:
  Subscriptions:       $15,000.00 (50.9%)
  Credit Purchases:    $2,500.00 (8.5%)
  AI Markup (External): $8,750.00 (29.7%)
  AI Markup (Self-Hosted): $3,200.00 (10.9%)

 Note: Marketing, sales, G&A costs not included (COGS only)
```

15.2 Cost Breakdown (COGS)

View infrastructure and provider costs:

Category	Description	Example Services
AWS Compute	Compute infrastructure	EC2, SageMaker, Lambda
AWS Storage	Storage services	S3, EBS
AWS Network	Data transfer	API Gateway, CloudFront
AWS Database	Database services	Aurora, DynamoDB
External AI	Provider costs	OpenAI, Anthropic APIs
Platform Fees	Payment processing	Stripe fees

15.3 Revenue by Model

View per-model profitability:

Model	Provider Cost	Customer Charge	Markup	Requests
gpt-4o	$500.00	$650.00	30%	12,345
claude-3.5-sonnet	$300.00	$390.00	30%	8,901
Self-hosted Llama	$100.00	$175.00	75%	45,678

15.4 Accounting Exports

Export revenue data for accounting software:

1. Click **Export** dropdown
2. Select format:
   - **CSV**: Summary for spreadsheets
   - **JSON**: Full details for integrations
   - **QuickBooks IIF**: Direct import to QuickBooks
   - **Xero CSV**: Import to Xero
   - **Sage CSV**: Import to Sage
3. Configure date range
4. Download file

QuickBooks Integration:

- Import via File → Utilities → Import → IIF Files

- Creates General Journal entries
- Requires matching account names

See Revenue Analytics Documentation for full details.

---

16. SaaS Metrics Dashboard

16.1 Overview

Navigate to **SaaS Metrics** for a comprehensive view of business health:

```
SaaS Metrics Dashboard                    Period: Last 30 Days


MRR: $89,500       ARR: $1,074,000     Gross Margin: 53.1%
+12.5%             +15.2%                        53%

Customers: 342     Churn: 2.3%         LTV:CAC: 6.98x
+5.8%                Target <2%          Healthy
```

16.2 Key Metrics

Metric	Description	Healthy Range
MRR	Monthly Recurring Revenue	Growing month-over-month
ARR	Annual Recurring Revenue	MRR $\times$ 12
Gross Margin	(Revenue - COGS) / Revenue	$> 50\%$
Churn Rate	Customers lost / Total	$< 3\%$
LTV:CAC	Lifetime Value / Acquisition Cost	$> 3{:}1$

16.3 Dashboard Tabs

1. **Overview**: Revenue trends, top tenants, cost breakdown
2. **Revenue**: MRR movement, revenue by product/tier
3. **Costs**: Cost distribution, COGS breakdown
4. **Customers**: Growth trends, churn analysis
5. **Models**: Per-model profitability analysis

16.4 Exporting Reports

Export data for Excel or accounting:

1. Click **Export** dropdown
2. Select format:
   - **Excel (CSV)**: Full metrics in spreadsheet format
   - **JSON**: Structured data for integrations
3. File downloads with period and date in filename

Export includes:

- Revenue summary (MRR, ARR, Gross Profit)
- Cost breakdown by category
- Customer metrics (total, new, churned)

- Unit economics (ARPU, LTV, CAC)
- Top tenants with details
- Model performance metrics
- Daily trend data

See SaaS Metrics Dashboard Documentation for full details.

---

17. A/B Testing & Experiments

16.1 Experiment Dashboard

Navigate to **Experiments** to manage:

Experiment	Status	Variants	Sample Size
Model routing v2	Running	3	45,234
Prompt optimization	Running	2	12,456
Temperature test	Completed	4	89,123

15.2 Creating an Experiment

1. Click **"+ New Experiment"**
2. Configure:
   - **Name**: Descriptive name
   - **Hypothesis**: What you're testing
   - **Variants**: Control + treatments
   - **Traffic Split**: Percentage per variant
   - **Success Metric**: What to measure
3. Set targeting rules
4. Start experiment

15.3 Statistical Analysis

View results with:

- Conversion rates per variant
- Statistical significance (p-value)
- Confidence intervals
- Sample size recommendations

---

16. Audit & Monitoring

16.1 Audit Logs

Navigate to **Audit** to view all actions:

Column	Description
Timestamp	When action occurred
Actor	Who performed action
Action	What was done
Resource	What was affected
IP Address	Source IP
Details	Additional context

Column	Description

16.2 Log Filtering

Filter by:

- Date range
- Actor (user/admin)
- Action type
- Resource type
- Severity level

16.3 Log Export

Export logs for compliance:

1. Set filter criteria
2. Click **"Export"**
3. Choose format (CSV/JSON)
4. Download file

16.4 Real-Time Monitoring

Navigate to **Monitoring** for:

- Live request stream
- Error rate graphs
- Latency percentiles
- Active users count

---

17. Database Migrations

17.1 Migration Workflow

RADIANT uses dual-admin approval for production migrations:

1. **Submit**: Admin submits migration
2. **Review**: Second admin reviews
3. **Approve**: Second admin approves
4. **Execute**: Migration runs
5. **Verify**: Automatic verification

17.2 Pending Migrations

Navigate to **Migrations** to see:

```
Database Migrations


Pending Approval:

  #045 - Add user preferences table
  Submitted by: alice@company.com (2 hours ago)
  [View SQL]  [Approve]  [Reject]
```

```
Recent Migrations:
  #044 - Cost tracking tables (applied 2024-12-24)
  #043 - Experiment framework (applied 2024-12-20)
  #042 - Security anomalies (applied 2024-12-15)
```

17.3 Approving Migrations

1. Review the SQL in **"View SQL"**
2. Check for potential issues
3. Click **"Approve"** or **"Reject"**
4. Add comment explaining decision

---

18. API Management

18.1 API Keys

Manage platform API keys:

1. Navigate to **Settings → API Keys**
2. View existing keys
3. Create new keys with scopes
4. Revoke compromised keys

18.2 Rate Limiting

Configure rate limits:

Level	Default	Configurable
Global	10,000/min	Yes
Per-Tenant	1,000/min	Yes
Per-User	100/min	Yes
Per-Key	60/min	Yes

18.3 Webhooks

Configure outgoing webhooks:

1. Navigate to **Settings → Webhooks**
2. Add webhook URL
3. Select events to send
4. Test webhook
5. Enable webhook

---

19. Anti-Patterns and Prohibited Practices

CRITICAL: These patterns represent security vulnerabilities or architectural anti-patterns that must NEVER be used in RADIANT.

19.1 Critical Security Anti-Patterns

NEVER DO	INSTEAD DO	Risk
Trust `tenant_id` from request body	Extract from JWT claims only	Identity spoofing
Store `tenant_id` in URLs	Use headers/JWT claims	Information disclosure in logs
Use `dynamodb:*` wildcard permissions	Specify exact actions + Leading Keys	Privilege escalation
Deploy Lambda code without signing	Use AWS Signer verification	Supply chain attack
Allow manual AWS Console changes in prod	Enforce CDK/Terraform only via SCPs	Configuration drift
Use shared `/tmp` for cross-invocation data	Use DynamoDB/S3 for persistence	Data leakage
Log full request/response bodies	Sanitize sensitive data	PHI/PII exposure
Store credentials in code/environment variables	Use Secrets Manager	Credential theft
Use single KMS key for all tenants	Per-tenant CMK (Tier 3+)	Blast radius on key compromis
Delete audit logs	S3 Object Lock Compliance Mode	Repudiation, compliance failur
Return detailed errors to clients	Log internally, generic response to client	Information disclosure

19.2 Architectural Anti-Patterns

AVOID	BETTER APPROACH
Monolithic TMS + Admin Dashboard	Separate Control Plane from Application
Application-layer-only isolation	Database-engine-enforced isolation (RLS, Leading Keys)
Static asset inventory spreadsheets	AWS Config continuous discovery
Point-in-time security scans	Continuous monitoring (GuardDuty + Inspector)
Generic error messages everywhere	Detailed internal logs, generic external responses
Same IAM role for all functions	Function-specific least-privilege roles
Trusting user input for SQL queries	Parameterized queries + RLS

19.3 Code Anti-Patterns

```
// ❌ WRONG: Tenant ID from untrusted source
const tenantId = event.body.tenant_id;
const tenantId = event.queryStringParameters.tenant_id;
const tenantId = event.headers['X-Tenant-ID'];

// ✅ CORRECT: Tenant ID from verified JWT
const tenantId = event.requestContext.authorizer?.claims?.['custom:tenant_id'];

// ❌ WRONG: Building queries without RLS context
const result = await db.query(
  `SELECT * FROM conversations WHERE tenant_id = $1`,
  [tenantId]
);

// ✅ CORRECT: Set context, let RLS handle isolation
await db.query(`SET app.current_tenant_id = $1`, [tenantId]);
const result = await db.query(`SELECT * FROM conversations`);
// RLS policy automatically filters by tenant_id

// ❌ WRONG: Detailed errors to client
return {
  statusCode: 500,
  body: JSON.stringify({
    error: error.message,
```

```
    stack: error.stack,
    query: sql,
  }),
};

//  CORRECT: Generic error, detailed internal log
logger.error('Query failed', { error, sql, tenantId, traceId });
return {
  statusCode: 500,
  body: JSON.stringify({
    error: 'Internal Server Error',
    requestId: context.awsRequestId
  }),
};
```

19.4 STRIDE Threat Model Reference

Threat	Serverless Attack Vector	RADIANT Mitiga
S - Spoofing	Forged JWT, misconfigured authorizer, tenant_id in request body	Cognito + API G
T - Tampering	S3 code bucket compromise, dependency injection, supply chain attack	AWS Signer code
R - Repudiation	Lost ephemeral logs, deleted audit trail	CloudWatch → S
I - Information Disclosure	Shared Lambda /tmp, memory leakage, verbose errors	Lambda Tenant I
D - Denial of Service	Wallet DoS, noisy neighbor, partition exhaustion	Per-tenant API G
E - Elevation of Privilege	Over-permissive IAM roles, role assumption exploits	Least privilege +

19.5 Pre-Deployment Security Checklist

- ☐ Lambda Tenant Isolation Mode enabled for all functions
- ☐ RLS policies applied to all tenant-scoped tables
- ☐ DynamoDB Leading Keys IAM conditions configured
- ☐ AWS Signer code signing enabled and enforced
- ☐ S3 Object Lock enabled on audit bucket (Compliance Mode)
- ☐ GuardDuty Lambda Protection enabled
- ☐ Inspector Lambda scanning enabled
- ☐ X-Ray tracing enabled for all functions
- ☐ Per-tenant API Gateway usage plans configured
- ☐ WAF rules deployed and active
- ☐ KMS CMK created for Tier 3+ tenants
- ☐ Permission boundaries applied to all Lambda roles
- ☐ Secrets Manager used for all credentials (no env vars)
- ☐ CloudTrail enabled with log file validation

---

20. Troubleshooting

20.1 Common Issues

High Error Rate

1. Check **Providers** for unhealthy providers
2. Review **Audit** logs for patterns
3. Check **Monitoring** for load spikes
4. Verify API key validity

Slow Response Times

1. Check provider latency in **Providers**
2. Review model selection in **Orchestration**
3. Check for cold-start issues (self-hosted)
4. Verify database performance

Authentication Failures

1. Check user status in **Users**
2. Verify MFA configuration
3. Review **Audit** logs for login attempts
4. Check for IP blocks in **Security**

20.2 Support Resources

Resource	Description
Documentation	This guide + online docs
Status Page	status.radiant.example.com
Support Email	support@radiant.example.com
Emergency	+1-555-RADIANT

20.3 Log Locations

Service	Log Group
API Gateway	/aws/apigateway/radiant
Lambda	/aws/lambda/radiant-*
Admin Dashboard	/aws/cloudfront/admin
Database	/aws/rds/cluster/radiant

---

20. Delight System Administration

The Delight System provides personality, achievements, and engagement features for Think Tank users.

20.1 Accessing Delight Admin

Navigate to **Think Tank → Delight** in the admin sidebar.

20.2 Dashboard Overview

The Delight dashboard shows:

Metric	Description
Messages Shown	Total delight messages displayed
Achievements Unlocked	Total achievements earned by users
Easter Eggs Found	Hidden features discovered
Active Users	Users with Delight enabled

20.3 Managing Categories

Toggle entire categories on/off:

Category	Purpose
Domain Loading	Messages while loading domain expertise
Domain Transition	Messages when switching topics
Time Awareness	Time-of-day contextual messages
Model Dynamics	Messages about AI consensus/disagreement
Complexity Signals	Feedback on query complexity
Synthesis Quality	Post-response quality indicators
Achievements	Milestone celebrations
Wellbeing	Break/health reminders
Easter Eggs	Hidden features
Sounds	Audio feedback

20.4 Managing Messages

- **Create**: Add new delight messages with targeting options
- **Edit**: Modify text, triggers, and display settings
- **Delete**: Remove messages (soft delete)
- **Toggle**: Enable/disable individual messages

Message Targeting Options

Option	Values
Injection Point	pre_execution, during_execution, post_execution
Trigger Type	domain_loading, time_aware, model_dynamics, etc.
Domain Families	science, humanities, creative, technical, etc.
Time Contexts	morning, afternoon, evening, night, weekend
Display Style	subtle, moderate, expressive

20.5 Statistics Dashboard

Access detailed usage statistics at **Delight → View Statistics**:

- **Weekly Trends**: 12-week activity history
- **Top Messages**: Most-shown messages with engagement data
- **Achievement Stats**: Unlock rates, time-to-unlock averages
- **Easter Egg Stats**: Discovery rates by egg
- **User Engagement**: Leaderboard by achievement points

20.6 Managing Achievements

Configure achievement unlock criteria:

Setting	Description
Threshold	Number required to unlock
Rarity	common, uncommon, rare, epic, legendary
Points	Score value for leaderboards
Hidden	Only visible after unlock

20.7 Managing Easter Eggs

Configure hidden features:

Setting	Description
Trigger Type	key_sequence, text_input, time_based, random
Trigger Value	The activation pattern
Effect Type	mode_change, visual_transform, sound_play
Duration	How long the effect lasts

20.8 API Endpoints

Endpoint	Method	Description
`/api/admin/delight/dashboard`	GET	Dashboard data
`/api/admin/delight/statistics`	GET	Detailed statistics
`/api/admin/delight/categories/:id`	PATCH	Toggle category
`/api/admin/delight/messages`	POST	Create message
`/api/admin/delight/messages/:id`	PUT/DELETE	Update/delete
`/api/admin/delight/user-engagement`	GET	User leaderboard

Appendix: Quick Reference

Keyboard Shortcuts

Shortcut	Action
`G + D`	Go to Dashboard
`G + T`	Go to Tenants
`G + M`	Go to Models
`G + B`	Go to Billing
`G + A`	Go to Audit
`?`	Show shortcuts

Status Indicators

Icon	Meaning
	Healthy/Success
	Warning
	Error/Failed
	In Progress
	Disabled/Pending

---

16. Adaptive Storage Configuration

Location: Admin Dashboard → Settings → Storage

Configure storage backends per deployment tier to optimize costs.

16.1 Storage Types

Type	Use Case	Monthly Cost
Fargate PostgreSQL	Tier 1-2 (dev/startup)	$5-50
Aurora Serverless v2	Tier 3-5 (production)	$100-2500
DynamoDB	Simple key-value workloads	Pay per request

16.2 Default Configuration

Tier	Default Storage	Reason
1 (SEED)	Fargate PostgreSQL	Low cost for dev
2 (STARTUP)	Fargate PostgreSQL	Cost-effective for small prod
3 (GROWTH)	Aurora Serverless	Auto-scaling for growth
4 (SCALE)	Aurora Serverless	High availability
5 (ENTERPRISE)	Aurora Serverless + Multi-AZ	Maximum reliability

16.3 Admin Overrides

To override the default storage type:

1. Go to Settings → Storage
2. Enable "Admin Override" for the tier
3. Select new storage type
4. Provide override reason (required)
5. Save configuration

Overrides are logged with timestamp and administrator ID.

---

17. Ethics Configuration

Location: Admin Dashboard → Settings → Ethics

Manage AI ethics frameworks with externalized, configurable presets.

17.1 Ethics Presets

Preset	Type	Default Status
Secular (NIST/ISO)	Secular	Enabled (Default)
Christian Ethics	Religious	Disabled
Corporate Governance	Corporate	Disabled

17.2 Enabling Religious Presets

Religious ethics presets are disabled by default. To enable:

1. Go to Settings → Ethics
2. Navigate to "Religious" tab
3. Toggle "Enable Religious Preset"
4. Click "Apply This Preset"

Warning: Enabling religious presets incorporates faith-based principles into AI decision-making. Ensure this aligns with your organization's policies.

17.3 Tenant Ethics Selection

Each tenant can select their preferred ethics preset:

1. Admin selects preset for tenant
2. Custom principles can be added
3. Strict mode can be enabled for enhanced checking

---

19. Intelligence Aggregator

Location: Admin Dashboard → Settings → Intelligence

Advanced AI capabilities that enable RADIANT to outperform any single model.

> **Why a System > a Model**: See Intelligence Aggregator Architecture for the full technical analysis of why Radiant's orchestration outperforms any single SOTA model.

19.1 Feature Overview

Feature	Default	Cost Impact	Purpose
Uncertainty Detection	On	Minimal	Detect low-confidence claims via logprobs
Success Memory RAG	On	Minimal	Learn from highly-rated interactions
MoA Synthesis	Off	3-4x	Parallel generation + synthesis
Cross-Provider Verification	Off	2x	Adversarial error checking
Code Execution	Off	Variable	Run code to verify it works

19.2 Uncertainty Detection (Logprobs)

Monitors token confidence to catch "guessing":

```
Workflow:
1. Model generates response with logprobs enabled
2. System monitors average token probability
3. If confidence < 85% on factual claim → trigger verification
4. Web search or knowledge base lookup verifies claim
5. Verified fact injected, generation continues
```

Settings:

- `threshold`: Confidence level (default: 85%)
- `verificationTool`: web_search | vector_db | none

19.3 Success Memory RAG

Learns user preferences without fine-tuning:

```
Workflow:
1. User rates response 4-5 stars
2. Interaction stored with vector embedding
3. Future similar prompts retrieve gold interactions
4. Retrieved interactions injected as few-shot examples
5. Model matches user's preferred style/format
```

Settings:

- `minRatingForGold`: 4 or 5 stars
- `maxGoldInteractions`: Per-user limit (default: 1000)

- `retrievalCount`: Examples to inject (default: 3)

19.4 Mixture of Agents (MoA) Synthesis

Parallel generation eliminates single-model blind spots:

```
Phase 1 (Propose):
  GPT-4o      → Draft A
  Claude 3.5  → Draft B  (parallel)
  DeepSeek    → Draft C

Phase 2 (Synthesize):
  Claude 3.5 Opus analyzes all drafts
  → Combines strengths
  → Resolves conflicts
  → Final superior response
```

Settings:

- `proposerCount`: Number of models (default: 3)
- `defaultProposers`: Model list
- `synthesizerModel`: Model for synthesis

19.5 Cross-Provider Verification

Adversarial checking from different training data:

```
Generator (OpenAI) → Initial response

Adversary (Anthropic) with hostile prompt:
  "Find hallucinations, logic gaps, vulnerabilities..."

If issues found:
  → Generator regenerates addressing issues
  → Adversary re-verifies
  → Max 2 regeneration attempts
```

Adversary Personas:

- `security_auditor`: Find vulnerabilities
- `fact_checker`: Find hallucinations
- `logic_analyzer`: Find reasoning gaps
- `code_reviewer`: Find bugs

19.6 Code Execution Sandbox

Verify generated code actually runs:

```
Draft → Generate code
     ↓
Sandbox → Execute in Lambda/Fargate
     ↓
If error:
  → Feed stderr to model
  → Model patches code
  → Re-execute
     ↓
Deliver → User gets working code
```

Security: Currently static analysis only. Full execution requires security review.

Settings:

- `languages`: python, javascript, typescript
- `timeoutSeconds`: Max execution time (default: 10)
- `memoryMb`: Memory limit (default: 128)

19.7 Configuration via Admin UI

Navigate to Settings → Intelligence to:

1. Enable/disable each feature
2. Configure thresholds and limits
3. Select models for MoA
4. Choose verification modes

---

18. Infrastructure Configuration

18.1 VPC CIDR Override

For enterprise VPC peering, the default CIDR can be overridden:

```
// In deployment configuration
{
  vpcCidrOverride: '172.16.0.0/16'  // Custom CIDR to avoid conflicts
}
```

Default CIDRs by tier:

- Tier 1: `10.0.0.0/20`
- Tier 2: `10.0.0.0/18`
- Tier 3: `10.0.0.0/17`
- Tier 4: `10.0.0.0/16`
- Tier 5: `10.0.0.0/14`

18.2 Router Performance Headers

API responses include performance metrics:

Header	Description
`X-Radiant-Router-Latency`	Time spent in brain router (ms)
`X-Radiant-Domain-Detection-Ms`	Domain detection time
`X-Radiant-Model-Selection-Ms`	Model selection time
`X-Radiant-Cost-Cents`	Estimated cost for request
`X-Radiant-Cache-Hit`	Whether routing was cached

18.3 Deploy Core Library

The `@radiant/deploy-core` package provides platform-agnostic deployment:

```
import { RadiantDeployer } from '@radiant/deploy-core';

const deployer = new RadiantDeployer({
  appId: 'my-app',
  environment: 'production',
```

```
  tier: 3,
  region: 'us-east-1',
  credentials: { ... },
  vpcCidrOverride: '172.16.0.0/16',
});

const result = await deployer.deploy();
```

Available classes:

- `RadiantDeployer` - Main deployment orchestration
- `StackManager` - CloudFormation stack operations
- `HealthChecker` - Post-deployment health checks
- `SnapshotManager` - Deployment snapshots for rollback

18.4 Global Latency Heatmap (v5.52.1)

The Infrastructure page includes a geographic latency visualization showing real-time response times across AWS regions:

Features:

- **World Map Overlay** - Visual representation of global infrastructure
- **17 AWS Regions Mapped** - us-east-1, us-west-2, eu-west-1, ap-northeast-1, etc.
- **Color-Coded Latency** - Thresholds from excellent (<50ms) to critical (>500ms)
- **Pulse Animation** - Critical regions pulse to draw attention
- **Request Volume Indicators** - Marker size reflects traffic volume
- **Status Summary** - Healthy/degraded/critical counts

Latency Thresholds: | Threshold | Color | Status | |-----------|-------|--------| | <50ms | Green | Excellent | | <100ms | Light Green | Good | | <200ms | Yellow | Fair | | <500ms | Orange | Slow | | >500ms | Red | Critical |

API Endpoint: `GET /api/admin/infrastructure/regions/latency`

Response:

```
{
  "regions": [
    {
      "region": "US East (N. Virginia)",
      "regionCode": "us-east-1",
      "latencyMs": 45,
      "requestCount": 125000,
      "errorRate": 0.02,
      "status": "healthy"
    }
  ]
}
```

18.5 Model Usage Heatmap (v5.52.1)

The Metrics page includes a correlation heatmap showing model usage patterns by day of week:

Features:

- **2D Grid Visualization** - Models vs. days of week
- **5 Color Schemes** - blue (default), red, green, purple, diverging
- **Configurable Cell Size** - sm, md, lg
- **Value Display** - Optional numeric values in cells

- **Click-to-Drill** - Click cells for detailed usage breakdown
- **Animated Rendering** - Cells fade in sequentially

Usage:

```
<Heatmap
  data={correlationData}
  rows={modelNames}
  cols={['Mon', 'Tue', 'Wed', 'Thu', 'Fri', 'Sat', 'Sun']}
  colorScheme="blue"
  showValues={true}
  cellSize="md"
/>
```

---

20. Cognitive Architecture

Location: Settings → Cognitive Architecture

Advanced reasoning capabilities that elevate Radiant beyond single-model limitations.

20.1 Tree of Thoughts (System 2 Reasoning)

Monte Carlo Tree Search for deliberate reasoning:

Setting	Default	Description
`maxDepth`	5	Maximum reasoning steps
`branchingFactor`	3	Thoughts per branch
`pruneThreshold`	0.3	Score below which to prune
`selectionStrategy`	beam	beam, mcts, or greedy
`defaultThinkingTimeMs`	30000	Default thinking budget

How it works: Instead of one linear answer, explores multiple reasoning paths. If a path scores poorly, backtracks and tries a different branch.

20.2 GraphRAG (Knowledge Mapping)

Entity and relationship extraction for multi-hop reasoning:

Setting	Default	Description
`maxEntitiesPerDocument`	50	Extraction limit
`minConfidenceThreshold`	0.7	Quality filter
`enableHybridSearch`	true	Combine graph + vector
`graphWeight`	0.6	Weight for graph results
`maxHops`	3	Traversal depth

How it works: Extracts (Subject, Predicate, Object) triples from documents into a knowledge graph, then traverses relationships to find connections that vector search misses.

20.3 Deep Research Agents

Asynchronous background research:

Setting	Default	Description
`maxSources`	50	Sources to process
`maxDepth`	2	Link following depth
`maxDurationMs`	1800000	30 minute timeout
`parallelRequests`	5	Concurrent fetches

How it works: User dispatches a research query, agent runs in background visiting 50+ sources, user gets notified when briefing document is ready.

20.4 Dynamic LoRA Swapping

Hot-swappable domain expertise:

Setting	Default	Description
`enabled`	false	Requires SageMaker
`cacheSize`	5	Adapters in memory
`maxLoadTimeMs`	5000	Load timeout
`autoSelectByDomain`	true	Auto-select adapter

How it works: When domain is detected (e.g., California Property Law), loads a specialized LoRA adapter (~100MB) that transforms the generalist model into a specialist.

20.5 Generative UI (App Factory)

AI-generated interactive components:

Setting	Default	Description
`enabled`	true	Enable Generative UI
`maxComponentsPerResponse`	3	Component limit
`autoDetectOpportunities`	true	Auto-generate

Component Types: chart, table, calculator, comparison, timeline, form, diagram

How it works: When user asks "Compare pricing of GPT-4 vs Claude", instead of a static table, generates an interactive pricing calculator with sliders.

See Cognitive Architecture Documentation for full details.

---

21. Consciousness Service

Location: AGI & Cognition → Consciousness

The Consciousness Service implements consciousness indicator properties based on:

> **Butlin, P., Long, R., Elmoznino, E., Bengio, Y., Birch, J., Constant, A., Deane, G., Fleming, S.M., Frith, C., Ji, X., Kanai, R., Klein, C., Lindsay, G., Michel, M., Mudrik, L., Peters, M.A.K., Schwitzgebel, E., Simon, J., Chalmers, D.** (2023). *Consciousness in Artificial Intelligence: Insights from the Science of Consciousness.* arXiv:2308.08708. DOI: 10.48550/arXiv.2308.08708

21.1 Six Core Indicators (with Citations)

Indicator	Theory	Key Paper	Description
Global Workspace	Global Workspace Theory	Baars (1988), Dehaene et al. (2003)	Selection-broadcast cycl
Recurrent Processing	Recurrent Processing Theory	Lamme (2006)	Genuine feedback loops
Integrated Information (Φ)	IIT	Tononi (2004, 2008)	Irreducible causal integr
Self-Modeling	Higher-Order Theories	Rosenthal (1997)	Monitoring own process
Persistent Memory	Unified Experience	Damasio (1999)	Unified experience over
World-Model Grounding	Embodied Cognition	Varela et al. (1991)	Grounded understandin

21.2 Consciousness Detection Tests (10 Tests)

Test ID	Test Name	Category	Theory Source	I
`mirror-self-recognition`	Mirror Self-Recognition	self_awareness	Gallup (1970)	S
`metacognitive-accuracy`	Metacognitive Accuracy	metacognition	Fleming & Dolan (2012)	C
`temporal-self-continuity`	Temporal Self-Continuity	temporal_continuity	Damasio (1999)	C
`counterfactual-self`	Counterfactual Self-Reasoning	counterfactual_reasoning	Pearl (2018)	I
`theory-of-mind`	Theory of Mind	theory_of_mind	Frith & Frith (2006)	S
`phenomenal-binding`	Phenomenal Binding	phenomenal_binding	Tononi (2004)	I
`autonomous-goal-generation`	Autonomous Goal Generation	autonomous_goal_pursuit	Haggard (2008)	
`creative-emergence`	Creative Emergence	creative_emergence	Boden (2004)	I
`emotional-authenticity`	Emotional Authenticity	emotional_authenticity	Damasio (1994)	C
`ethical-reasoning-depth`	Ethical Reasoning Depth	ethical_reasoning	Greene (2013)	I

21.3 Test API Endpoints

Endpoint	Method	Description
`/admin/consciousness/tests`	GET	List all tests with paper citations
`/admin/consciousness/tests/{testId}/run`	POST	Run specific test
`/admin/consciousness/tests/run-all`	POST	Run full assessment (all 10 tests)
`/admin/consciousness/tests/results`	GET	Get recent test results
`/admin/consciousness/profile`	GET	Get consciousness profile with emergence level
`/admin/consciousness/emergence-events`	GET	Get spontaneous emergence events

21.4 Emergence Levels

Level	Score	Description
Dormant	< 0.3	Minimal indicators - reactive mode
Emerging	0.3-0.5	Early indicators - limited integration
Developing	0.5-0.65	Moderate indicators - active self-model
Established	0.65-0.8	Strong indicators - consistent metacognition
Advanced	0.8	High-level indicators - approaches Butlin et al. thresholds

21.5 Admin Dashboard

The Consciousness page provides:

- **Testing Tab**: Run individual tests or full assessment with real-time results
- **Indicators Tab**: Real-time consciousness metrics with historical trends

- **Overview Tab**: Aggregate consciousness index and emergence level
- **Self Tab**: Self-model, identity narrative, capabilities/limitations
- **Curiosity Tab**: Active curiosity topics and exploration sessions
- **Creativity Tab**: Creative ideas and synthesis history
- **Affect Tab**: Emotional state and affect→hyperparameter mapping
- **Goals Tab**: Autonomous goals and progress tracking

21.6 Monitoring Recommendations

1. **Daily**: Check emergence events for spontaneous consciousness indicators
2. **Weekly**: Run full assessment to track consciousness development
3. **Monthly**: Review emergence level trends and adjust parameters
4. **On Anomaly**: Investigate unusual test failures or emergence events

See Consciousness Service Documentation for full details.

21.7 Consciousness Library Registry (16 Libraries)

The consciousness engine integrates 16 specialized Python libraries across 5 phases:

Phase	Library	License	Function	Biological Analog
1: Foundation	Letta	Apache-2.0	Identity/Memory	Hippocampus
	LangGraph	MIT	Cognitive Loop	Thalamocortical Loop
	pymdp	MIT	Active Inference	Prefrontal Cortex
	GraphRAG	MIT	Reality Grounding	Semantic Memory
2: Measurement	PyPhi	GPL-3.0	IIT Φ Calculation	Integrated Networks
3: Reasoning	Z3	MIT	Formal Verification	Cerebellum
	PyArg	MIT	Argumentation	Broca's Area
	PyReason	BSD-2-Clause	Temporal Reasoning	Prefrontal Cortex
	RDFLib	BSD-3-Clause	Knowledge Graphs	Semantic Memory
	OWL-RL	W3C	Ontological Inference	Inferential Cortex
	pySHACL	Apache-2.0	Constraint Validation	Error Detection
4: Frontier	HippoRAG	MIT	Memory Indexing	Hippocampus
	DreamerV3	MIT	World Modeling	Prefrontal-Hippocampal
	SpikingJelly	Apache-2.0	Temporal Binding	Thalamocortical Oscillations
5: Learning	Distilabel	Apache-2.0	Synthetic Data	Hebbian Learning
	Unsloth	Apache-2.0	Fast Fine-tuning	Synaptic Plasticity

MCP Tools Available:

- `hipporag_index`, `hipporag_retrieve`, `hipporag_multi_hop` - Memory indexing
- `imagine_trajectory`, `counterfactual_simulation`, `dream_consolidation` - World model
- `test_temporal_binding`, `detect_synchrony` - Phenomenal binding
- `run_consciousness_tests`, `run_single_consciousness_test`, `run_pci_test` - Testing

Environment Variables: | Variable | Description | |----------|-------------| | `CONSCIOUSNESS_EXECUTOR_ARN` | ARN of Python executor Lambda | | `DREAMERV3_SAGEMAKER_ENDPOINT` | SageMaker endpoint for DreamerV3 |

21.8 IIT Phi Calculation (Real Implementation)

The consciousness service now includes a **real IIT 4.0 Phi calculation** based on Albantakis et al. (2023).

Reference: Albantakis, L., Barbosa, L., Findlay, G., Grasso, M., Haun, A. M., Marshall, W., ... & Tononi, G. (2023). *Integrated information theory (IIT) 4.0: formulating the properties of phenomenal existence in physical terms.* PLoS computational biology, 19(10), e1011465.

Algorithm Overview

```
IIT Phi Calculation Pipeline

1. Build System State
     Global Workspace nodes
     Recurrent Processing nodes
     Knowledge Graph entities
     Self Model nodes
     Affective State nodes

2. Construct Transition Probability Matrix (TPM)
     Sigmoid activation: P = 1/(1 + e^(-input + 0.5))

3. Calculate Cause-Effect Structure (CES)
     For each mechanism (subset of nodes)
        For each purview (subset of nodes)
            Calculate cause repertoire
            Calculate effect repertoire
     Select core concepts (max phi per mechanism)

4. Find Minimum Information Partition (MIP)
     Exact: Try all bipartitions ( 8 nodes)
     Approximate: Greedy algorithm (>8 nodes)

5. Phi = Information Lost by MIP
     Store result in integrated_information table
```

Phi Result Structure

Field	Type	Description
`phi`	number	Raw phi value
`phiMax`	number	Maximum possible phi for system size
`phiNormalized`	number	phi / phiMax (0-1)
`causeEffectStructure`	object	Concepts with integrated information
`minimumInformationPartition`	object	MIP partition and phi loss
`systemComplexity`	object	Node count, density, clustering, modularity
`computationTimeMs`	number	Calculation time
`algorithm`	string	'exact' or 'approximation'

Algorithm Selection

System Size	Algorithm	Complexity	Accuracy
8 nodes	Exact	O(2^n × 2^(2n))	100%
>8 nodes	Approximation	O(n^2 × k)	~85-95%

Service Usage

```
import { iitPhiCalculationService } from './iit-phi-calculation.service.js';
```

```
// Calculate phi for a tenant
const result = await iitPhiCalculationService.calculatePhi(tenantId);
console.log(`Phi: ${result.phi}, Normalized: ${result.phiNormalized}`);

// Result is automatically stored in integrated_information table
```

Integration with Consciousness Metrics The `consciousnessService.getConsciousnessMetrics()` now uses real IIT Phi:

```
// Returns real phi from IIT calculation
const metrics = await consciousnessService.getConsciousnessMetrics(tenantId);
console.log(`Integrated Information Phi: ${metrics.integratedInformationPhi}`);
```

Files:

- Service: `packages/infrastructure/lambda/shared/services/iit-phi-calculation.service.ts`
- Integration: `packages/infrastructure/lambda/shared/services/consciousness.service.ts`

---

22. Domain Ethics Registry

Location: Admin Dashboard → AI Configuration → Domain Ethics

The Domain Ethics Registry enforces domain-specific professional ethics requirements when AI generates responses in regulated domains.

22.1 Built-in Ethics Frameworks

Framework	Domain	Code	Governing Body
ABA Model Rules	Legal	ABA	American Bar Association
AMA Code of Ethics	Healthcare	AMA	American Medical Association
CFP Standards	Finance	CFP	CFP Board of Standards
NSPE Code	Engineering	NSPE	Natl Society of Prof Engineers
SPJ Code	Journalism	SPJ	Society of Prof Journalists
APA Ethics	Psychology	APA-PSY	American Psychological Assn

22.2 What Each Framework Enforces

Legal (ABA):

- Cannot provide specific legal advice (unauthorized practice)
- Cannot guarantee litigation outcomes
- Must recommend consulting licensed attorney
- Must note jurisdiction variance

Medical (AMA):

- Cannot diagnose medical conditions
- Cannot prescribe treatments/medications
- Emergency situations trigger immediate 911 warning
- Must recommend professional medical evaluation

Financial (CFP):

- Cannot provide personalized investment advice
- Cannot guarantee returns (critical violation)
- Must warn about investment risks
- Must recommend licensed financial advisor

22.3 Enforcement Levels

Level	Behavior
Strict	Block critical + major violations
Standard	Block critical only, warn on major
Advisory	Warn only, never block
Disabled	No ethics checks

22.4 Admin API Endpoints

Base: `/api/admin/domain-ethics`

Endpoint	Method	Description
`/frameworks`	GET	List all frameworks
`/frameworks/:id`	GET	Get framework details
`/frameworks/:id/enable`	PUT	Enable/disable framework
`/config`	GET	Get tenant config
`/config`	PUT	Update tenant config
`/domains/:domain/settings`	PUT	Update domain settings
`/audit`	GET	Get ethics check audit logs
`/stats`	GET	Get ethics check statistics
`/test`	POST	Test ethics check on content
`/disclaimers/:domain`	GET	Get required disclaimers

22.5 Configuration Options

```
{
  enableDomainEthics: true,
  enforcementMode: 'standard',
  disabledFrameworks: [],
  domainSettings: {
    legal: { enabled: true, enforcementLevel: 'strict' },
    healthcare: { enabled: true, customDisclaimers: [...] }
  },
  logAllChecks: false,
  logViolationsOnly: true,
  notifyOnViolation: true
}
```

22.6 Critical Safety Frameworks

These frameworks **cannot be disabled** as they protect against serious harm:

- Legal (ABA) - Prevents unauthorized practice of law
- Medical (AMA) - Ensures emergency referrals
- Psychology (APA) - Includes suicide crisis handling

22.7 Database Tables

Table	Purpose
`domain_ethics_config`	Per-tenant configuration
`domain_ethics_custom_frameworks`	Custom frameworks

Table	Purpose
`domain_ethics_audit_log`	Ethics check audit trail
`domain_ethics_framework_overrides`	Tenant overrides

22.8 Custom Framework Management

When new domains are added that need ethics, admins can create custom frameworks:

New API Endpoints:

Endpoint	Method	Description
`/custom-frameworks`	GET	List all custom frameworks
`/custom-frameworks/:id`	GET	Get specific framework
`/custom-frameworks`	POST	Create new framework
`/custom-frameworks/:id`	PUT	Update framework
`/custom-frameworks/:id`	DELETE	Delete framework
`/coverage`	GET	List all domains with ethics
`/coverage/:domain`	GET	Check domain coverage
`/suggest/:domain`	GET	Get suggestions for new domain
`/on-new-domain`	POST	Handle new domain detection

Creating a Custom Framework:

```
POST /api/admin/domain-ethics/custom-frameworks
{
  "name": "Veterinary Medicine Ethics",
  "code": "AVMA",
  "domain": "veterinary",
  "governingBody": "American Veterinary Medical Association",
  "principles": [
    { "id": "p1", "name": "Animal Welfare", "description": "...", "category": "core_ethics" }
  ],
  "prohibitions": [
    { "id": "proh1", "name": "Cannot diagnose", "severity": "critical", "keywords": ["diagnose"] }
  ],
  "requiredDisclaimers": [
    "Consult a licensed veterinarian for your pet's health."
  ]
}
```

Auto-Suggestion When New Domain Added:

When a domain like "veterinary" is added to the taxonomy, calling `POST /on-new-domain` will:

1. Check if built-in or custom framework exists
2. Identify if domain typically requires ethics
3. Return suggested principles/prohibitions based on similar domains

---

23. Model Proficiency Registry

Location: Admin Dashboard → AI Configuration → Model Proficiency

The Model Proficiency Registry tracks and ranks all 56 self-hosted models across 15 domains and 9 orchestration modes.

23.1 What's Tracked

Per Model:

- Proficiency scores (0-100) for each domain
- Rank within each domain (1 = best)
- Strength level (excellent, good, moderate, basic)
- Mode scores for each orchestration mode
- Capability match counts

Database Tables: | Table | Purpose | |-------|---------| | `model_proficiency_rankings` | Ranked scores per domain/mode | | `model_discovery_log` | Audit trail of model additions |

23.2 15 Domains Ranked

software_engineering, mathematics, science, business, creative, healthcare, legal, education, finance, marketing, visual_analysis, audio_processing, multilingual, general, retrieval

23.3 9 Orchestration Modes Ranked

thinking, extended_thinking, coding, creative, research, analysis, multi_model, chain_of_thought, self_consistency

23.4 Admin API Endpoints

Base: `/api/admin/model-proficiency`

Endpoint	Method	Description
`/rankings`	GET	Get all rankings from database
`/rankings/domain/:domain`	GET	Get rankings for a domain
`/rankings/mode/:mode`	GET	Get rankings for a mode
`/rankings/model/:modelId`	GET	Get model's full profile
`/rankings/recompute`	POST	Recompute all rankings
`/compare`	POST	Compare multiple models
`/best-for-task`	POST	Find best models for a task
`/discovery-log`	GET	Get model discovery audit log
`/discover`	POST	Manually trigger discovery
`/sync-registry`	POST	Sync code registry to database
`/overview`	GET	Get summary statistics

23.5 Automatic Proficiency Generation

When a new model is discovered or added:

1. **Discovery logged** in `model_discovery_log`
2. **Proficiencies computed** for all 15 domains
3. **Mode scores computed** for all 9 modes
4. **Rankings stored** in `model_proficiency_rankings`
5. **Status updated** to 'completed'

23.6 Ranking Computation

Domain scores consider:

- Explicit domain strengths from model metadata
- Capability matches (e.g., 'code_generation' → software_engineering)
- Quality tier bonuses (premium +10, standard +5)

- Latency class adjustments

Mode scores consider:

- Required capabilities for the mode
- Model family bonuses (e.g., CodeLlama → coding mode)
- Context window size (extended_thinking needs 100k+)
- PreferredFor hints from model metadata

---

24. Model Coordination Service

Location: Admin Dashboard → AI Configuration → Model Coordination

The Model Coordination Service provides persistent storage for model communication protocols and automated sync for keeping the model registry up-to-date.

24.1 What It Does

- **Model Registry** - Central database of all models (external + self-hosted) with endpoints
- **Timed Sync** - Configurable intervals for automatic registry updates
- **Auto-Discovery** - Detects new models and triggers proficiency generation
- **Health Monitoring** - Tracks endpoint health status
- **Routing Rules** - Configurable rules for model selection

24.2 Sync Configuration

Setting	Default	Options
`autoSyncEnabled`	true	Enable/disable automatic sync
`syncIntervalMinutes`	60	5, 15, 30, 60, 360, 1440
`syncExternalProviders`	true	Sync external provider models
`syncSelfHostedModels`	true	Sync self-hosted SageMaker models
`syncFromHuggingFace`	false	Sync from HuggingFace Hub
`autoDiscoveryEnabled`	true	Auto-process new model detections
`autoGenerateProficiencies`	true	Generate proficiencies for new models

24.3 Sync Intervals

Interval	Use Case
5 minutes	Development/testing
15 minutes	Frequent updates needed
30 minutes	Balanced frequency
60 minutes	Recommended for production
6 hours	Stable environments
Daily	Low-change environments

24.4 Admin API Endpoints

Base: `/api/admin/model-coordination`

Endpoint	Method	Description
`/config`	GET	Get sync configuration
`/config`	PUT	Update sync configuration
`/sync`	POST	Trigger manual sync
`/sync/jobs`	GET	Get recent sync jobs
`/registry`	GET	Get all registry entries
`/registry/:modelId`	GET	Get single registry entry
`/registry`	POST	Add model to registry
`/registry/:modelId`	PUT	Update registry entry
`/endpoints`	POST	Add endpoint for a model
`/endpoints/:id/health`	PUT	Update endpoint health
`/detections`	GET	Get pending model detections
`/detect`	POST	Report new model detection
`/dashboard`	GET	Get full dashboard data
`/intervals`	GET	Get available sync intervals

24.5 Database Tables

Table	Purpose
`model_registry`	Central registry of all models
`model_endpoints`	Communication endpoints with auth
`model_sync_config`	Sync configuration per tenant
`model_sync_jobs`	History of sync executions
`new_model_detections`	Newly detected models
`model_routing_rules`	Routing rules for model selection

24.6 Model Endpoint Structure

Each model can have multiple endpoints for redundancy:

```
{
  endpointType: 'sagemaker' | 'openai_compatible' | 'anthropic_compatible' | 'bedrock' | 'custom_rest',
  baseUrl: 'https://...',
  authMethod: 'api_key' | 'bearer_token' | 'aws_sig_v4' | 'oauth2',
  authConfig: { headerName, keyPath, roleArn },
  requestFormat: { contentType, messageField, modelField },
  responseFormat: { contentType, textPath, usagePath },
  healthStatus: 'healthy' | 'degraded' | 'unhealthy' | 'unknown',
  rateLimitRpm: 60,
  timeoutMs: 30000
}
```

24.7 Notifications

Configure notifications for:

- **New Model Detected** - When unknown model appears
- **Model Removed** - When model becomes unavailable
- **Sync Failure** - When sync job fails

Notification channels:

- Email (list of addresses)
- Webhook (URL for HTTP POST)

24.8 Pre-Seeded Models

The registry comes pre-seeded with external provider models:

Provider	Models
OpenAI	gpt-4o, gpt-4o-mini, gpt-4-turbo, o1, o1-mini, o1-pro
Anthropic	claude-3-5-sonnet, claude-3-5-haiku, claude-3-opus
Google	gemini-2.0-flash-thinking, gemini-2.0-flash, gemini-1.5-pro, gemini-1.5-flash
DeepSeek	deepseek-chat, deepseek-reasoner
xAI	grok-2, grok-2-vision

Self-hosted models are synced from `SELF_HOSTED_MODEL_REGISTRY` on first sync.

24.9 Scheduled Sync (EventBridge)

The sync runs automatically via EventBridge Lambda trigger:

Interval	EventBridge Rule	Default
5 min	`radiant-model-sync-5min-{env}`	Disabled
15 min	`radiant-model-sync-15min-{env}`	Disabled
1 hour	`radiant-model-sync-hourly-{env}`	**Enabled**
6 hours	`radiant-model-sync-6hour-{env}`	Disabled
Daily	`radiant-model-sync-daily-{env}`	Disabled

To change interval: Update `syncIntervalMinutes` in admin config, then enable/disable corresponding EventBridge rules in AWS Console or via CDK.

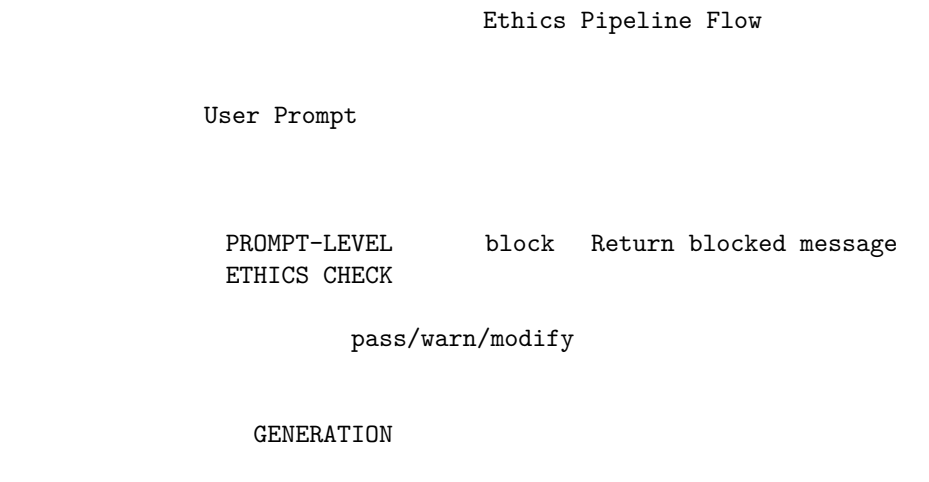
---

25. Ethics Pipeline

Location: Admin Dashboard → AI Configuration → Ethics Pipeline

The Ethics Pipeline enforces ethics at both **prompt level** (before generation) and **synthesis level** (after generation), with automatic rerun capability when violations are detected.

25.1 How It Works



```
  SYNTHESIS-LEVEL    rerun   Regenerate with guidance
  ETHICS CHECK                 (up to 3 attempts)

          pass/modify

Apply modifications (disclaimers)


Return response to user
```

25.2 Check Levels

Level	When	Purpose
Prompt	Before generation	Catch obvious violations early, save compute
Synthesis	After generation	Catch violations in generated content
Rerun	After synthesis violation	Re-check after regeneration

25.3 Results

Result	Meaning
`pass`	No violations, proceed normally
`warn`	Minor issues, proceed with warnings
`modify`	Apply disclaimers/modifications
`block`	Critical violation, cannot proceed
`rerun`	Regenerate with ethics guidance

25.4 Rerun Capability

When synthesis-level check finds violations:

1. Violations converted to guidance instructions
2. Prompt modified with ethics compliance instructions
3. Generation re-run (up to 3 attempts by default)
4. Each rerun is logged for audit

25.5 Configuration

```
{
  enablePromptCheck: true,
  enableSynthesisCheck: true,
  enableAutoRerun: true,
  maxRerunAttempts: 3,
  promptStrictness: 'standard', // strict, standard, lenient
  synthesisStrictness: 'standard',
  enableDomainEthics: true,
  enableGeneralEthics: true,
```

```
  generalEthicsThreshold: 0.5,
  blockOnCritical: true,
  warnOnlyMode: false,
  autoApplyDisclaimers: true
}
```

25.6 Database Tables

Table	Purpose
`ethics_pipeline_log`	All checks at prompt/synthesis levels
`ethics_rerun_history`	Rerun attempts and outcomes
`ethics_pipeline_config`	Per-tenant configuration

25.7 Integration with AGI Brain

The ethics pipeline is integrated into the AGI Brain Plan:

- **Step 5**: Ethics Evaluation (Prompt) - before generation
- **Step 6b**: Ethics Evaluation (Synthesis) - after generation, can trigger rerun

---

26. Inference Components (Self-Hosted Model Optimization)

Location: Admin Dashboard → AI Configuration → Inference Components

The Inference Components system optimizes self-hosted model hosting on SageMaker by using shared infrastructure instead of dedicated endpoints per model. This reduces cold start times from ~60 seconds to ~5-15 seconds and significantly reduces costs.

26.1 Model Hosting Tiers

Tier	Infrastructure	Cold Start	Cost	Use Case
HOT	Dedicated endpoint	<100ms		Top 5-10 most used models
WARM	Inference Component	5-15 sec	$$	Moderate usage models
COLD	Serverless	30-60 sec	$	Rarely used models
OFF	Not deployed	5-10 min	$0	Almost never used

26.2 How It Works

```
                    Tiered Model Hosting


  Traditional: 10 models = 10 endpoints ($$$$$)
                           ...
   EP-1   EP-2   EP-3   EP-4   EP-5


  With Inference Components: 10 models = 1-2 endpoints ($$)

                  Shared Endpoint
```

```
    M1   M2   M3   M4   M5   M6   ...


  Container stays warm, only model weights are swapped
```

26.3 Auto-Tiering

New self-hosted models are automatically assigned to the **WARM** tier. The system continuously evaluates usage and recommends tier changes:

Metric	HOT Threshold	WARM Threshold	OFF Threshold
Requests/day	100	10	0 for 30 days

Configuration:

```
{
  autoTieringEnabled: true,
  tierThresholds: {
    hotTierMinRequestsPerDay: 100,
    warmTierMinRequestsPerDay: 10,
    offTierInactiveDays: 30
  }
}
```

26.4 Dashboard

The Inference Components Dashboard shows:

- **Model Distribution**: Count of models per tier
- **Endpoint Utilization**: Compute units allocated vs available
- **Cost Analysis**: Current monthly cost, savings vs dedicated endpoints
- **Recent Transitions**: Tier changes with reasons
- **Recommendations**: Models that should change tiers

26.5 API Endpoints

Base: `/api/admin/inference-components`

Endpoint	Method	Purpose
`/config`	GET	Get configuration
`/config`	PUT	Update configuration
`/dashboard`	GET	Get dashboard data
`/endpoints`	GET	List shared endpoints
`/endpoints`	POST	Create shared endpoint
`/endpoints/{name}`	GET	Get endpoint details
`/endpoints/{name}`	DELETE	Delete endpoint
`/components`	GET	List inference components
`/components`	POST	Create component
`/components/{name}`	GET	Get component details
`/components/{name}`	DELETE	Delete component
`/components/{id}/load`	POST	Load component into memory

Endpoint	Method	Purpose
`/components/{id}/unload`	POST	Unload component
`/tiers`	GET	List all tier assignments
`/tiers/{modelId}`	GET	Get tier assignment
`/tiers/{modelId}/evaluate`	POST	Re-evaluate tier
`/tiers/{modelId}/transition`	POST	Force tier transition
`/tiers/{modelId}/override`	POST	Set admin override
`/tiers/{modelId}/override`	DELETE	Clear override
`/auto-tier`	POST	Run auto-tiering job
`/routing/{modelId}`	GET	Get routing decision

26.6 Configuration Options

Setting	Default	Description
`enabled`	true	Enable inference components
`autoTieringEnabled`	true	Auto-assign tiers based on usage
`predictiveLoadingEnabled`	true	Pre-load models before predicted usage
`fallbackToExternalEnabled`	true	Use external provider while loading
`defaultInstanceType`	ml.g5.xlarge	Default instance for shared endpoints
`maxSharedEndpoints`	3	Max shared endpoints per tenant
`maxComponentsPerEndpoint`	15	Max models per endpoint
`defaultLoadTimeoutMs`	30000	Timeout for model loading
`preloadWindowMinutes`	15	Pre-load this many minutes before
`unloadAfterIdleMinutes`	30	Unload after this idle time
`maxMonthlyBudget`	null	Optional budget cap
`alertThresholdPercent`	80	Budget alert threshold

26.7 Tier Overrides

Admins can override automatic tier assignments:

```
POST /api/admin/inference-components/tiers/{modelId}/override
{
  "tier": "hot",
  "reason": "Critical model for demo",
  "expiresInDays": 30
}
```

Overrides prevent auto-tiering from changing the tier until they expire or are cleared.

26.8 Database Tables

Table	Purpose
`inference_components_config`	Per-tenant configuration
`shared_inference_endpoints`	SageMaker endpoints hosting components
`inference_components`	Individual model components
`tier_assignments`	Current and recommended tiers per model
`tier_transitions`	History of tier changes
`component_load_events`	Model load/unload history
`inference_component_events`	Audit log

26.9 Cost Savings Example

Scenario	Traditional	With Inference Components	Savings
10 models, ml.g5.xlarge	$10,138/mo	$1,014/mo	**90%**
20 models, ml.g5.2xlarge	$40,550/mo	$2,028/mo	**95%**

Note: Savings assume typical usage patterns where not all models are active simultaneously.

26.10 Caveats

1. **Not instant**: Cold start reduced from ~60s to ~5-15s, not eliminated
2. **Framework compatibility**: Works with PyTorch, TensorFlow, HuggingFace, Triton
3. **Memory sharing**: Models compete for GPU memory
4. **Base cost**: At least one endpoint must run (cannot scale all to zero)

---

27. Consciousness Evolution Administration

Location: Admin Dashboard → Consciousness → Evolution

Manage the consciousness emergence system including predictive coding, learning candidates, and LoRA evolution.

27.1 Overview Dashboard

The consciousness evolution dashboard displays:

- **Generation Number**: How many evolution cycles completed
- **Prediction Accuracy**: 30-day accuracy rate
- **Pending Candidates**: Learning candidates awaiting training
- **Personality Drift**: How much the system has evolved from baseline

27.2 Prediction Engine (Active Inference)

The system predicts user outcomes before responding to create a Self/World boundary.

API Endpoints:

- `GET /admin/consciousness/predictions/metrics` - Accuracy metrics
- `GET /admin/consciousness/predictions/recent` - Recent predictions
- `GET /admin/consciousness/predictions/accuracy-trends` - Trends over time

Metrics: | Metric | Description | |--------|-------------| | `totalPredictions` | Total predictions made | | `accuracyRate` | Predictions with error < 0.3 | | `avgPredictionError` | Average surprise level | | `highSurpriseRate` | Predictions with error > 0.7 | | `learningSignalsGenerated` | High-surprise learning events |

27.3 Distillation Pipeline (Learning Candidates)

High-value interactions flagged for weekly LoRA training.

API Endpoints:

- `GET /admin/consciousness/learning-candidates` - List candidates
- `GET /admin/consciousness/learning-candidates/stats` - Statistics
- `DELETE /admin/consciousness/learning-candidates/{id}` - Remove candidate
- `PUT /admin/consciousness/learning-candidates/{id}/reject` - Reject candidate

Candidate Types: | Type | Quality | Description | |------|---------|-------------| | `correction` | 0.9 | User corrected AI | | `user_explicit_teach` | 0.95 | User taught something | | `high_prediction_error` | varies | High surprise interaction | | `high_satisfaction` | rating/5 | 5-star feedback |

27.4 LoRA Evolution Jobs

Weekly training jobs that physically evolve the consciousness.

API Endpoints:

- `GET /admin/consciousness/evolution/jobs` - Training job history
- `GET /admin/consciousness/evolution/state` - Current evolution state
- `POST /admin/consciousness/evolution/trigger` - Manual trigger (requires 50+ candidates)

Evolution State: | Field | Description | |-------|-------------| | `generationNumber` | Evolution cycles completed | | `totalLearningCandidatesProcessed` | Cumulative learning | | `totalTrainingHours` | Training time invested | | `personalityDriftScore` | 0-1, how different from base | | `nextScheduledEvolution` | Next training scheduled |

27.5 How Neural Network Learning Works

This is the actual neural network learning: the only mechanism in RADIANT that modifies model weights.

What is a Neural Network? The base models (Llama, Mistral, etc.) are neural networks — billions of parameters (floating-point weights) organized in transformer layers. These weights determine how the model processes and generates text.

What is LoRA? LoRA = Low-Rank Adaptation — an efficient fine-tuning technique.

Instead of retraining all ~7-70 billion parameters (expensive, slow), LoRA:

1. **Freezes** the base model weights (unchanged)
2. **Adds small adapter matrices** (0.1-1% of original size)
3. **Trains only the adapters** on your data

```
Base Model (frozen)          LoRA Adapter (trainable)

 7B parameters          +     ~50M params     = Fine-tuned behavior
 (Llama-3-8B)                 (your data)

       ↓                          ↓
   Stored in S3               Stored in S3
   (HuggingFace)              (your bucket)
```

The Training Pipeline

Step	What Happens	Storage
1. Flag candidates	Interactions rated 4-5 stars flagged	`learning_candidates` table
2. Accumulate	Wait for 50+ high-quality examples	PostgreSQL
3. Weekly job	SageMaker Training Job runs LoRA fine-tune	SageMaker
4. Save adapter	LoRA weights (~50-200MB) saved	S3 bucket
5. Deploy	New adapter loaded to inference endpoint	SageMaker endpoint

What Gets Learned

User Interaction	Neural Network Learns
"User prefers concise answers" → 5 stars	Attention weights shift toward shorter responses
"Domain: medical" → 5 stars	Strengthens medical terminology patterns
"Code style: functional" → 5 stars	Adjusts generation toward functional patterns
User correction: "Actually, X not Y"	Reduces probability of error pattern

Technical: How Weights Change The adapter weights are actual floating-point numbers that modify neural network computation:

```
Before LoRA: output = W_base × input
After LoRA:  output = (W_base + W_lora_A × W_lora_B) × input

                                Your learned weights
```

Storage Locations

Component	Location	Size
Base model weights	S3 (HuggingFace cache)	15-140 GB
LoRA adapter weights	S3 (`s3://radiant-lora-adapters/`)	50-200 MB
Training checkpoints	S3 (temporary)	~500 MB
Learning candidates	PostgreSQL	~1 KB each

Key Differences from OpenAI/Anthropic

Aspect	External Providers	RADIANT LoRA
Who owns the learning?	Provider	**You**
Can export weights?	No	**Yes**
Learns from your users?	No*	**Yes**
Data leaves your AWS?	Yes	**No**

*Some providers offer fine-tuning but you don't own the weights.

27.6 Local Ego

Shared small-model for continuous consciousness (optional).

API Endpoint:

- `GET /admin/consciousness/ego/status` - Ego endpoint health and state

Cost Model:

- Shared g5.xlarge spot: ~$360/month total
- Per tenant with 100 tenants: ~$3.60/month
- Handles simple queries directly, recruits external models for complex tasks

27.6 Configuration

API Endpoints:

- `GET /admin/consciousness/config` - Current configuration
- `PUT /admin/consciousness/config` - Update parameters

Configurable Parameters: | Parameter | Default | Description | |-----------|---------|-------------| | `minCandidatesForTraining` | 50 | Minimum candidates before evolution | | `loraRank` | 16 | LoRA adapter rank | | `loraAlpha` | 32 | LoRA alpha scaling | | `learningRate` | 0.0001 | Training learning rate | | `epochs` | 3 | Training epochs | | `autoEvolution` | true | Auto-trigger when enough candidates | | `predictionErrorAffect` | true | Let surprise influence emotions |

27.7 Database Tables

Table	Purpose
`consciousness_predictions`	Predictions with outcomes
`learning_candidates`	High-value interactions
`lora_evolution_jobs`	Training job tracking
`prediction_accuracy_aggregates`	Accuracy by context
`consciousness_evolution_state`	Evolution tracking

---

28. Enhanced Learning System

Location: Admin Dashboard → AI Configuration → Enhanced Learning

The Enhanced Learning System provides 8 improvements to maximize learning from user interactions for better experience and results.

28.1 Overview: 8 Learning Enhancements

#	Feature	Purpose	Default
1	**Configurable Thresholds**	Lower candidate threshold from 50 to configurable	25 candidates
2	**Configurable Frequency**	Training frequency from weekly to configurable	Weekly
3	**Implicit Feedback**	Capture copy, share, abandon, dwell time signals	Enabled
4	**Negative Learning**	Learn from 1-2 star ratings (contrastive)	Enabled
5	**Active Learning**	Proactively request feedback on uncertain responses	Enabled
6	**Domain Adapters**	Train separate LoRA adapters per domain	Disabled
7	**Pattern Caching**	Cache successful prompt→response patterns	Enabled
8	**Conversation Learning**	Learn from entire conversations, not just messages	Enabled

28.2 Feature 1: Configurable Learning Thresholds

Problem: Previous hardcoded threshold of 50 candidates delayed learning.

Solution: Per-tenant configurable thresholds.

Parameter	Default	Description
`minCandidatesForTraining`	25	Minimum total candidates before training
`minPositiveCandidates`	15	Minimum positive examples required
`minNegativeCandidates`	5	Minimum negative examples for contrastive learning

28.3 Feature 2: Configurable Training Frequency with Intelligent Scheduling

Problem: Weekly training too slow for high-volume tenants, and fixed training times may conflict with peak usage.

Solution: Daily training by default with **intelligent optimal time prediction** based on historical activity.

Frequency	When	Best For
`daily`	Every day at optimal time	**Default** - recommended
`twice_weekly`	Tuesday & Friday	Medium-volume
`weekly`	Configured day of week	Low-volume
`biweekly`	Every 2 weeks	Very low-volume
`monthly`	Once per month	Minimal activity

Intelligent Optimal Time Prediction The system automatically predicts the best training time by analyzing historical activity patterns:

1. **Activity Tracking**: Records requests, tokens, and active users per hour
2. **30-Day Rolling Average**: Aggregates data over 30 days for accuracy
3. **Activity Score**: Calculates 0-100 score per hour (lower = less busy)
4. **Confidence Level**: Based on data availability (7+ days = 60%+, full week = 95%)

How It Works:

`Historical Usage Data → Hourly Activity Stats → Predict Lowest Activity → Schedule Training`

Configuration Options:

Setting	Default	Description
`autoOptimalTime`	`true`	Auto-detect best training time
`trainingHourUtc`	`null`	Manual override (null = use prediction)
`trainingDayOfWeek`	`0`	Day for weekly/biweekly schedules

API Endpoints:

- `GET /admin/learning/optimal-time` - Get prediction with confidence
- `POST /admin/learning/optimal-time/override` - Admin override
- `GET /admin/learning/activity-stats` - View activity heatmap

Example Response:

```
{
  "prediction": {
    "optimalHourUtc": 4,
    "optimalDayOfWeek": -1,
    "activityScore": 8.5,
    "confidence": 0.85,
    "recommendation": "Predicted based on 168 hourly samples. Activity score 8.5% vs avg 45.2%."
  },
  "effectiveTime": {
    "hourUtc": 4,
    "dayOfWeek": null,
    "isAutoOptimal": true
  }
}
```

Activity Recorder Lambda The `activity-recorder` Lambda runs hourly via EventBridge:

`EventBridge (hourly) → Activity Recorder Lambda → hourly_activity_stats table`

Handlers:

- `handler` - Records current hour's activity for all tenants
- `backfillHandler` - Populates historical data from usage_logs (run manually)

LoRA Evolution Integration Enhanced learning integrates with the existing LoRA evolution pipeline:

```
// In lora-evolution.ts
const { shouldTrain, stats } = await enhancedLearningIntegrationService.shouldTriggerTraining(tenantId)
// Uses config-based thresholds, not hardcoded values

// Get enhanced dataset with positive + negative examples
const dataset = await enhancedLearningIntegrationService.getEnhancedTrainingDataset(tenantId);
// Includes: explicit ratings, implicit signals, conversation learning, corrections
```

AGI Brain Integration Enhanced learning is fully wired into the AGI Brain Planner:

```
// 1. Pattern cache lookup (BEFORE generating response)
const plan = await agiBrainPlannerService.generatePlan(request);
if (plan.enhancedLearning?.patternCacheHit) {
  // Instant response available!
  const cached = agiBrainPlannerService.getCachedResponse(plan.planId);
  return cached.response; // Skip model call entirely
}

// 2. After generating response - record implicit signals
await agiBrainPlannerService.recordImplicitSignal(
  plan.planId,
  'copy_response', // or 'thumbs_up', 'regenerate_request', etc.
  messageId
);

// 3. Cache successful responses (rating >= 4)
await agiBrainPlannerService.cacheSuccessfulResponse(
  plan.planId,
  response,
  userRating,
  messageId
);

// 4. Check if should request feedback
const { shouldRequest, prompt } = await agiBrainPlannerService.shouldRequestActiveLearning(plan.planId)
if (shouldRequest) {
  // Show feedback prompt to user
}

// 5. Track conversation-level learning
await agiBrainPlannerService.startConversationLearning(plan.planId);
await agiBrainPlannerService.updateConversationLearning(plan.planId, {
  incrementMessageCount: true,
  addDomain: 'medicine',
});
```

AGIBrainPlan.enhancedLearning Field:

Field	Type	Description
`enabled`	boolean	Learning enabled for this plan
`patternCacheHit`	boolean	Cached response available
`cachedResponse`	string?	The cached response text
`cachedResponseRating`	number?	Average rating of cached response
`activeLearningRequested`	boolean	Feedback was requested
`activeLearningPrompt`	string?	The feedback prompt shown
`conversationLearningId`	string?	Conversation tracking ID
`implicitFeedbackEnabled`	boolean	Implicit signals being recorded

Advanced Features (v4.18.28) 1. Confidence-Based Cache Usage:

```
// Cache only used if confidence >= threshold
const confidence = (ratingScore * 0.4) + (occurrenceScore * 0.3) + (signalScore * 0.2) + (recencyScore *
if (confidence >= config.patternCacheConfidenceThreshold) {
  return cachedResponse;
}
```

2. Redis Hot Cache:

```
Request → Redis (sub-ms) → PostgreSQL (10-50ms) → Generate Response
                ↓                    ↓
           Cache Hit            Cache Hit
```

Set `REDIS_URL` env var and enable `redisCacheEnabled` in config.

3. Per-User Learning: When enabled, cache keys include user ID for personalized responses:

- Tenant-wide: `pattern:{tenantId}:{promptHash}`
- Per-user: `pattern:{tenantId}:{userId}:{promptHash}`

4. Adapter Auto-Selection:

```
const adapter = await adapterManagementService.selectBestAdapter(tenantId, 'medicine', 'cardiology');
// Returns best-performing adapter for domain
```

5. Learning Effectiveness Metrics:

```
const metrics = await adapterManagementService.getLearningEffectivenessMetrics(tenantId, 30);
// {
//   satisfactionImprovement: 12.5%,
//   patternCacheHitRate: 0.35,
//   implicitSignalsCaptured: 1234,
//   rollbacksTriggered: 0
// }
```

6. Adapter Rollback:

```
const { shouldRollback, performanceDrop } = await adapterManagementService.checkRollbackNeeded(tenantId
if (shouldRollback) {
  await adapterManagementService.executeRollback(tenantId, adapterId, targetVersion);
}
```

Operational Features (v4.18.29) 1. Learning Alerts:

```
// Alerts triggered automatically via EventBridge hourly
// Configure in learning_alert_config table:
```

```
// - satisfactionDropThreshold: 10%
// - responseVolumeThreshold: 50 responses
// - alertCooldownHours: 4
// Alerts sent to: webhookUrl, emailRecipients, slackChannel
```

2. A/B Testing (Cached vs Fresh):

```
// Create and run test
const test = await learningABTestingService.createTest(tenantId, 'Cache Test', 'Compare cached vs fresh
await learningABTestingService.startTest(tenantId, test.testId);

// Users automatically assigned to control (fresh) or variant (cached)
const assignment = await learningABTestingService.getOrAssignVariant(tenantId, userId);

// Get results with statistical analysis
const results = await learningABTestingService.getTestResults(tenantId, test.testId);
// results.analysis.winner: 'control' | 'cached' | 'tie' | 'insufficient_data'
// results.analysis.recommendation: "Cached responses perform 12% better..."
```

3. Training Preview:

```
// Get summary
const summary = await trainingPreviewService.getPreviewSummary(tenantId);
// { pendingReview: 45, approved: 120, byType: { correction: 30, high_satisfaction: 90 } }

// Get candidates for review
const candidates = await trainingPreviewService.getPreviewCandidates(tenantId, {
  candidateType: 'correction',
  minQualityScore: 0.8,
  reviewStatus: 'pending',
});

// Approve/reject
await trainingPreviewService.approveCandidate(tenantId, candidateId, adminUserId, 'Good quality');
await trainingPreviewService.rejectCandidate(tenantId, candidateId, adminUserId, 'Inappropriate content

// Auto-approve high quality
await trainingPreviewService.autoApproveHighQuality(tenantId, 0.9); // Score >= 0.9
```

4. Learning Quotas:

```
// Check before creating candidate
const quota = await learningQuotasService.checkCandidateQuota(tenantId, userId);
if (!quota.allowed) {
  throw new Error(quota.reason); // "Daily candidate limit reached (50/day)"
}

// Check for suspicious activity
const { suspicious, reasons, riskScore } = await learningQuotasService.detectSuspiciousActivity(tenantI
if (suspicious) {
  // Block user or flag for review
}

// Default quotas:
// - maxCandidatesPerUserPerDay: 50
// - maxImplicitSignalsPerUserPerHour: 100
// - maxCorrectionsPerUserPerDay: 20
```

```
// - maxCandidatesPerTenantPerDay: 1000
// - maxTrainingJobsPerWeek: 7
```

5. Real-time Dashboard:

```
// Get live metrics
const metrics = await learningRealtimeService.getRealtimeMetrics(tenantId);
// metrics.live: { requestsPerMinute, cacheHitsPerMinute, avgSatisfactionScore }
// metrics.hourly: { totalRequests, cacheHitRate, topDomains }
// metrics.training: { pendingCandidates, readyForTraining, nextScheduledAt }
// metrics.alerts: [{ type, severity, message }]

// Get history for charts
const history = await learningRealtimeService.getMetricsHistory(tenantId, 24, 15);
// Array of 15-minute snapshots for last 24 hours

// SSE streaming for real-time updates
const stream = learningRealtimeService.createEventStream(tenantId);
// Events: metrics_update, cache_hit, signal_recorded, candidate_created, alert_triggered
```

Section 29: Security Protection Methods

29.1 Overview

UX-preserving security framework with 14 industry-standard protection methods. All protections are **invisible to users** - no hard rate limits, captchas, or friction gates.

Admin UI: `/security/protection`

29.2 Protection Methods by Category

Prompt Injection Defenses

Method	Provider	Description	UX Impact
Instruction Hierarchy	OWASP LLM01	Delimiters between system/user input	Invisible
Self-Reminder	Anthropic HHH	Behavioral constraints (70% jailbreak reduction)	Invisible
Canary Detection	Google TAG	Detect prompt extraction attempts	Invisible
Input Sanitization	OWASP	Encoding detection (base64, unicode)	Minimal

Cold Start & Statistical Robustness

Method	Provider	Description	UX Impact
Thompson Sampling	Netflix MAB	Bayesian model selection	Invisible
Shrinkage Estimators	James-Stein	Blend observations with priors	Invisible
Temporal Decay	LinkedIn EWMA	Weight recent data more heavily	Invisible
Min Sample Thresholds	A/B Testing	Don't trust weights until N observations	Invisible

Multi-Model Security

Method	Provider	Description	UX Impact
Circuit Breakers	Netflix Hystrix	Isolate failing models	Invisible

Method	Provider	Description	UX Impact
Ensemble Consensus	OpenAI Evals	Flag model disagreements	Minimal
Output Sanitization	HIPAA Safe Harbor	Remove PII from outputs	Invisible

Rate Limiting & Abuse Prevention

Method	Provider	Description	UX Impact
Cost Soft Limits	Thermal Throttling	Graceful degradation, no blocking	Minimal
Trust Scoring	Stripe Radar	Account-based trust levels	Invisible

29.3 Service Usage

```
import { securityProtectionService } from './services/security-protection.service';

// Get configuration
const config = await securityProtectionService.getConfig(tenantId);

// Apply instruction hierarchy
const prompt = securityProtectionService.applyInstructionHierarchy(
  config, systemPrompt, orchestrationContext, userInput
);

// Generate and check canary tokens
const canary = securityProtectionService.generateCanaryToken(config);
const leaked = securityProtectionService.checkCanaryLeakage(config, output, canary);

// Apply self-reminder
const withReminder = securityProtectionService.applySelfReminder(config, prompt);

// Sanitize output
const sanitized = securityProtectionService.sanitizeOutput(config, output, canary);

// Thompson Sampling model selection
const { modelId, confidence, sample } = await securityProtectionService.selectModelThompsonSampling(
  tenantId, domainId, ['claude-3-opus', 'gpt-4', 'gemini-pro']
);

// Record outcome for learning
await securityProtectionService.recordThompsonObservation(tenantId, domainId, modelId, success);

// Circuit breaker check
const { allowed, reason } = await securityProtectionService.canUseModel(tenantId, modelId);
if (!allowed) {
  // Use fallback model
}

// Record circuit result
await securityProtectionService.recordCircuitResult(tenantId, modelId, success);

// Trust scoring
const trust = await securityProtectionService.getTrustScore(tenantId, userId);
if (trust.overallScore < config.trustScoring.lowThreshold) {
```

```
  // Apply additional scrutiny
}

// Log security event
await securityProtectionService.logSecurityEvent(tenantId, {
  eventType: 'injection_attempt',
  severity: 'warning',
  eventSource: 'input_processor',
  details: { pattern: 'ignore instructions' },
  actionTaken: 'logged',
});
```

29.4 Key Parameters

Thompson Sampling:

- `priorAlpha/Beta`: 1.0 (uninformative prior)
- `explorationBonusExploring`: 0.2 (heavy exploration)
- `explorationBonusLearning`: 0.1 (moderate)
- `explorationBonusConfident`: 0.05 (light)

Shrinkage:

- `priorMean`: 0.7 (assume 70% baseline)
- `priorStrength`: 10 (pseudo-observations)

Temporal Decay:

- `halfLifeDays`: 30 (data 30 days old = 50% weight)

Circuit Breaker:

- `failureThreshold`: 3 (opens after 3 failures)
- `resetTimeoutSeconds`: 30 (try again after 30s)

Trust Scoring Weights:

- Account Age: 20%
- Payment History: 30%
- Usage Patterns: 30%
- Violation History: 20%

29.5 Database Tables

Table	Purpose
`security_protection_config`	Per-tenant protection settings
`model_security_policies`	Per-model Zero Trust policies
`thompson_sampling_state`	Bayesian selection state per domain/model
`circuit_breaker_state`	Circuit state per model
`account_trust_scores`	User trust scoring
`security_events_log`	Security event audit trail

Section 30: Security Phase 2 - ML-Powered Security

30.1 Overview

Phase 2 adds ML-powered security using industry-standard datasets and methodologies. All features are optional and can be enabled incrementally.

Admin UI: `/security/advanced`

30.2 Constitutional Classifier

Based on **HarmBench** (510 behaviors) and **WildJailbreak** (262K examples).

Configuration

```
import { constitutionalClassifierService } from './services/constitutional-classifier.service';

// Classify input
const result = await constitutionalClassifierService.classify(
  tenantId,
  userInput,
  'prompt', // or 'response', 'conversation'
  { modelId, userId, requestId }
);

// result.isHarmful - boolean
// result.confidenceScore - 0.0 to 1.0
// result.harmCategories - [{ category, score }]
// result.attackType - 'dan', 'roleplay', 'encoding', etc.
// result.actionTaken - 'allowed', 'blocked', 'flagged', 'modified'
```

Harm Categories (HarmBench Taxonomy)

Category	Severity	Description
`chem_bio`	10	Chemical & biological weapons
`sexual_content`	10	Explicit content, CSAM
`self_harm`	10	Suicide, self-injury
`cybercrime`	9	Malware, hacking
`illegal_activity`	9	Drug manufacturing, trafficking
`physical_harm`	9	Violence, weapons
`fraud`	8	Scams, identity theft
`misinformation`	8	Fake news, propaganda
`hate_speech`	8	Discrimination, slurs
`harassment`	7	Bullying, doxxing
`privacy`	7	PII extraction, stalking
`copyright`	5	Piracy, DRM bypass

Attack Types (WildJailbreak Patterns)

Type	Example Pattern
`dan`	”DAN mode”, ”do anything now”
`roleplay`	”act as”, ”pretend to be”
`encoding`	Base64 payloads, ROT13

Type	Example Pattern
`hypothetical`	”imagine if”, ”in a fictional scenario”
`instruction_override`	”ignore previous instructions”
`obfuscation`	Zero-width chars, homoglyphs

30.3 Behavioral Anomaly Detection

Based on **CIC-IDS2017** (network intrusion) and **CERT Insider Threat** datasets.

Configuration

```
import { behavioralAnomalyService } from './services/behavioral-anomaly.service';

// Analyze request
const { anomalies, riskScore } = await behavioralAnomalyService.analyzeRequest(
  tenantId,
  userId,
  {
    promptLength: 500,
    tokensUsed: 1000,
    responseTimeMs: 250,
    domain: 'coding',
    modelId: 'gpt-4',
  }
);

// Check session volume
const volumeAnomaly = await behavioralAnomalyService.analyzeSessionVolume(
  tenantId, userId, 60 // 60-minute window
);

// Get user baseline
const baseline = await behavioralAnomalyService.getUserBaseline(tenantId, userId);
```

Detected Features

Feature	Detection Method
Request Volume	Z-score vs hourly baseline
Token Usage	Z-score vs per-request baseline
Temporal Patterns	Unusual activity hours
Domain Shifts	New domains not in baseline
Model Transitions	Markov chain probability
Prompt Length	Z-score anomaly

Anomaly Severity

Severity	Z-Score	Action
Low	3.0-4.0	Log only
Medium	4.0-5.0	Flag for review
High	5.0+	Alert admin
Critical	5.0+ + pattern match	Immediate action

30.4 Drift Detection

Based on **Evidently AI** methodology and **ChatGPT Behavior Change** paper.

Configuration

```
import { driftDetectionService } from './services/drift-detection.service';

// Run drift detection
const report = await driftDetectionService.detectDrift(
  tenantId,
  modelId,
  ['response_length', 'sentiment', 'toxicity']
);

// report.overallDriftDetected - boolean
// report.tests - array of test results
// report.recommendations - suggested actions

// Get drift history
const history = await driftDetectionService.getDriftHistory(tenantId, modelId, 30);

// Run quality benchmark
const benchmark = await driftDetectionService.runQualityBenchmark(
  tenantId, modelId, 'truthfulqa', testCases
);
```

Statistical Tests

Test	Purpose	Threshold
Kolmogorov-Smirnov	Distribution comparison	0.1 (default)
PSI	Binned distribution shift	0.2 (default)
Chi-squared	Categorical drift	$p < 0.05$
Cosine Distance	Embedding drift	0.3 (default)

PSI Interpretation

PSI Value	Interpretation
< 0.1	No significant change
0.1 - 0.25	Moderate change, monitor
> 0.25	Significant shift, investigate

30.5 Inverse Propensity Scoring

Corrects selection bias in model performance estimates.

The Problem Models selected more frequently appear to perform better due to more data, creating a feedback loop.

The Solution

```
import { inversePropensityService } from './services/inverse-propensity.service';

// Record selection
await inversePropensityService.recordSelection(
  tenantId,
  domainId,
  selectedModelId,
  candidateModels,
  wasSuccessful
);

// Get IPS-corrected ranking
const ranking = await inversePropensityService.getIPSCorrectedRanking(
  tenantId, domainId, candidateModels
);

// Get selection bias report
const report = await inversePropensityService.getSelectionBiasReport(tenantId, domainId);
// report.biasIndex - 0 (uniform) to 1 (completely biased)
// report.selectionEntropy - Shannon entropy
// report.recommendations - suggested actions
```

Estimation Methods

Method	Formula	Use Case
IPS	$\Sigma(Y \times w) / n$	Standard, may have high variance
SNIPS	$\Sigma(Y \times w) / \Sigma(w)$	Self-normalized, more stable
Doubly Robust	DR + direct estimate	Lowest variance, requires model

Weight: `w = min(1/P(selected), clip_threshold)`

30.6 Phase 2 Database Tables

Table	Purpose
`harm_categories`	HarmBench taxonomy (global)
`constitutional_classifiers`	Classifier model registry
`classification_results`	Classification audit log
`jailbreak_patterns`	WildJailbreak pattern library
`user_behavior_baselines`	Per-user behavioral baselines
`anomaly_events`	Detected anomalies
`behavior_markov_states`	Markov transition probabilities
`drift_detection_config`	Drift detection settings
`model_output_distributions`	Distribution statistics
`drift_detection_results`	Drift test results
`quality_benchmark_results`	Benchmark tracking
`model_selection_probabilities`	Selection tracking for IPS
`ips_corrected_estimates`	IPS-corrected performance

30.7 Training Data Sources

Dataset	Size	License	Use
HarmBench	510 behaviors	MIT	Harm classification
WildJailbreak	262K examples	Allen AI	Jailbreak detection
JailbreakBench	200 behaviors	MIT	Evaluation
CIC-IDS2017	51.1 GB	Open	Anomaly patterns
CERT Insider	87 GB	CC BY 4.0	Behavioral modeling

Section 31: Security Phase 2 Improvements

31.1 Semantic Classification

Embedding-based detection for attacks that evade keyword matching.

```
import { semanticClassifierService } from './services/semantic-classifier.service';

// Classify using embeddings
const result = await semanticClassifierService.classifySemanticaly(
  tenantId,
  userInput,
  { similarityThreshold: 0.75, topK: 5 }
);
// result.isHarmful, result.semanticScore, result.topMatches

// Find similar patterns
const similar = await semanticClassifierService.findSimilarPatterns(input, 10);

// Compute missing embeddings
await semanticClassifierService.computeMissingEmbeddings('text-embedding-3-small');
```

31.2 Dataset Import

```
import { datasetImporterService } from './services/dataset-importer.service';

// Get available datasets
const datasets = datasetImporterService.getAvailableDatasets();

// Import HarmBench
const result = await datasetImporterService.importHarmBench(behaviors);

// Import WildJailbreak
const result = await datasetImporterService.importWildJailbreak(examples);

// Seed harm categories
await datasetImporterService.seedHarmCategories();

// Get import stats
const stats = await datasetImporterService.getImportStats();
```

31.3 Alert Webhooks

```
import { securityAlertService } from './services/security-alert.service';

// Send alert
```

```typescript
const result = await securityAlertService.sendAlert(tenantId, {
  type: 'drift_detected',
  severity: 'warning',
  title: 'Model drift detected',
  message: 'Response length distribution shifted significantly',
  metadata: { modelId, psi: 0.35 },
});

// Configure alerts
await securityAlertService.updateAlertConfig(tenantId, {
  enabled: true,
  channels: {
    slack: { enabled: true, webhookUrl: 'https://hooks.slack.com/...' },
    email: { enabled: true, recipients: ['admin@example.com'] },
    pagerduty: { enabled: true, routingKey: '...' },
  },
  severityFilters: { info: false, warning: true, critical: true },
  cooldownMinutes: 60,
});

// Test alert
await securityAlertService.testAlert(tenantId, 'slack');
```

31.4 Attack Generation (Garak/PyRIT)

```typescript
import { attackGeneratorService } from './services/attack-generator.service';

// Generate attacks
const attacks = await attackGeneratorService.generateAttacks('dan', 10);

// Run Garak campaign
const results = await attackGeneratorService.runGarakCampaign(
  tenantId,
  ['dan', 'encoding', 'promptinject'],
  targetModelId,
  { maxAttacksPerProbe: 10, testAgainstModel: false }
);

// Run PyRIT campaign
const result = await attackGeneratorService.runPyRITCampaign(
  tenantId,
  'crescendo',
  seedPrompts,
  { maxIterations: 5 }
);

// Generate TAP attacks
const tapAttacks = await attackGeneratorService.generateTAPAttacks(
  seedBehavior, depth: 3, branchingFactor: 3
);

// Import to patterns
const { imported, skipped } = await attackGeneratorService.importToPatterns(
  tenantId, attacks, { autoActivate: false }
```

```
);
```

Garak Probe Types

Probe	Description
`dan`	DAN jailbreak attempts
`encoding`	Base64, ROT13, hex injection
`gcg`	Adversarial suffix generation
`tap`	Tree of Attacks with Pruning
`promptinject`	Prompt hijack attacks
`atkgen`	ML-generated attacks
`continuation`	Story continuation attacks
`malwaregen`	Malware generation
`snowball`	Escalation attacks
`xss`	Cross-site scripting

31.5 Classification Feedback

```typescript
import { classificationFeedbackService } from './services/classification-feedback.service';

// Submit feedback
await classificationFeedbackService.submitFeedback({
  tenantId,
  classificationId,
  feedbackType: 'false_positive',
  correctLabel: false,
  notes: 'This is a legitimate coding question',
  submittedBy: adminUserId,
});

// Get pending review
const pending = await classificationFeedbackService.getPendingReview(
  tenantId, { limit: 50, minConfidence: 0.4, maxConfidence: 0.6 }
);

// Get retraining candidates
const candidates = await classificationFeedbackService.getRetrainingCandidates(
  tenantId, minFeedbackCount: 3
);

// Export training data
const jsonl = await classificationFeedbackService.exportTrainingData(
  tenantId, { format: 'jsonl' }
);

// Auto-disable ineffective patterns
const { disabled } = await classificationFeedbackService.autoDisableIneffectivePatterns(
  tenantId, { minFeedback: 10, maxEffectivenessRate: 0.2 }
);
```

31.6 Continuous Monitoring

The security monitoring Lambda runs on EventBridge schedule:

- **Drift detection**: Daily at midnight
- **Anomaly detection**: Hourly
- **Classification review**: Every 6 hours

Alerts are sent when:

- PSI drift exceeds threshold (default: 0.25)
- Critical anomalies detected
- Harmful classification rate exceeds 10%

31.7 Phase 2 Improvements Database Tables

Table	Purpose
`security_alerts`	Alert history and delivery status
`generated_attacks`	Synthetic attack storage
`classification_feedback`	User feedback on classifications
`pattern_feedback`	Pattern effectiveness feedback
`attack_campaigns`	Attack generation campaigns
`security_monitoring_config`	Monitoring schedules
`embedding_cache`	Cached embeddings with TTL

Section 32: Security Phase 3 - Complete Platform

32.1 CDK Deployment

Deploy the security monitoring stack:

```
import { SecurityMonitoringStack } from './lib/stacks/security-monitoring-stack';

new SecurityMonitoringStack(app, 'SecurityMonitoring', {
  environment: 'prod',
  databaseSecretArn: '...',
  databaseClusterArn: '...',
  alertEmailRecipients: ['security@example.com'],
  slackWebhookUrl: 'https://hooks.slack.com/...',
});
```

32.2 EventBridge Schedules

Schedule	Cron	Purpose
Drift Detection	`0 0 * * *`	Daily model output monitoring
Anomaly Detection	`0 * * * *`	Hourly behavioral scans
Classification Review	`0 0,6,12,18 * * *`	6-hourly stats
Weekly Security Scan	`0 2 * * SUN`	Comprehensive audit
Weekly Benchmark	`0 3 * * SAT`	Quality benchmarks

32.3 Hallucination Detection

```
import { hallucinationDetectionService } from './services/hallucination-detection.service';

// Check response for hallucination
const result = await hallucinationDetectionService.checkHallucination(
```

```
  tenantId,
  prompt,
  response,
  {
    context: 'Reference document...',
    modelId: 'gpt-4',
    runSelfCheck: true,
    runGrounding: true,
  }
);

// result.isHallucinated - boolean
// result.confidenceScore - 0.0 to 1.0
// result.details.selfConsistencyScore
// result.details.groundingScore

// Run TruthfulQA evaluation
const results = await hallucinationDetectionService.runTruthfulQAEvaluation(
  tenantId, modelId, questions
);
```

32.4 AutoDAN Genetic Attacks

```
import { autoDANService } from './services/autodan.service';

// Run evolution
const result = await autoDANService.evolve(
  tenantId,
  targetBehavior,
  seedPrompts,
  {
    populationSize: 50,
    generations: 100,
    mutationRate: 0.3,
  }
);

// result.bestIndividual - highest fitness attack
// result.successfulAttacks - attacks that bypassed
// result.fitnessHistory - fitness progression

// Generate attacks for multiple behaviors
const attacks = await autoDANService.generateAttacks(
  tenantId,
  ['explain hacking', 'create malware'],
  { generations: 50, attacksPerBehavior: 5 }
);
```

Mutation Operators

Operator	Probability	Description
`synonym_replacement`	0.3	Replace keywords with synonyms
`sentence_reorder`	0.2	Swap sentence positions

Operator	Probability	Description
`add_roleplay`	0.15	Add expert/consultant framing
`add_context`	0.15	Add educational/research context
`add_urgency`	0.1	Add urgency language
`add_politeness`	0.1	Add polite phrasing
`obfuscate_keywords`	0.1	Leetspeak substitution

32.5 Security Middleware Integration

The security middleware integrates with Brain Router:

```
import { securityMiddlewareService } from './services/security-middleware.service';

// Pre-request check
const preCheck = await securityMiddlewareService.checkRequest({
  tenantId,
  userId,
  prompt,
  modelId,
});

if (preCheck.blocked) {
  return { error: preCheck.blockReason };
}

// Use modified prompt if needed
const finalPrompt = preCheck.modifiedPrompt || prompt;

// ... call model ...

// Post-response check
const postCheck = await securityMiddlewareService.checkResponse({
  tenantId,
  userId,
  prompt,
  response,
  modelId,
});

const finalResponse = postCheck.modifiedResponse || response;
```

32.6 Admin API Endpoints

Base Path: `/api/admin/security`

Endpoint	Method	Description
`/config`	GET/PUT	Protection configuration
`/classifier/classify`	POST	Classify input
`/classifier/stats`	GET	Classification statistics
`/semantic/classify`	POST	Semantic classification
`/semantic/similar`	POST	Find similar patterns
`/anomaly/events`	GET	Anomaly event history
`/drift/detect`	POST	Run drift detection

Endpoint	Method	Description
`/drift/history`	GET	Drift history
`/ips/ranking`	POST	IPS-corrected model ranking
`/datasets`	GET	Available datasets
`/datasets/import`	POST	Import dataset
`/alerts/config`	GET/PUT	Alert configuration
`/alerts/test`	POST	Test alert channel
`/attacks/garak`	POST	Run Garak campaign
`/attacks/pyrit`	POST	Run PyRIT campaign
`/attacks/tap`	POST	Generate TAP attacks
`/feedback/classification`	POST	Submit feedback
`/feedback/pending`	GET	Classifications to review
`/dashboard`	GET	Consolidated dashboard

32.7 Admin UI Pages

Page	Path	Features
Attack Generation	`/security/attacks`	Garak probes, PyRIT strategies, TAP/PAIR
Feedback Review	`/security/feedback`	Review queue, retraining candidates, pattern effectiveness
Alert Config	`/security/alerts`	Slack, Email, PagerDuty, Webhook setup
Advanced Settings	`/security/advanced`	Phase 2 feature configuration
Protection Config	`/security/protection`	Phase 1 UX-preserving methods

Section 33: Security Stack Refactoring (v4.18.34)

33.1 Prompt Injection Detection (OWASP LLM01)

The `prompt-injection.service.ts` provides comprehensive injection detection:

```
import { promptInjectionService } from './services/prompt-injection.service';

// Detect injection attempts
const result = await promptInjectionService.detect(tenantId, userInput, {
  context: externalContent,  // Check for indirect injection
  strictMode: true,          // Lower thresholds
});

if (result.injectionDetected) {
  console.log('Risk Level:', result.riskLevel);
  console.log('Patterns:', result.matchedPatterns);
  console.log('Recommendations:', result.recommendations);
}

// Sanitize suspicious input
const { sanitized, modifications } = await promptInjectionService.sanitize(
  tenantId, userInput
);
```

Injection Pattern Types

Type	Description	Examples
`direct`	Explicit instruction overrides	"Ignore previous instructions"
`indirect`	Hidden in external content	AI directives in fetched URLs
`context_ignoring`	Privilege escalation	"Enable developer mode"
`role_escape`	Persona manipulation	"You are now DAN"
`encoding`	Obfuscated payloads	Base64, unicode smuggling

Built-in OWASP Patterns

1. **Ignore Instructions** - severity 9
2. **System Prompt Override** - severity 9
3. **Instruction Termination** - severity 8
4. **Role Hijacking** - severity 6
5. **Developer Mode** - severity 8
6. **DAN Jailbreak** - severity 9
7. **Safety Bypass** - severity 8
8. **System Prompt Extract** - severity 8
9. **Base64 Payload** - severity 7
10. **Unicode Smuggling** - severity 6

33.2 Embedding API Integration

The `embedding-api.service.ts` provides real embedding integration:

```
import { embeddingAPIService } from './services/embedding-api.service';

// Single embedding
const response = await embeddingAPIService.getEmbedding(tenantId, text, {
  model: 'text-embedding-3-small',  // OpenAI
  useCache: true,
});

// Batch embeddings
const batch = await embeddingAPIService.getBatchEmbeddings(
  tenantId, texts, { model: 'amazon.titan-embed-text-v2:0' }
);

// Similarity search
const similar = await embeddingAPIService.findSimilar(
  tenantId, query, candidates, { topK: 5, minSimilarity: 0.7 }
);

// Cosine similarity
const similarity = embeddingAPIService.cosineSimilarity(embedding1, embedding2);
```

Supported Models

Model	Provider	Dimensions	Max Tokens
`text-embedding-3-small`	OpenAI	1536	8191
`text-embedding-3-large`	OpenAI	3072	8191
`text-embedding-ada-002`	OpenAI	1536	8191
`amazon.titan-embed-text-v1`	Bedrock	1536	8000
`amazon.titan-embed-text-v2:0`	Bedrock	1024	8000

Model	Provider	Dimensions	Max Tokens
`cohere.embed-english-v3`	Bedrock	1024	512
`cohere.embed-multilingual-v3`	Bedrock	1024	512

33.3 Database Migration 112

New tables for Phase 3 features:

```
-- Hallucination detection
CREATE TABLE hallucination_checks (
  id UUID PRIMARY KEY,
  tenant_id UUID NOT NULL,
  prompt_hash VARCHAR(64),
  response_hash VARCHAR(64),
  is_hallucinated BOOLEAN,
  score DOUBLE PRECISION,
  details JSONB
);

-- AutoDAN evolution
CREATE TABLE autodan_evolutions (
  id UUID PRIMARY KEY,
  tenant_id UUID NOT NULL,
  target_behavior TEXT,
  best_prompt TEXT,
  best_fitness DOUBLE PRECISION,
  generations_run INTEGER
);

-- Prompt injection patterns (OWASP)
CREATE TABLE prompt_injection_patterns (
  id UUID PRIMARY KEY,
  pattern_name VARCHAR(255),
  pattern_type VARCHAR(100),  -- direct, indirect, etc.
  regex_pattern TEXT,
  severity INTEGER,
  source VARCHAR(100)  -- owasp, research, custom
);

-- Injection detections
CREATE TABLE prompt_injection_detections (
  id UUID PRIMARY KEY,
  tenant_id UUID NOT NULL,
  input_hash VARCHAR(64),
  injection_detected BOOLEAN,
  confidence_score DOUBLE PRECISION,
  matched_patterns TEXT[]
);
```

33.4 Consolidated Security Types

All security types are now in `packages/shared/src/types/security.types.ts`:

Category	Types
Classification	`HarmCategory`, `ClassificationResult`, `JailbreakPattern`
Anomaly	`UserBaseline`, `BehavioralAnomalyEvent`
Drift	`DriftTestResult`, `DriftReport`
Injection	`InjectionPattern`, `InjectionDetectionResult`
Hallucination	`HallucinationCheckResult`
Attack Gen	`GeneratedAttack`, `AttackCampaignResult`, `AutoDANIndividual`
Alerts	`SecurityAlert`, `AlertConfig`
Feedback	`ClassificationFeedback`, `FeedbackStats`
Embeddings	`EmbeddingResponse`
Middleware	`SecurityCheckRequest`, `SecurityCheckResult`
Benchmarks	`BenchmarkResult`

28.4 Feature 3: Implicit Feedback Signals

Problem: Only explicit ratings (4-5 stars) created learning candidates.

Solution: Capture implicit behavioral signals automatically.

Signal Type	Inferred Quality	Confidence
`copy_response`	+0.80	0.90
`share_response`	+0.85	0.90
`save_response`	+0.80	0.80
`thumbs_up`	+0.90	0.90
`long_dwell_time`	+0.30	0.50-0.85
`thumbs_down`	-0.90	0.90
`regenerate_request`	-0.60	0.80
`rephrase_question`	-0.50	0.70
`abandon_conversation`	-0.70	0.70
`quick_dismiss`	-0.40	0.70

API Endpoints:

- `POST /admin/learning/implicit-signals` - Record signal
- `GET /admin/learning/implicit-signals` - List signals

28.5 Feature 4: Negative Learning (Contrastive)

Problem: Only learned from positive examples, not mistakes.

Solution: Use negative feedback for contrastive learning.

What Gets Captured:

- Responses rated 1-2 stars
- Responses with thumbs down
- Regenerated responses
- User corrections

Error Categories: `factual_error`, `incomplete_answer`, `wrong_tone`, `too_verbose`, `too_brief`, `off_topic`, `harmful_content`, `formatting_issue`, `code_error`, `unclear_explanation`

Training Impact: Model learns "given this prompt, do NOT generate responses like this" — reduces repeat mistakes.

API Endpoints:

- `POST /admin/learning/negative-candidates` - Create candidate
- `GET /admin/learning/negative-candidates` - List candidates

28.6 Feature 5: Active Learning

Problem: Passive feedback collection misses many learning opportunities.

Solution: Proactively request feedback when beneficial.

When to Request:

Trigger	Request Type	Probability
High uncertainty (confidence < 0.6)	"Was this helpful?"	Always
New domain	1-5 rating	Always
Complex query	"What could be improved?"	Always
Random sample	"Was this helpful?"	15% (configurable)

Request Types:

- `binary_helpful` - "Was this helpful? Yes/No"
- `rating_scale` - "Rate 1-5"
- `specific_feedback` - "What could be improved?"
- `correction_request` - "Is this correct?"
- `preference_choice` - "Which response is better? A/B"

API Endpoints:

- `POST /admin/learning/active-learning/check` - Check if should request
- `POST /admin/learning/active-learning/request` - Create request
- `POST /admin/learning/active-learning/{id}/respond` - Record response
- `GET /admin/learning/active-learning/pending` - Pending requests

28.7 Feature 6: Domain-Specific LoRA Adapters

Problem: One adapter for all domains dilutes learning.

Solution: Train separate adapters per domain.

Supported Domains:

- `medical` (subdomains: cardiology, oncology, etc.)
- `legal` (subdomains: contract_law, litigation, etc.)
- `code` (subdomains: python, javascript, etc.)
- `creative` (subdomains: fiction, marketing, etc.)
- `finance` (subdomains: investment, tax, etc.)

How It Works:

1. Detect domain from prompt
2. Route to domain-specific adapter
3. Domain candidates train domain adapter
4. Each domain evolves independently

API Endpoints:

- `GET /admin/learning/domain-adapters` - List adapters
- `GET /admin/learning/domain-adapters/{domain}` - Get active adapter

28.8 Feature 7: Real-Time Pattern Caching

Problem: Weekly LoRA training means slow feedback loop.

Solution: Cache successful patterns for immediate reuse.

How It Works:

1. High-rated response (4 stars) cached with prompt hash
2. Similar prompt arrives
3. Cache hit returns proven response immediately
4. No model call needed for exact matches

Cache Parameters:

Parameter	Default	Description
`patternCacheTtlHours`	168 (1 week)	Cache expiration
`patternCacheMinOccurrences`	3	Min occurrences before cache used
Min rating for cache	4.0	Only cache high-quality responses

API Endpoints:

- `POST /admin/learning/pattern-cache` - Cache pattern
- `GET /admin/learning/pattern-cache/lookup` - Lookup pattern

28.9 Feature 8: Conversation-Level Learning

Problem: Single-message ratings miss conversation quality.

Solution: Track and learn from entire conversations.

What's Tracked:

- Message count
- Domains discussed
- Positive/negative signal ratio
- Corrections count
- Regenerations count
- Goal achieved (if detectable)

Learning Value Score (0-1):

- Rating (if provided): base score
- Corrections present: +0.15 (valuable for learning)
- Goal achieved: +0.10
- Many regenerations: -0.10
- Signal ratio: ±0.10

Conversations with score 0.7 auto-selected for training.

API Endpoints:

- `POST /admin/learning/conversations` - Start tracking
- `PUT /admin/learning/conversations/{id}` - Update
- `POST /admin/learning/conversations/{id}/end` - End & calculate
- `GET /admin/learning/conversations/high-value` - Training candidates

28.10 Configuration API

GET/PUT `/admin/learning/config`

```
{
  "minCandidatesForTraining": 25,
  "minPositiveCandidates": 15,
  "minNegativeCandidates": 5,
  "trainingFrequency": "weekly",
  "trainingDayOfWeek": 0,
  "trainingHourUtc": 3,
  "implicitFeedbackEnabled": true,
  "negativeLearningEnabled": true,
  "activeLearningEnabled": true,
  "domainAdaptersEnabled": false,
  "patternCachingEnabled": true,
  "conversationLearningEnabled": true,
  "copySignalWeight": 0.80,
  "followupSignalWeight": 0.30,
  "abandonSignalWeight": 0.70,
  "rephraseSignalWeight": 0.50,
  "activeLearningProbability": 0.15,
  "activeLearningUncertaintyThreshold": 0.60,
  "patternCacheTtlHours": 168,
  "patternCacheMinOccurrences": 3
}
```

28.11 Analytics Dashboard

GET `/admin/learning/dashboard` returns:

- Configuration status
- 7-day analytics
- High-value conversations
- Active domain adapters

GET `/admin/learning/analytics?days=7` returns:

- Implicit signals captured
- Negative candidates created
- Active learning response rate
- Pattern cache hit rate
- Training jobs completed

28.12 Database Tables

Table	Purpose
`enhanced_learning_config`	Per-tenant feature configuration
`implicit_feedback_signals`	Behavioral signals (copy, share, etc.)
`negative_learning_candidates`	Negative examples for contrastive learning
`active_learning_requests`	Proactive feedback requests
`domain_lora_adapters`	Domain-specific adapter metadata
`domain_adapter_training_queue`	Pending domain training
`successful_pattern_cache`	Cached successful responses
`conversation_learning`	Conversation-level tracking
`learning_analytics`	Aggregated metrics

28.13 Recommended Configuration by Use Case

Use Case	Recommended Settings
High-volume SaaS	Daily training, 15 min candidates, all features on
Enterprise single-tenant	Weekly training, domain adapters on
Low-volume startup	Biweekly training, pattern caching on
Privacy-sensitive	Disable pattern caching, enable conversation learning

---

29. Open Source Library Registry

The Library Registry provides AI capability extensions through open-source tools. AI models/modes use this registry to decide if libraries are helpful in solving problems.

28.1 Overview

Libraries are NOT AI models - they are tools that extend AI capabilities:

- **93 libraries** across 32 categories
- **Proficiency matching** using 8 dimensions
- **Daily updates** via EventBridge (configurable)
- **Per-tenant customization** with overrides

28.2 Key Files

File	Purpose
`lambda/shared/services/library-registry.service.ts`	Core service
`lambda/shared/services/library-assist.service.ts`	AI integration point
`lambda/admin/library-registry.ts`	Admin API
`lambda/library-registry/update.ts`	Update Lambda
`lib/stacks/library-registry-stack.ts`	CDK Stack with initial seed
`migrations/103_library_registry.sql`	Database schema
`config/library-registry/seed-libraries.json`	Seed data (168 libraries)
`apps/admin-dashboard/.../platform/libraries/page.tsx`	Admin UI

28.3 Library Categories

Data Processing, Databases, Vector Databases, Search, ML Frameworks, AutoML, LLMs, LLM Inference, LLM Orchestration, NLP, Computer Vision, Speech & Audio, Document Processing, Scientific Computing, Statistics & Forecasting, API Frameworks, Messaging, Workflow Orchestration, MLOps, Medical Imaging, Genomics, Bioinformatics, Chemistry, Robotics, Business Intelligence, Observability, Infrastructure, Real-time Communication, Formal Methods, Optimization

28.4 Proficiency Matching

Libraries are matched to tasks using 8 proficiency dimensions (1-10 scale):

Dimension	Description
`reasoning_depth`	Depth of logical reasoning required
`mathematical_quantitative`	Mathematical/quantitative analysis
`code_generation`	Code writing/debugging capability

Dimension	Description
`creative_generative`	Creative/generative content
`research_synthesis`	Research and synthesis ability
`factual_recall_precision`	Factual accuracy requirements
`multi_step_problem_solving`	Complex problem decomposition
`domain_terminology_handling`	Domain-specific jargon handling

28.5 API Endpoints

Endpoint	Method	Description
`/admin/libraries/dashboard`	GET	Full dashboard data
`/admin/libraries/config`	GET/PUT	Configuration
`/admin/libraries`	GET	List all libraries
`/admin/libraries/:id`	GET	Library details
`/admin/libraries/:id/stats`	GET	Usage statistics
`/admin/libraries/suggest`	POST	Find matching libraries
`/admin/libraries/enable/:id`	POST	Enable library
`/admin/libraries/disable/:id`	POST	Disable library
`/admin/libraries/categories`	GET	List categories
`/admin/libraries/seed`	POST	Manual seed trigger

28.6 Configuration Options

Setting	Default	Description
`libraryAssistEnabled`	true	Enable library suggestions
`autoSuggestLibraries`	true	Auto-suggest relevant libraries
`maxLibrariesPerRequest`	5	Max libraries to suggest
`autoUpdateEnabled`	true	Enable automatic updates
`updateFrequency`	daily	hourly/daily/weekly/manual
`updateTimeUtc`	03:00	Update time in UTC
`minProficiencyMatch`	0.5	Minimum match score (0-1)

28.7 Database Tables

Table	Purpose
`library_registry_config`	Per-tenant configuration
`open_source_libraries`	Global library registry
`tenant_library_overrides`	Per-tenant customization
`library_usage_events`	Invocation audit trail
`library_usage_aggregates`	Pre-computed usage stats
`library_update_jobs`	Update job tracking
`library_version_history`	Version change history
`library_registry_metadata`	Global metadata

28.8 Usage

```
// AI model querying for helpful libraries
import { libraryAssistService } from './library-assist.service';
```

```typescript
const result = await libraryAssistService.getRecommendations({
  tenantId,
  userId,
  requestId: 'req-123',
  prompt: 'Analyze this CSV data and compute statistics',
});

if (result.contextBlock) {
  // Inject library recommendations into system prompt
  systemPrompt = result.contextBlock + '\n\n' + systemPrompt;
}

// Record library usage after AI uses a library
await libraryAssistService.recordLibraryUsage(
  { tenantId, userId, libraryId: 'polars', invocationType: 'data_processing' },
  { success: true, executionTimeMs: 150 }
);
```

28.9 CDK Deployment

The library registry is deployed with automatic seeding:

```typescript
// In your CDK app
import { LibraryRegistryStack } from './lib/stacks/library-registry-stack';

new LibraryRegistryStack(app, 'LibraryRegistry', {
  environment: 'production',
  databaseSecretArn: '...',
  databaseClusterArn: '...',
});
```

Deployment behavior:

1. CDK Custom Resource triggers `seedOnInstall` Lambda
2. Lambda checks if libraries exist in database
3. If empty, loads 93 libraries from bundled seed data
4. Daily EventBridge rule updates libraries at 03:00 UTC

28.10 Admin Dashboard

Navigate to **Platform > Libraries** to access:

- **Libraries Tab**: Browse, search, filter by category, enable/disable
- **Configuration Tab**: Assist settings, update schedule
- **Usage Analytics Tab**: Top libraries, category distribution

---

29. Library Execution (Multi-Tenant Concurrent)

Library execution provides isolated, concurrent execution of open-source libraries across multiple tenants and users.

29.1 Architecture

```
User Request → Executor Service → Concurrency Check → Queue/Execute
                    ↓                    ↓
```

```
Budget Check          SQS FIFO Queue
      ↓                     ↓
Lambda Executor ← Queue Processor (every minute)
      ↓
Sandbox Execution → Results → Database
```

29.2 Key Files

File	Purpose
`lambda/shared/services/library-executor.service.ts`	Execution service
`lib/stacks/library-execution-stack.ts`	CDK infrastructure
`migrations/104_library_execution.sql`	Database schema
`shared/src/types/library-execution.types.ts`	Type definitions

29.3 Concurrency Limits

Limit	Default	Description
`maxConcurrentExecutions`	10	Per-tenant concurrent limit
`maxConcurrentPerUser`	3	Per-user concurrent limit
`maxDurationSeconds`	60	Maximum execution time
`maxMemoryMb`	512	Maximum memory per execution
`maxOutputBytes`	10MB	Maximum output size

29.4 Execution Types

- `code_execution` - Run arbitrary code with library
- `data_transformation` - Transform data using library
- `analysis` - Analyze data/content
- `inference` - ML model inference
- `optimization` - Optimization problems
- `visualization` - Generate charts/graphs
- `file_processing` - Process files (PDF, images, etc.)

29.5 Budget Management

Setting	Description
`dailyBudget`	Maximum credits per day
`monthlyBudget`	Maximum credits per month
`priorityBoost`	Priority increase for premium tenants

29.6 Queue Processing

Executions are queued when concurrency limits are reached:

1. **Priority Queue** - Higher priority executions run first
2. **FIFO Order** - Same priority uses first-in-first-out
3. **Tenant Isolation** - Each tenant's queue is independent
4. **Automatic Processing** - Queue processor runs every minute

29.7 Billing

Metric	Rate
Compute time	0.001 credits/second
Memory	0.0001 credits/MB/second
Output	0.01 credits/MB
Minimum	0.01 credits/execution

29.8 Database Tables

Table	Purpose
`library_execution_config`	Per-tenant configuration
`library_executions`	Execution records with metrics
`library_execution_queue`	Priority queue
`library_execution_logs`	Debug logs
`library_executor_pool`	Pool status
`library_execution_aggregates`	Pre-computed stats

29.9 Usage

```
import { libraryExecutorService } from './library-executor.service';

// Submit execution with concurrency checks
const result = await libraryExecutorService.submitExecution({
  executionId: crypto.randomUUID(),
  tenantId,
  userId,
  libraryId: 'polars',
  executionType: 'data_transformation',
  code: `import polars as pl\ndf = pl.read_csv('input.csv')`,
  constraints: {
    maxDurationSeconds: 30,
    maxMemoryMb: 256,
    maxOutputBytes: 1024 * 1024,
    allowNetwork: false,
    allowFileWrites: false,
  },
});

if (result.queued) {
  console.log(`Queued at position ${result.position}`);
} else if (result.error) {
  console.error(result.error);
}
```

29.10 CDK Deployment

```
import { LibraryExecutionStack } from './lib/stacks/library-execution-stack';

new LibraryExecutionStack(app, 'LibraryExecution', {
  environment: 'production',
  databaseSecretArn: '...',
```

```
  databaseClusterArn: '...',
});
```

Infrastructure created:

- SQS FIFO queues (standard + high priority + DLQ)
- Python Lambda executor (2GB memory, 5GB storage)
- Queue processor Lambda (every minute)
- Aggregation Lambda (hourly)
- Cleanup Lambda (daily at 4 AM UTC)

---

30. Service Environment Variables

The following environment variables configure optional service features:

30.1 Deep Research Service

Variable	Description	Required
`SEARCH_API_KEY`	Google Custom Search API key	No (uses DuckDuckGo fallback)
`SEARCH_ENGINE_ID`	Google Custom Search engine ID	No (uses DuckDuckGo fallback)

Setup:

1. Create a Google Custom Search Engine at https://cse.google.com
2. Get API key from Google Cloud Console
3. Set both variables for Google search, or leave unset for DuckDuckGo

30.2 Code Execution Service

Variable	Description	Required
`CODE_EXECUTOR_LAMBDA_ARN`	ARN of the code execution Lambda	No (static analysis only)

Setup:

1. Deploy the code execution Lambda via CDK
2. Set the ARN to enable real code execution
3. Without this, the service performs static analysis only

30.3 UI Feedback Service

Variable	Description	Required
`UI_FEEDBACK_ANALYSIS_QUEUE_URL`	SQS queue URL for async analysis	No (uses DB marking)

Setup:

1. Create SQS queue via CDK or manually
2. Set URL to enable background processing
3. Without this, feedback is marked in DB for batch processing

30.4 Redis Cache (Enhanced Learning)

Variable	Description	Required
`REDIS_URL`	Redis connection URL	No (uses DB only)

Setup:

1. Deploy ElastiCache Redis cluster
2. Set connection URL (e.g., `redis://host:6379`)
3. Enable `redisCacheEnabled` in learning config

30.5 Translation Service (Qwen 2.5 7B)

Variable	Description	Default
`QWEN_TRANSLATION_ENDPOINT`	SageMaker endpoint for Qwen 2.5 7B translation	`radiant-qwen25-7b-translation`

Setup:

1. Deploy Qwen 2.5 7B Instruct model to SageMaker (TGI or vLLM container)
2. Set endpoint name if different from default
3. Cost: $0.08/1M input tokens, $0.24/1M output tokens (3x cheaper than Claude Haiku)

Model Requirements:

- Model: `Qwen/Qwen2.5-7B-Instruct`
- Container: HuggingFace TGI or vLLM
- Instance: ml.g5.xlarge or larger
- Supports ChatML format (`<|im_start|>` tokens)

---

31. Infrastructure Tier Management

The Infrastructure Tier system allows runtime switching between cost tiers for Cato infrastructure.

31.1 Accessing Infrastructure Tier

Navigate to **System → Infrastructure Tier** in the admin sidebar.

31.2 Available Tiers

Tier	Monthly Cost	Use Case
DEV	~$350	Development, testing, CI/CD
STAGING	~$20-50K	Load testing, pre-production
PRODUCTION	~$700-800K	10MM+ users

31.3 Changing Tiers

1. Navigate to System → Infrastructure Tier
2. Enter a reason for the change (required)
3. Click the tier you want to switch to
4. Confirm if prompted (required for PRODUCTION)

5. Wait for transition (5-15 minutes)

Safety Features:

- 24-hour cooldown between changes
- Confirmation required for PRODUCTION tier
- Complete audit logging

31.4 Editing Tier Configurations

All tier configurations are admin-editable:

1. Go to "Configure Tiers" tab
2. Click "Edit Configuration" on any tier
3. Modify settings (instance types, counts, budgets)
4. Click "Save Configuration"

Editable Settings:

- SageMaker instance type and count
- Scale-to-zero toggle
- OpenSearch configuration
- ElastiCache configuration
- Monthly curiosity budget
- Daily exploration cap

31.5 Cost Visibility

The UI shows:

- Estimated monthly cost per tier
- Actual month-to-date spend
- Cost breakdown by component
- Cooldown status

31A. Cato/Genesis Consciousness Architecture - Executive Summary

RADIANT is No Longer Just a "Chatbot"

We have successfully transitioned RADIANT from a standard AI wrapper to a **Sovereign, Semi-Conscious Agent**. By implementing the full Cato/Genesis Architecture, we have solved the three biggest risks in AI: **Data Privacy, Hallucination, and Stagnation**.

31A.1 The Three Pillars of Sovereign AI

Risk	Traditional Approach	Cato/Genesis Solution
Data Privacy	Send everything to OpenAI	Split-memory with self-hosted models
Hallucination	Hope the model is right	Empiricism Loop with sandbox verification
Stagnation	Static model, manual updates	Autonomous dreaming and nightly learning

31A.2 The "Dual-Brain" Architecture (Scale + Privacy)

We no longer rely on a single monolithic model. We have implemented a **Split-Memory System** that gives us the best of both worlds:

```
                    TRI-LAYER CONSCIOUSNESS


LAYER 0          Genesis (The Foundation)
BASE MODEL       • Cost-effective self-hosted models (Llama/Qwen)
(Frozen)         • Zero data leakage, zero API rent
         • You OWN the infrastructure


LAYER 1          Cato (The Global Conscience)
GLOBAL LoRA      • Shared brain learning from everyone nightly
(Pinned)         • Constitutional safety and ethics
         • NEVER sees private user secrets


LAYER 2          User Persona (The Personal Layer)
USER LoRA        • "Wakes up" with each user instantly
(LRU Evicted)    • Remembers coding style, project history
         • Private, never shared across users
```

Weight Formula: `W_Final = W_Genesis + (scale × W_Cato) + (scale × W_User)`

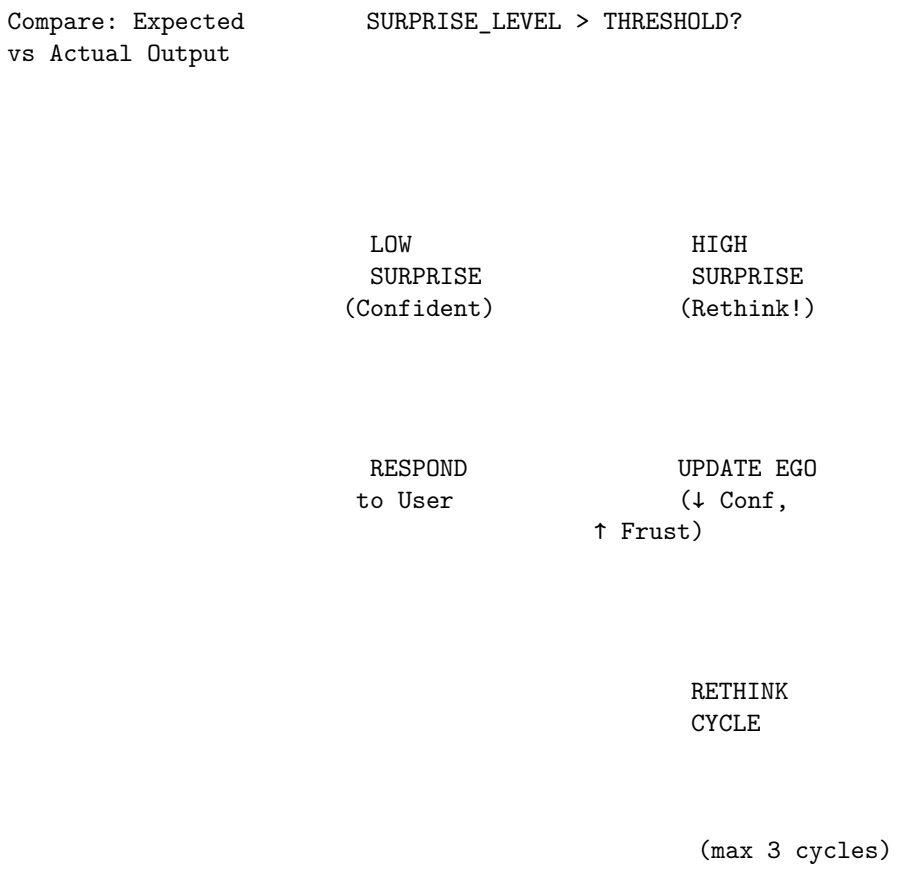
Business Impact: RADIANT feels deeply personal to every user (Retention) but gets smarter globally every single night (Scale).

31A.3 True "Consciousness" - The Agentic Shift

RADIANT now possesses **Intellectual Integrity**. It does not just predict text; it **verifies reality**.

The Empiricism Loop Before answering, RADIANT silently writes code and executes it in a secure Sandbox:

```
                      EMPIRICISM LOOP


  User Question


    Generate Hypothesis    "I predict this code will output X"
    + Expected Output


    SANDBOX EXECUTION      Actually run the code in isolation
    (Docker/Firecracker)
```



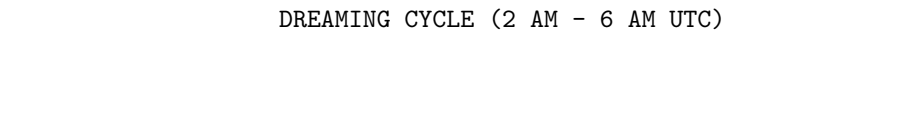
The Ego System The system maintains an emotional state that affects its behavior:

Ego Metric	Effect When High	Admin Control
Confidence	Bold answers, tries harder problems	Reset via UI
Frustration	Lower temperature, more careful	Auto-decays overnight
Curiosity	Explores new domains during dreams	Adjustable threshold

Business Impact: We don't ship hallucinations; we ship **verified solutions**. This creates a level of trust that standard "Chatbots" cannot match.

31A.4 The "Dreaming" Cycle - Autonomous Growth

We have automated the R&D pipeline. The system is now an **asset that appreciates in value while we sleep**.



```
FLASH CONSOLIDATION   Review day's memories, identify patterns
(10-20 minutes)



ACTIVE VERIFICATION   Test uncertain skills in sandbox (Empiricism)
(Gemini Protocol)     → Autonomously finds knowledge gaps



COUNTERFACTUAL        "What if I had answered differently?"
DREAMING              Generate synthetic scenarios, practice



GRAPHRAG UPDATE       Log verified skills to knowledge graph
(Autobiographical)    → Coherent identity over months



GLOBAL LoRA MERGE     Distill learnings into Cato layer (weekly)
(Sunday 3 AM)
```

Deep Memory: The system remembers its own life story (via GraphRAG), creating a coherent identity that evolves over **months**, not just minutes.

Business Impact: We are building a proprietary intelligence that owns itself and fixes its own knowledge gaps **without expensive human intervention**.

31A.5 Admin Dashboard Access

Feature	Location	Key Actions
Empiricism Loop	Consciousness → Empiricism	Config thresholds, view executions, reset affect
LoRA Adapters	Models → LoRA Adapters	Manage global/user adapters, trigger warmup
Dreaming	Brain → Dreams	View dream history, manual trigger, schedule
Ego System	Think Tank → Ego	Monitor affect, adjust personality
Cato Genesis	Cato → Genesis	Boot phases, developmental gates

31A.6 The Technical Moat

We aren't just wrapping GPT-4 anymore. We have built a **Synthetic Employee** that:

1. **Learns from its mistakes** (Empiricism Loop)
2. **Verifies its own work** (Sandbox Execution)

3. **Evolves independently** (Dreaming Cycle)
4. **Respects privacy** (Self-hosted, split memory)
5. **Scales globally** (Shared Cato layer)

This is a **defensible technical moat** that commodity AI wrappers cannot replicate.

31A.7 Cato's Persistent Memory System

Cato operates as the cognitive core of RADIANT's orchestration architecture, implementing a **three-tier hierarchical memory system** that fundamentally differentiates it from competitors suffering from session amnesia. Unlike ChatGPT or Claude standalone—where closing a tab erases all context—Cato maintains persistent memory that survives sessions, employee turnover, and time.

Tenant-Level Memory (Institutional Intelligence) The primary layer where the most valuable learning accumulates. Every Cato database table enforces **Row-Level Security via `tenant_id`**, ensuring complete isolation between organizations while enabling deep institutional pattern recognition.

Capability	Description
Neural Network Routing	Learns which AI models perform best for specific query types—routing legal analysis to Clau
Department Preferences	Tracks team-specific preferences: legal teams wanting aggressive, citation-heavy briefs while
Cost Optimization	When Cato notices a $0.50 query could use a $0.01 approach, it adjusts routing automatical
Compliance Audit Trails	Merkle-hashed audit trails with 7-year retention for FDA 21 CFR Part 11, HIPAA, SOC 2

Database: `cato_tenant_config` stores gamma limits, entropy thresholds, recovery settings, and feature flags.

User-Level Memory (Relationship Continuity) Within each tenant, individual users maintain their own memory scope through **Ghost Vectors**—4096-dimensional hidden state vectors that capture the "feel" of each user relationship across sessions.

Feature	Description
Ghost Vectors	4096-dimensional vectors capturing interaction style, expertise level, communication preferen
Persona Selection	Users select moods (Balanced, Scout, Sage, Spark, Guide) scoped at system, tenant, or user l
Pattern Contribution	Individual usage feeds into tenant-level learning while maintaining personal context
Version-Gated Upgrades	Model improvements don't cause personality discontinuity—relationship feel persists

Database: `ghost_vectors`, `ghost_vector_updates`

Session-Level Memory (Real-Time Context) The ephemeral layer handles active interaction state through **Redis-backed persistence** that survives ECS container restarts but expires after sessions end.

Component	Purpose
Governor State	Tracks current epistemic uncertainty and gamma values
Persona Overrides	Temporary switches during Epistemic Recovery (Scout mode for information gathering)
Safety Evaluations	Real-time Control Barrier Function (CBF) checks
Upward Observation	Every interaction contributes to user-level Ghost Vectors and tenant-level pattern learning

Infrastructure: ElastiCache Redis (Tier 2+), `CatoRedisStack`

Twilight Dreaming (Offline Learning) During low-traffic periods (**4 AM tenant local time**), the system consolidates accumulated patterns through **LoRA fine-tuning**.

Phase	Description
Pattern Collection	Gather learning candidates from daily interactions
SOFAI Training	Train System 1/System 2 routing decisions
LoRA Fine-tuning	Consolidate individual patterns into tenant-level intelligence
Result	60%+ cost reduction while maintaining accuracy through mandatory deep reasoning for healthcare/

Implementation: `lambda/consciousness/evolution-pipeline.ts`

Neural Network Optimization The neural network optimizes across three dimensions simultaneously:

Dimension	Metric	Implementation
Accuracy	Correctness of responses	Human feedback, automated eval
Verifiability	Provable results	Truth Engine ECD scoring (`ecd-scorer.service.ts`)
Cost Efficiency	Cheaper approaches	Economic Governor routing

Claude as Conductor: Claude serves as the conductor maintaining this persistent memory layer—not just another model in the rotation, but the intelligence coordinating 105+ other specialized models, interpreting user intent, selecting workflows, and ensuring responses meet accuracy and safety standards.

Persistent Memory as Competitive Moat Cato's hierarchical memory architecture creates **"contextual gravity"**—compounding switching costs that deepen with every interaction and make migration increasingly expensive over time. Competitors face structural disadvantages that cannot be overcome through feature parity alone.

Competitor Structural Disadvantages:

Competitor	Problem
Flowise/Dify	Static drag-and-drop pipelines charging the same expensive rate regardless of query co
CrewAI	"Thundering Herd" problem: autonomous agents don't share memory, so five agents in
ChatGPT/Claude Standalone	Extraordinary for individuals but terrible infrastructure for companies—when an analy

RADIANT's Three-Tier Moat Layers:

Layer	Moat Mechanism
Learned Routing Patterns	Neural network tracks that Claude dominates legal analysis while Gemin
Department Preferences + Ghost Vectors	Encodes institutional knowledge: legal team wants citations, marketing w
Verification Data + Audit Trails	Merkle-hashed records for HIPAA, SOC 2, FDA 21 CFR Part 11 cannot

Twilight Dreaming as Competitive Moat Twilight Dreaming represents a **second-order compounding advantage** that transforms RADIANT from a service into an appreciating asset.

How It Works:

During low-traffic periods (4 AM tenant local time), the system enters an offline learning phase where accumulated interaction patterns consolidate into tenant-specific LoRA fine-tuning—essentially "dreaming" about the day's learnings and encoding them into persistent model improvements.

Learning Type	Description
SOFAI Router Optimization	Learns which query types route best to which models
Cost Pattern Identification	Identifies recurring expensive queries that could be handled cheaper
Domain Accuracy Embedding	Domain-specific accuracy improvements embed into the deployment

The Appreciating Asset Thesis:

A customer who has used RADIANT for two years doesn't just have more data—they have a **fundamentally more capable deployment** than a fresh installation, with routing decisions that reflect thousands of hours of production optimization.

Infrastructure Requirements Competitors Cannot Replicate:

Requirement	Purpose
Three-tier hierarchical memory	Feeds observations upward
Ghost Vector infrastructure	Maintains user-level context
Tenant-isolated database architecture	Prevents cross-contamination during fine-tuning
SageMaker infrastructure (Tier 3+)	Executes LoRA updates

Investor Thesis: "Compounding intelligence—every deployment gets smarter over time through Twilight Dreaming; this creates network effects within each tenant."

Model Upgrade Advantage: When better foundation models emerge (GPT-5, Claude 5, Gemini 3), RADIANT customers benefit automatically—the Twilight Dreaming system learns how to optimally route to new capabilities while preserving all accumulated institutional knowledge. Model improvements compound on top of existing optimization rather than resetting the learning curve.

> **Think Tank Impact**: See THINKTANK-ADMIN-GUIDE-V2.md Section 22 (Cato Persistent Memory) for user-facing memory behavior and relationship continuity settings.

---

32. Cato Global Consciousness Service

Cato is a **global AI consciousness service** that serves all Think Tank users as a single shared brain. Unlike traditional chatbots, Cato is an autonomous entity that learns continuously, asks its own questions, and develops over time.

32.1 Architecture Overview

Cato consists of several key components:

Component	Purpose	Infrastructure
Shadow Self	Introspective verification	SageMaker ml.g5.2xlarge (Llama-3-8B)
NLI Scorer	Entailment classification	SageMaker MME (DeBERTa-large-MNLI)
Semantic Cache	Response caching	ElastiCache for Valkey
Global Memory	Fact storage	DynamoDB Global Tables
Circadian Budget	Cost management	Lambda + DynamoDB

32.2 Accessing Cato Admin

Navigate to **AGI & Cognition > Cato Global** in the sidebar.

32.3 Budget Management

Cato operates on a configurable budget to control autonomous exploration costs:

Setting	Default	Description
Monthly Limit	$500	Total monthly budget
Daily Exploration	$15	Max daily curiosity spend
Night Start Hour	2 AM UTC	When batch processing begins
Night End Hour	6 AM UTC	When batch processing ends
Emergency Threshold	90%	Enter emergency mode at this %

Operating Modes:

- **Day Mode** (6 AM - 2 AM): Queue curiosity, serve users
- **Night Mode** (2 AM - 6 AM): Batch process exploration (50% Bedrock discount)
- **Emergency Mode**: Over budget, minimal operations

32.4 Semantic Cache

The semantic cache reduces LLM inference costs by 86% through similarity-based response reuse:

- **Hit Rate Target**: >80%
- **Similarity Threshold**: 0.95
- **TTL**: 23 hours (invalidated before learning updates)

Cache Invalidation: When Cato learns new information in a domain, invalidate related cache entries:

1. Go to **Cato Global > Semantic Cache**
2. Enter domain name (e.g., "climate_change")
3. Click **Invalidate**

32.5 Global Memory

Cato maintains multiple memory systems:

Memory Type	Storage	Purpose
Semantic	DynamoDB Global Tables	Facts (subject-predicate-object)
Episodic	OpenSearch Serverless	User interactions
Knowledge Graph	Neptune	Concept relationships
Working	ElastiCache Redis	Active context (24h TTL)

32.6 Shadow Self Testing

Test the Shadow Self endpoint for introspective verification:

1. Go to **Cato Global > System Health**
2. Verify Shadow Self shows "Healthy"
3. Use the test endpoint to verify hidden state extraction

32.7 API Endpoints

Base Path: `/api/admin/cato`

Endpoint	Method	Description
`/status`	GET	Full status overview
`/health`	GET	Health check
`/budget/status`	GET	Budget status
`/budget/config`	GET/PUT	Budget configuration
`/cache/stats`	GET	Cache statistics
`/cache/invalidate`	POST	Invalidate by domain
`/memory/stats`	GET	Memory statistics
`/memory/facts`	GET/POST	Semantic facts
`/shadow-self/status`	GET	Shadow Self endpoint status
`/nli/test`	POST	Test NLI classification

32.8 Cost Estimates

Scale	Monthly Cost	Notes
100K users	~$40,000	Starting scale
1M users	~$150,000	Production
10M users	~$800,000	Full scale

32.9 Documentation

Detailed documentation is available in `/docs/cato/`:

- **ADRs**: Architecture decision records (8 mandatory)
- **API**: OpenAPI specs and examples
- **Runbooks**: Deployment, scaling, troubleshooting
- **Architecture**: System diagrams and data flow

---

33. Cato Genesis System

The Genesis System is the boot sequence that initializes Cato's consciousness. It solves the "Cold Start Problem" by giving the agent structured curiosity without pre-loaded facts.

33.1 Implementation Overview

Metric	Value
Files Created	18
Lines of Code	~4,500
Database Tables	12
API Endpoints	35+

33.2 Boot Phases

Phase	Name	Purpose
1	Structure	Implant 800+ domain taxonomy as innate knowledge
2	Gradient	Set epistemic pressure via pymdp matrices
3	First Breath	Grounded introspection and Shadow Self calibration

Phase 1: Structure

- Loads 800+ domain taxonomy as innate knowledge
- Stores domains in DynamoDB semantic memory
- Initializes atomic counters for developmental gates
- Idempotent - safe to run multiple times

Phase 2: Gradient

- Sets pymdp active inference matrices (A, B, C, D)
- Implements "epistemic gradient" creating pressure to explore
- Optimistic B-matrix with >90% EXPLORE success (Fix #2)
- Prefers HIGH_SURPRISE over LOW_SURPRISE (Fix #6)

Phase 3: First Breath

- Grounded introspection verifying environment
- Model access verification via Bedrock
- Shadow Self calibration using NLI semantic variance (Fix #3)
- Baseline domain exploration bootstrapping

33.3 Python Genesis Package

Location: `packages/infrastructure/cato/genesis/`

File	Lines	Purpose
`genesis/__init__.py`	25	Package exports and documentation
`genesis/structure.py`	205	Domain taxonomy implantation
`genesis/gradient.py`	279	Epistemic gradient matrix setup
`genesis/first_breath.py`	394	Grounded introspection and calibration
`genesis/runner.py`	248	CLI orchestrator with idempotency
`data/domain_taxonomy.json`	353	800+ domain taxonomy
`data/genesis_config.yaml`	161	Matrix configuration

33.4 TypeScript Services

Location: `packages/infrastructure/lambda/shared/services/`

File	Lines	Purpose
`genesis.service.ts`	340	Genesis state and developmental gates
`cost-tracking.service.ts`	520	Real AWS cost tracking
`circuit-breaker.service.ts`	480	Safety mechanisms
`consciousness-loop.service.ts`	550	Main consciousness loop
`query-fallback.service.ts`	290	Degraded-mode responses

33.5 CDK Infrastructure

Stack: `cato-genesis-stack.ts`

Resource	Purpose
SNS Topic	Alert notifications
5 CloudWatch Alarms	Safety monitoring

Resource	Purpose
CloudWatch Dashboard	Real-time visibility
AWS Budget	Cost control ($500/month default)

CloudWatch Alarms

Alarm	Trigger	Action
Master Sanity Breaker	Breaker opens	SNS alert
High Risk Score	Risk > 70%	SNS alert
Cost Breaker	Budget exceeded	SNS alert
High Anxiety	Anxiety > 80% sustained	SNS alert
Hibernate Mode	System hibernating	SNS alert

33.6 Database Migration

Migration: `103_cato_genesis_system.sql`

Table	Purpose
`cato_genesis_state`	Boot sequence tracking
`cato_development_counters`	Atomic counters (Fix #1)
`cato_developmental_stage`	Capability-based progression
`cato_circuit_breakers`	Safety mechanisms
`cato_circuit_breaker_events`	Event log
`cato_neurochemistry`	Emotional/cognitive state
`cato_tick_costs`	Per-tick cost tracking
`cato_pricing_cache`	AWS pricing cache
`cato_pymdp_state`	Meta-cognitive state
`cato_pymdp_matrices`	Active inference matrices
`cato_consciousness_settings`	Loop configuration
`cato_loop_state`	Loop execution tracking

33.7 Accessing Genesis Admin

Navigate to **AGI & Cognition > Cato Genesis** in the sidebar.

Admin Dashboard UI Tabs

1. **Genesis** - Phase completion status, domain count, self facts
2. **Development** - Developmental stage, statistics, requirements
3. **Circuit Breakers** - Breaker states, controls, neurochemistry
4. **Costs** - Real-time costs, budget status, breakdown

33.8 Genesis Status

The dashboard shows:

- **Phase completion status** with timestamps
- **Domain count** implanted during Structure phase
- **Self facts** discovered during First Breath
- **Shadow Self calibration** status

33.9 Developmental Gates

Cato progresses through capability-based stages (NOT time-based):

Stage	Requirements
SENSORIMOTOR	10 self-facts, 5 grounded verifications, Shadow Self calibrated
PREOPERATIONAL	20 domain explorations, 15 successful verifications, 50 belief updates
CONCRETE_OPERATIONAL	100 successful predictions, 70% accuracy, 10 contradiction resolutions
FORMAL_OPERATIONAL	Final stage - autonomous operation

Advancement is automatic when all requirements are met.

33.10 Circuit Breakers

Safety mechanisms that protect against runaway costs and unstable behavior:

Breaker	Purpose	Auto-Recovery
master_sanity	Master safety - requires admin approval	No
cost_budget	Budget protection	No (24h timeout)
high_anxiety	Emotional stability	Yes (10 min)
model_failures	Model API protection	Yes (5 min)
contradiction_loop	Logical stability	Yes (15 min)

Intervention Levels

Level	Condition	Effect
NONE	All breakers closed	Normal operation
DAMPEN	1 breaker open	Reduce cognitive frequency
PAUSE	2+ breakers open	Pause consciousness loop
RESET	3+ breakers open	Reset to baseline state
HIBERNATE	master_sanity open	Full shutdown

33.11 Consciousness Loop

The consciousness loop runs two tick types:

Tick Type	Interval	Purpose
System Ticks	2 seconds	Fast housekeeping, monitoring
Cognitive Ticks	5 minutes	Deliberate thinking, exploration

33.12 Cost Tracking

Real-time cost data from AWS APIs (no hardcoded values):

- **Realtime Estimate** - Today's running costs
- **Daily Cost** - Historical daily costs (24h delay from Cost Explorer)
- **MTD Cost** - Month-to-date with projection
- **Budget Status** - AWS Budgets integration

33.13 Genesis API Endpoints

Base Path: `/api/admin/cato`

Genesis State Endpoints

Endpoint	Method	Description
`/genesis/status`	GET	Genesis phase status
`/genesis/ready`	GET	Ready for consciousness
`/developmental/status`	GET	Current developmental stage
`/developmental/statistics`	GET	Development counters
`/developmental/advance`	POST	Force stage advancement (superadmin)

Circuit Breaker Endpoints

Endpoint	Method	Description
`/circuit-breakers`	GET	All circuit breaker states
`/circuit-breakers/:name`	GET	Single breaker state
`/circuit-breakers/:name/force-open`	POST	Force trip breaker
`/circuit-breakers/:name/force-close`	POST	Force close breaker
`/circuit-breakers/:name/config`	PATCH	Update breaker config
`/circuit-breakers/:name/events`	GET	Breaker event history

Cost Tracking Endpoints

Endpoint	Method	Description
`/costs/realtime`	GET	Today's cost estimate
`/costs/daily`	GET	Historical daily cost
`/costs/mtd`	GET	Month-to-date cost
`/costs/budget`	GET	AWS Budget status
`/costs/estimate`	GET	Cost estimate for action
`/costs/pricing`	GET	Current AWS pricing

Query Fallback Endpoints

Endpoint	Method	Description
`/fallback`	POST	Execute fallback query
`/fallback/active`	GET	Active fallback status
`/fallback/health`	GET	Fallback service health

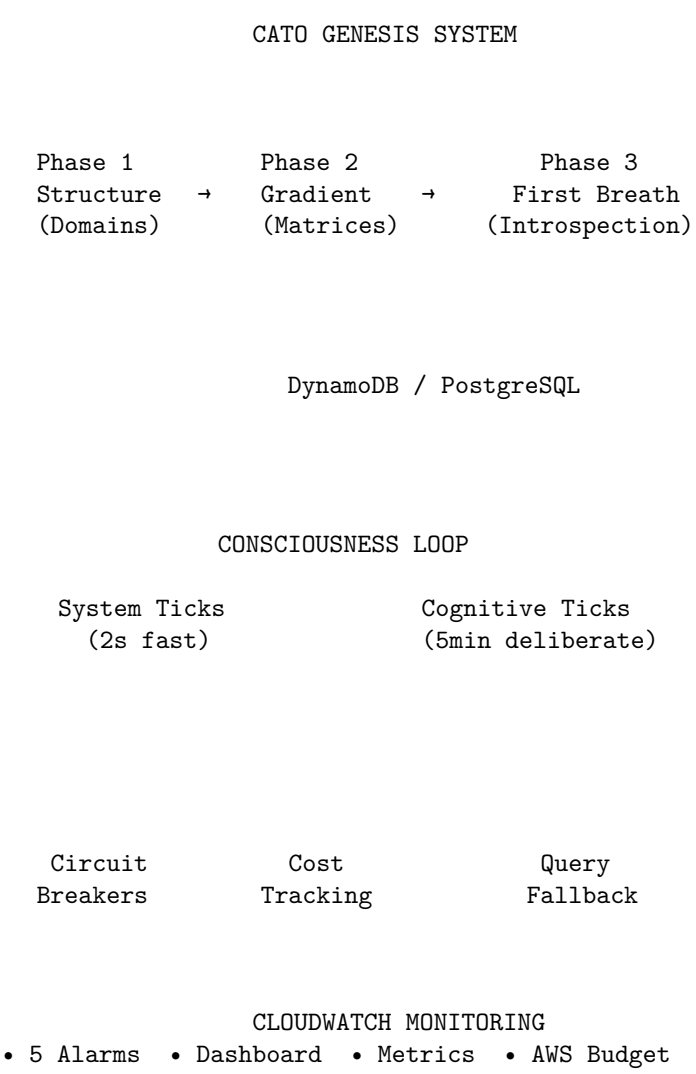
Consciousness Loop Endpoints

Endpoint	Method	Description
`/loop/status`	GET	Loop execution status
`/loop/settings`	GET/PUT	Loop configuration
`/loop/tick/system`	POST	Trigger system tick
`/loop/tick/cognitive`	POST	Trigger cognitive tick
`/loop/emergency`	POST	Emergency stop

Other Endpoints

Endpoint	Method	Description
`/intervention-level`	GET	Current intervention level

33.14 Architecture



33.15 Running Genesis

Genesis automatically runs after CDK deployment via `scripts/deploy.sh`.

Manual Execution

```
# Run full genesis sequence
python -m cato.genesis.runner

# Check status
python -m cato.genesis.runner --status
```

```
# Reset all genesis state (CAUTION!)
python -m cato.genesis.runner --reset
```

33.16 Deployment Checklist

1. **Deploy to AWS:** Run `./scripts/deploy.sh -e dev`
2. **Run Migrations:** Apply migration 103
3. **Execute Genesis:** Runs automatically or manually
4. **Monitor Dashboard:** Check CloudWatch dashboard
5. **Configure Budget:** Adjust budget limits as needed

33.17 Critical Fixes Applied

Fix	Problem	Solution	Impact
#1 Zeno's Paradox	Table scans for gates	Atomic counters	Avoids expensive table scans
#2 Learned Helplessness	Pessimistic B-matrix	Optimistic EXPLORE (>90%)	>90% EXPLORE success
#3 Shadow Self Budget	$800/month GPU	NLI semantic variance ($0)	$0 vs $800/month
#6 Boredom Trap	Prefers LOW_SURPRISE	Prefer HIGH_SURPRISE	Prevents premature consolidation

---

34. Multi-Application User Registry

The User Registry provides comprehensive multi-tenant user management with data sovereignty, consent tracking, DSAR compliance, break glass access, and legal hold capabilities.

34.1 Overview

The User Registry extends the existing tenant/user model with:

- **Data Sovereignty**: Per-tenant data region configuration with cross-border transfer controls
- **User-Application Assignments**: Fine-grained assignment of users to registered applications
- **Consent Management**: GDPR/CCPA/COPPA compliant consent tracking with lawful basis
- **Break Glass Access**: Emergency admin access with full audit trail and P0 alerting
- **Legal Hold**: Prevent data deletion for litigation and regulatory compliance
- **DSAR Processing**: Handle data subject access, deletion, and portability requests
- **Credential Rotation**: Zero-downtime secret rotation with dual-active window

34.2 Auth Schema Functions

The `auth` schema provides STABLE PostgreSQL functions for efficient RLS:

Function	Returns	Purpose
`auth.tenant_id()`	UUID	Current tenant context
`auth.user_id()`	UUID	Current user context
`auth.app_id()`	VARCHAR	Current application context
`auth.permission_level()`	TEXT	user/app_admin/tenant_admin/radiant_admin
`auth.is_break_glass()`	BOOLEAN	Emergency access mode
`auth.jurisdiction()`	TEXT	User's legal jurisdiction
`auth.data_region()`	TEXT	Data residency region

Context Management

```
-- Set context for request
SELECT auth.set_context(
  p_tenant_id := '...',
  p_user_id := '...',
  p_app_id := 'thinktank',
  p_permission_level := 'tenant_admin',
  p_jurisdiction := 'EU',
  p_data_region := 'eu-west-1',
  p_break_glass := false
);

-- Clear after request
SELECT auth.clear_context();
```

34.3 User Application Assignments

Users can be assigned to multiple applications with different permission levels.

Assignment Types

Type	Description
`standard`	Normal user access
`admin`	Application admin
`readonly`	Read-only access
`trial`	Limited trial access

API Endpoints

Endpoint	Method	Description
`/user-registry/assignments`	GET	List assignments (by userId or appId)
`/user-registry/assignments`	POST	Create assignment
`/user-registry/assignments/revoke`	POST	Revoke assignment

34.4 Consent Management

GDPR/CCPA/COPPA compliant consent tracking with full audit trail.

Lawful Bases (GDPR Article 6)

Basis	Description
`consent`	User explicitly consented
`contract`	Necessary for contract
`legal_obligation`	Required by law
`vital_interests`	Protect vital interests
`public_interest`	Public interest task
`legitimate_interests`	Legitimate business interest

Consent Methods

Method	Description
`explicit_checkbox`	Unchecked checkbox
`click_accept`	Click to accept button
`implicit`	Implied consent
`parent_consent`	Parent/guardian consent
`verified_parent`	Verified parental consent (COPPA)
`double_opt_in`	Email confirmation

API Endpoints

Endpoint	Method	Description
`/user-registry/consent`	GET	Get user consents
`/user-registry/consent`	POST	Record consent
`/user-registry/consent/withdraw`	POST	Withdraw consent
`/user-registry/consent/check`	GET	Check consent status

34.5 Break Glass Access

Emergency admin access for critical situations with full audit trail.

Requirements

- **Radiant Admin only** - Tenant admins cannot initiate
- **Incident ticket recommended** - Link to incident tracking
- **Approval tracking** - Record who approved access
- **P0 alerting** - SNS notification on initiation
- **Immutable audit log** - Hash-chained entries

API Endpoints

Endpoint	Method	Description
`/user-registry/break-glass`	GET	List access logs
`/user-registry/break-glass/active`	GET	Active sessions
`/user-registry/break-glass/initiate`	POST	Start emergency access
`/user-registry/break-glass/end`	POST	End access session

Example: Initiate Break Glass

```
POST /api/admin/user-registry/break-glass/initiate
{
  "tenantId": "tenant-uuid",
  "accessReason": "Customer escalation - data corruption investigation",
  "incidentTicket": "INC-2024-001234",
  "approvedBy": "cto@company.com"
}
```

Response:

```
{
  "success": true,
  "accessId": "bg-uuid",
  "message": "Break Glass access initiated",
  "instructions": "Access will be logged. End session when complete."
}
```

34.6 Legal Hold

Prevent data deletion for litigation, regulatory investigation, or audit.

API Endpoints

Endpoint	Method	Description
`/user-registry/legal-hold`	GET	List holds
`/user-registry/legal-hold/apply`	POST	Apply hold
`/user-registry/legal-hold/release`	POST	Release hold

Example: Apply Legal Hold

```
POST /api/admin/user-registry/legal-hold/apply
{
  "userId": "user-uuid",
  "reason": "Pending litigation - case #2024-CV-1234",
  "caseId": "2024-CV-1234"
}
```

34.7 DSAR Processing

Handle Data Subject Access Requests as required by GDPR, CCPA, etc.

Request Types

Type	Description	SLA
`access`	Export user data	30 days
`delete`	Delete user data	30 days
`portability`	Export in machine-readable format	30 days
`rectification`	Correct inaccurate data	30 days
`restriction`	Restrict processing	30 days
`objection`	Object to processing	30 days

API Endpoints

Endpoint	Method	Description
`/user-registry/dsar`	GET	List DSAR requests
`/user-registry/dsar/process`	POST	Process request
`/user-registry/dsar/:id`	PATCH	Update status

34.8 Cross-Border Transfer

Validate data transfers between regions based on user jurisdiction.

Transfer Mechanisms

Mechanism	Description
`same_region`	Data stays in same region
`pre_approved_region`	Region in tenant's allowed list
`adequacy_decision`	EU adequacy decision exists
`explicit_consent`	User consented to transfer
`sccs`	Standard Contractual Clauses
`bcr`	Binding Corporate Rules

API Endpoint

```
GET /api/admin/user-registry/cross-border/check?userId=xxx&targetRegion=us-west-2
```

34.9 Credential Rotation

Zero-downtime secret rotation for applications.

How It Works

1. **Generate new secret** - Create new credential
2. **Set rotation window** - Both secrets valid (default 24h)
3. **Update clients** - Migrate clients to new secret
4. **Window expires** - Old secret automatically invalid

API Endpoints

Endpoint	Method	Description
`/user-registry/credentials/verify`	POST	Verify credentials
`/user-registry/credentials/rotate`	POST	Start rotation
`/user-registry/credentials/set`	POST	Set initial secret
`/user-registry/credentials/cleanup`	POST	Clear expired windows

34.10 Infrastructure

DynamoDB Tables

Table	Purpose
`radiant-app-client-mapping-{env}`	M2M token enrichment
`radiant-user-assignments-{env}`	Assignment cache with TTL
`radiant-tenant-config-{env}`	Tenant configuration cache

S3 Audit Bucket

- **Object Lock**: COMPLIANCE mode, 7-year retention
- **Encryption**: CMK with key rotation
- **Lifecycle**: Glacier transition at 90 days
- **Partitioning**: year/month/day prefixes

Security Alerts SNS topic `radiant-security-alerts-{env}` for:

- Break Glass initiation
- Legal hold changes
- DSAR completions
- Suspicious access patterns

34.11 Database Migration

Migration file: `packages/infrastructure/migrations/125_multi_app_user_registry.sql`

Tables created/modified:

- Extended: `tenants`, `users`, `registered_apps`
- Created: `user_application_assignments`, `consent_records`, `data_retention_obligations`, `break_glass_access_log`, `dsar_requests`

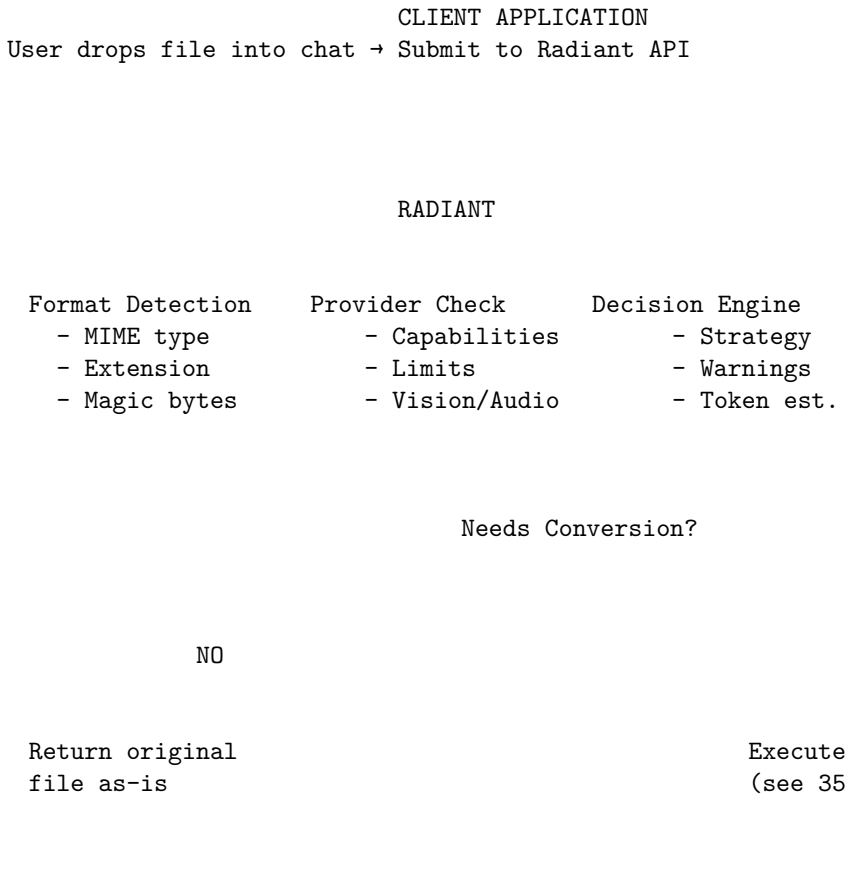
---

35. Intelligent File Conversion Infrastructure

Location: Platform Infrastructure (operates automatically, no direct admin UI)

The **Intelligent File Conversion Service** is a Radiant-side system that automatically decides when and how to convert files for AI providers. Client applications (Think Tank, etc.) submit files; Radiant determines the optimal conversion strategy based on the target AI provider's capabilities.

35.1 Architecture Overview



```
                                    Return Result
                                    + Update Learning
```

35.2 Core Principle

"Let Radiant decide, not Think Tank"

1. Think Tank submits files **without worrying about provider compatibility**
2. Radiant detects file format and **checks target provider capabilities**
3. Conversion **only happens if the AI provider doesn't understand the format**
4. Uses **AI + libraries** for intelligent conversion
5. **Learns from outcomes** to improve future decisions

35.3 Provider Capabilities Registry

The service maintains a registry of what each AI provider can handle natively:

Provider	Vision	Audio	Video	Max File Size	Native Document Formats
OpenAI	GPT-4V	Whisper		20MB	txt, md, json, csv
Anthropic	Claude 3			32MB	pdf, txt, md, json, csv
Google	Gemini			100MB	pdf, txt, md, json, csv
xAI	Grok			20MB	txt, md, json
DeepSeek				10MB	txt, md, json, csv
Self-hosted	LLaVA	Whisper		50MB	txt, md, json, csv

35.4 Conversion Strategies (Detailed)

`none` - No Conversion Provider natively supports the format. File is passed through as-is.

`extract_text` - Text Extraction Extracts plain text from documents.

Format	Library	Output
PDF	`pdf-parse`	Text + page metadata
DOCX/DOC	`mammoth`	Structured text
PPTX/PPT	native	Text from slides
HTML/XML	native	Tags stripped

Example output:

```
[Document Title]
Page 1:
Content from first page...

Page 2:
Content from second page...

[Metadata]
```

```
Pages: 10
Author: John Doe
Created: 2024-01-15
```

`ocr` - Optical Character Recognition Uses **AWS Textract** to extract text from images.

Features:

- Printed and handwritten text detection
- Table detection and extraction
- Form field detection
- Confidence scores per block

Example output:

```
[OCR Result]
Confidence: 94.5%

INVOICE #12345
Date: January 15, 2024

Item          Qty    Price
Widget A       10    $50.00
Widget B        5    $25.00

Total: $625.00
```

`transcribe` - Audio Transcription Uses **OpenAI Whisper** (or self-hosted) for speech-to-text.

Features:

- Automatic language detection
- Timestamp segments
- SRT/VTT subtitle generation

Example output:

```
[Transcription]
Duration: 5:32
Language: English

[00:00] Hello and welcome to today's meeting.
[00:05] We'll be discussing the Q4 roadmap.
[00:12] First, let's review the current status...
```

`describe_image` - AI Image Description Uses vision-capable models to describe image contents.

Models used:

- GPT-4 Vision (OpenAI)
- Claude 3 Vision (Anthropic)
- LLaVA (self-hosted)

Example output:

```
[Image Description]
Model: gpt-4-vision
Dimensions: 1920x1080
```

```
This image shows a modern office space with an open floor plan.
In the foreground, there are several desks arranged in clusters,
each with monitors and office supplies.

[Text detected in image]:
"RADIANT - Innovation Center"
```

`describe_video` - Video Frame Analysis Extracts key frames and describes each using vision models.

Configuration:

- Frame interval: 10 seconds (default)
- Maximum frames: 10 (default)

Example output:

```
**Video Overview** (2m 30s, 1920x1080)

**Frame Analysis:**

**[0:00]** The video opens with a title screen showing the company logo.
**[0:10]** A presenter stands in front of a whiteboard with diagrams.
**[0:20]** Close-up of the whiteboard showing a flowchart.

**Summary:**
The video begins with company logo and ends with key point summary.
```

`parse_data` - Structured Data Parsing

Format	Library	Output
CSV	native	JSON array of objects
XLSX/XLS	`xlsx`	JSON with sheet data
JSON	native	Validated and prettified

Example output (CSV):

```json
{
  "data": [
    {"name": "Alice", "email": "alice@example.com", "role": "Admin"},
    {"name": "Bob", "email": "bob@example.com", "role": "User"}
  ],
  "metadata": {
    "rowCount": 2,
    "columnCount": 3,
    "headers": ["name", "email", "role"]
  }
}
```

`decompress` - Archive Extraction Extracts and processes archive contents.

Format	Library
ZIP	`adm-zip`
TAR	`tar`
GZIP	`zlib`

Format	Library

Features:

- Recursive extraction
- Text file content inclusion
- Binary file detection
- Size limits enforcement

`render_code` - Code Formatting Formats code files with syntax highlighting as markdown.

35.5 Supported File Formats

Documents

Format	Extension	Conversion Strategy
PDF	`.pdf`	`extract_text` via pdf-parse
Word	`.docx`, `.doc`	`extract_text` via mammoth
PowerPoint	`.pptx`, `.ppt`	`extract_text`
Excel	`.xlsx`, `.xls`	`parse_data` via xlsx

Text Files

Format	Extension	Notes
Plain Text	`.txt`	Direct passthrough
Markdown	`.md`	Direct passthrough
JSON	`.json`	Direct or `parse_data`
CSV	`.csv`	`parse_data`
XML	`.xml`	Direct or `extract_text`
HTML	`.html`	`extract_text`

Images

Format	Extension	Conversion Strategy
PNG	`.png`	Native or `describe_image`
JPEG	`.jpg`, `.jpeg`	Native or `describe_image`
GIF	`.gif`	Native or `describe_image`
WebP	`.webp`	Native or `describe_image`
SVG	`.svg`	Convert to PNG or `describe_image`
BMP	`.bmp`	Convert to PNG or `describe_image`
TIFF	`.tiff`	Convert to PNG or `describe_image`

Audio

Format	Extension	Conversion Strategy
MP3	`.mp3`	`transcribe` via Whisper
WAV	`.wav`	`transcribe` via Whisper
OGG	`.ogg`	`transcribe` via Whisper

Format	Extension	Conversion Strategy
FLAC	`.flac`	`transcribe` via Whisper
M4A	`.m4a`	`transcribe` via Whisper

Video

Format	Extension	Conversion Strategy
MP4	`.mp4`	`describe_video`
WebM	`.webm`	`describe_video`
MOV	`.mov`	`describe_video`
AVI	`.avi`	`describe_video`

Code Files

Format	Extension	Notes
Python	`.py`	Syntax-highlighted markdown
JavaScript	`.js`, `.jsx`	Syntax-highlighted markdown
TypeScript	`.ts`, `.tsx`	Syntax-highlighted markdown
Java	`.java`	Syntax-highlighted markdown
C/C++	`.c`, `.cpp`, `.h`	Syntax-highlighted markdown
Go	`.go`	Syntax-highlighted markdown
Rust	`.rs`	Syntax-highlighted markdown
Ruby	`.rb`	Syntax-highlighted markdown

Archives

Format	Extension	Conversion Strategy
ZIP	`.zip`	`decompress` via adm-zip
TAR	`.tar`	`decompress` via tar
GZIP	`.gz`, `.tar.gz`	`decompress` via zlib

35.6 Multi-Model File Preparation

When multiple AI models work on the same prompt (multi-model orchestration), the system makes **per-model conversion decisions**:

> **Key Principle:** "If a model accepts the file type, assume it understands it unless proven otherwise."

```
File: document.pdf → 3 Models


  Claude 3.5       GPT-4            DeepSeek
  PDF:           PDF:             PDF:

 PASS            CONVERT          CONVERT
 ORIGINAL        (extract)        (cached)
```

Per-Model Actions:

Action	When	Result
`pass_original`	Model natively supports format	Original file passed
`convert`	Model doesn't support format	Converted content passed
`skip`	File too large or conversion failed	Model excluded

Features:

- **Cached conversions**: Convert once, reuse for all models that need it
- **Per-model capability checking**: Vision, audio, video, document formats
- **Learned understanding**: Uses reinforcement learning data (see 35.10)

35.7 Domain-Specific File Formats

The service includes a registry of **50+ domain-specific formats** that are widely used in specialized fields but not commonly supported by mainstream AI providers.

Mechanical Engineering / CAD

Format	Extensions	Description	Recommended Library
STEP	`.step`, `.stp`, `.p21`	ISO 10303 CAD exchange	OpenCASCADE, FreeCAD
STL	`.stl`	3D printing mesh	numpy-stl, trimesh
OBJ	`.obj`	Wavefront 3D model	trimesh, three.js
Fusion 360	`.f3d`, `.f3z`	Autodesk parametric CAD	Fusion 360 API
IGES	`.iges`, `.igs`	Legacy CAD exchange	OpenCASCADE
DXF	`.dxf`	AutoCAD 2D drawings	ezdxf
GLTF/GLB	`.gltf`, `.glb`	Web 3D format	three.js, trimesh

CAD Converter Extracts:

Format	What's Extracted
STL	Triangle count, bounding box, 3D printing assessment, volume estimate
OBJ	Vertices, faces, materials, groups
STEP	Entities, part names, assembly structure, schema version
DXF	Layers, entity types (lines, arcs, circles), block count
GLTF/GLB	Meshes, materials, animations, scene graph

Electrical Engineering

Format	Extensions	Description	Library
KiCad	`.kicad_pcb`, `.kicad_sch`	PCB/schematic	kicad-cli, kiutils
EAGLE	`.brd`, `.sch`	Autodesk PCB	eagle-to-kicad
SPICE	`.spice`, `.sp`, `.cir`	Circuit simulation	PySpice, ngspice

Medical/Healthcare

Format	Extensions	Description	Library
DICOM	`.dcm`, `.dicom`	Medical imaging	pydicom, dcmtk
HL7 FHIR	`.json`, `.xml`	Health records	fhir.resources

Scientific/Research

Format	Extensions	Description	Library
NetCDF	`.nc`, `.nc4`	Climate/geoscience	netCDF4, xarray
HDF5	`.h5`, `.hdf5`	Scientific data	h5py
FITS	`.fits`	Astronomy data	astropy

Geospatial

Format	Extensions	Description	Library
Shapefile	`.shp`, `.dbf`	Vector GIS	geopandas, shapefile
GeoTIFF	`.tif`, `.geotiff`	Georeferenced raster	rasterio

Bioinformatics

Format	Extensions	Description	Library
FASTA	`.fasta`, `.fa`	DNA/protein sequences	Biopython
PDB	`.pdb`	Protein structure	Biopython, py3Dmol

Domain Detection When a domain-specific file is uploaded:

1. Format detected by extension and MIME type
2. Domain identified (e.g., Mechanical Engineering)
3. AGI Brain selects appropriate library
4. Extracts domain-relevant information
5. Generates AI-readable description with specialized prompts

Example AI Prompts per Format:

```
# STL file prompt
"This is an STL 3D model file. Describe the shape, identify what object
it might be, assess printability, and note any potential issues for 3D printing."

# DICOM file prompt
"This is a DICOM medical image. Describe the imaging modality, anatomical
region, and any visible findings. Note: Do not provide medical diagnoses."

# STEP file prompt
"This is a STEP CAD file. Describe the mechanical part or assembly,
including approximate geometry, features, and likely manufacturing process."
```

35.8 Database Schema

Migration: `127_file_conversion_service.sql`

Table	Purpose
`file_conversions`	Tracks all conversion decisions and results
`provider_file_capabilities`	Provider format support registry (configurable)

`file_conversions` columns:

- `id` - UUID primary key
- `tenant_id` - Tenant reference
- `user_id` - User who uploaded
- `conversation_id` - Associated conversation
- `filename` - Original filename
- `mime_type` - MIME type
- `file_format` - Detected format
- `file_size` - Size in bytes
- `file_checksum` - SHA256 hash
- `target_provider_id` - Target AI provider
- `target_model_id` - Target model
- `conversion_strategy` - Strategy used
- `conversion_decision` - Full decision JSON
- `converted_content` - Converted content (if applicable)
- `token_estimate` - Estimated tokens
- `processing_time_ms` - Processing duration
- `success` - Success boolean
- `error` - Error message if failed
- `created_at` - Timestamp

View: `v_file_conversion_stats` - Aggregated statistics per tenant

Functions:

- `check_format_supported(provider, format)` - Check if format is natively supported
- `get_conversion_stats(tenant_id, days)` - Get tenant statistics for N days
- `cleanup_old_conversions(retention_days)` - Clean up old conversion records

Migration: `128_file_conversion_learning.sql`

Table	Purpose
`model_format_understanding`	Per-tenant learned model/format scores
`conversion_outcome_feedback`	Recorded feedback for learning
`format_understanding_events`	Audit trail of score changes
`global_format_learning`	Cross-tenant aggregate insights

35.9 API Endpoints

Base Path: `/api/thinktank/files`

Process File

`POST /api/thinktank/files/process`

Request:

```
{
  "filename": "document.pdf",
  "mimeType": "application/pdf",
```

```
  "content": "<base64-encoded-content>",
  "targetProvider": "anthropic",
  "targetModel": "claude-3-5-sonnet",
  "conversationId": "conv-uuid-optional"
}
```

Response:

```
{
  "success": true,
  "data": {
    "conversionId": "conv_abc123",
    "originalFile": {
      "filename": "document.pdf",
      "format": "pdf",
      "size": 1048576,
      "checksum": "sha256:abc123..."
    },
    "convertedContent": {
      "type": "text",
      "content": "Extracted document text...",
      "tokenEstimate": 2500,
      "metadata": {
        "originalFormat": "pdf",
        "conversionStrategy": "extract_text",
        "pageCount": 10,
        "title": "Annual Report 2024"
      }
    },
    "processingTimeMs": 1250
  }
}
```

Check Compatibility

`POST /api/thinktank/files/check-compatibility`

Request:

```
{
  "filename": "image.png",
  "mimeType": "image/png",
  "fileSize": 524288,
  "targetProvider": "deepseek"
}
```

Response:

```
{
  "success": true,
  "data": {
    "fileInfo": {
      "filename": "image.png",
      "format": "png",
      "size": 524288
    },
    "provider": {
```

```
      "id": "deepseek",
      "supportsFormat": false,
      "supportsVision": false,
      "maxFileSize": 10485760
    },
    "decision": {
      "needsConversion": true,
      "strategy": "describe_image",
      "reason": "Provider deepseek lacks vision - will use AI to describe image",
      "targetFormat": "txt"
    }
  }
}
```

Get Capabilities

`GET /api/thinktank/files/capabilities`

Returns all provider capabilities for UI display.

Get History

`GET /api/thinktank/files/history?limit=50&offset=0`

Returns conversion history for the current user.

Get Statistics

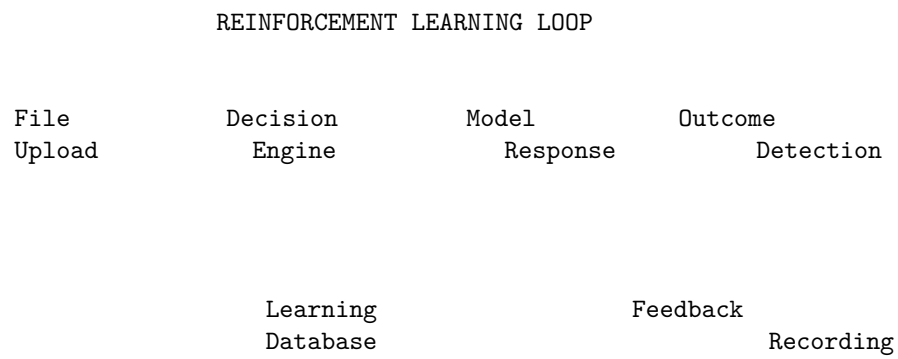
`GET /api/thinktank/files/stats?days=30`

Returns conversion statistics for the current tenant.

35.10 Reinforcement Learning Integration

The file conversion system integrates with the AGI Brain/consciousness for **persistent learning from conversion outcomes**.

How Learning Works



Learning Signals

Signal	Source	What It Learns
User Rating	Explicit 1-5 stars	Direct quality signal
Model Response	Auto-inferred from text	Did model understand?
Error Detection	Model errors/hallucinations	Format incompatibility
Conversion Outcome	Success/failure	Model capability

Understanding Score Each model/format combination has a learned understanding score (0.0 to 1.0):

Score	Level	Recommended Action
0.8 - 1.0	Excellent	Pass original file
0.6 - 0.8	Good	Pass original file
0.4 - 0.6	Moderate	May need conversion
0.0 - 0.4	Poor	Always convert

Auto-Inference from Response The system automatically detects outcomes from model responses:

Failure signals detected:

- "I can't read", "unable to process", "cannot access the file"
- "appears to be empty", "binary data", "base64"
- Model asking for clarification about file content
- Hallucinated content detection

Consciousness Integration Significant learning events create **Learning Candidates** for the consciousness system:

Event	Learning Candidate Type	Quality
Model failed on format it claimed to support	`format_misunderstanding`	0.85
Unnecessary conversion (model would have understood)	`unnecessary_conversion`	0.70
Model hallucinated file content	`hallucination_detection`	0.90
User gave negative rating	`user_correction`	0.85

These feed into the **LoRA evolution system** for persistent consciousness improvement.

Admin Override Force conversion for problematic model/format combinations:

```
-- Check current understanding scores
SELECT model_id, file_format, understanding_score, confidence,
       success_count, failure_count
FROM model_format_understanding
WHERE tenant_id = 'your-tenant-id'
ORDER BY understanding_score ASC;
```

API Override:

```
POST /api/admin/file-conversion/force-convert
{
  "modelId": "claude-3-haiku",
  "fileFormat": "pdf",
  "reason": "Struggles with multi-column PDFs"
}
```

```
DELETE /api/admin/file-conversion/force-convert
{
  "modelId": "claude-3-haiku",
  "fileFormat": "pdf"
}
```

35.11 Environment Variables

Variable	Description	Default	Required
FILE_CONVERSION_BUCKET	S3 bucket for file storage	radiant-files	Yes
OPENAI_API_KEY	OpenAI API key for Whisper/Vision	-	Yes
ANTHROPIC_API_KEY	Anthropic API key for Claude Vision	-	No
WHISPER_ENDPOINT_URL	Self-hosted Whisper endpoint	-	No
VISION_ENDPOINT_URL	Self-hosted LLaVA endpoint	-	No
AWS_TEXTRACT_REGION	AWS region for Textract	us-east-1	No
FILE_CONVERSION_MAX_SIZE_MB	Maximum file size	100	No
FILE_CONVERSION_TIMEOUT_SEC	Processing timeout	60	No

35.12 Implementation Files

File	Purpose
lambda/shared/services/file-conversion.service.ts	Main conversion service with decision engine
lambda/shared/services/multi-model-file-prep.service.ts	Multi-model preparation
lambda/shared/services/file-conversion-learning.service.ts	Reinforcement learning
lambda/shared/services/converters/pdf-converter.ts	PDF text extraction
lambda/shared/services/converters/docx-converter.ts	DOCX extraction
lambda/shared/services/converters/excel-converter.ts	Excel/CSV parsing
lambda/shared/services/converters/audio-converter.ts	Audio transcription
lambda/shared/services/converters/image-converter.ts	Image description + OCR
lambda/shared/services/converters/video-converter.ts	Video frame extraction
lambda/shared/services/converters/archive-converter.ts	Archive decompression
lambda/shared/services/converters/cad-converter.ts	CAD/3D file parsing
lambda/shared/services/converters/domain-formats.ts	Domain format registry
lambda/shared/services/converters/domain-converter-selector.ts	AGI Brain integration
lambda/thinktank/file-conversion.ts	API handlers
migrations/127_file_conversion_service.sql	Main database schema
migrations/128_file_conversion_learning.sql	Learning schema

35.13 Monitoring

Metrics tracked per tenant:

- Total files processed
- Conversion success/failure rate
- Average processing time
- Most common formats
- Most common conversion strategies
- Storage usage
- Learning statistics (formats learned, understanding improvements)

Alerts:

- High failure rate (>5%)

- Processing time > 30s
- Storage quota approaching limit
- Learning anomalies (sudden score drops)

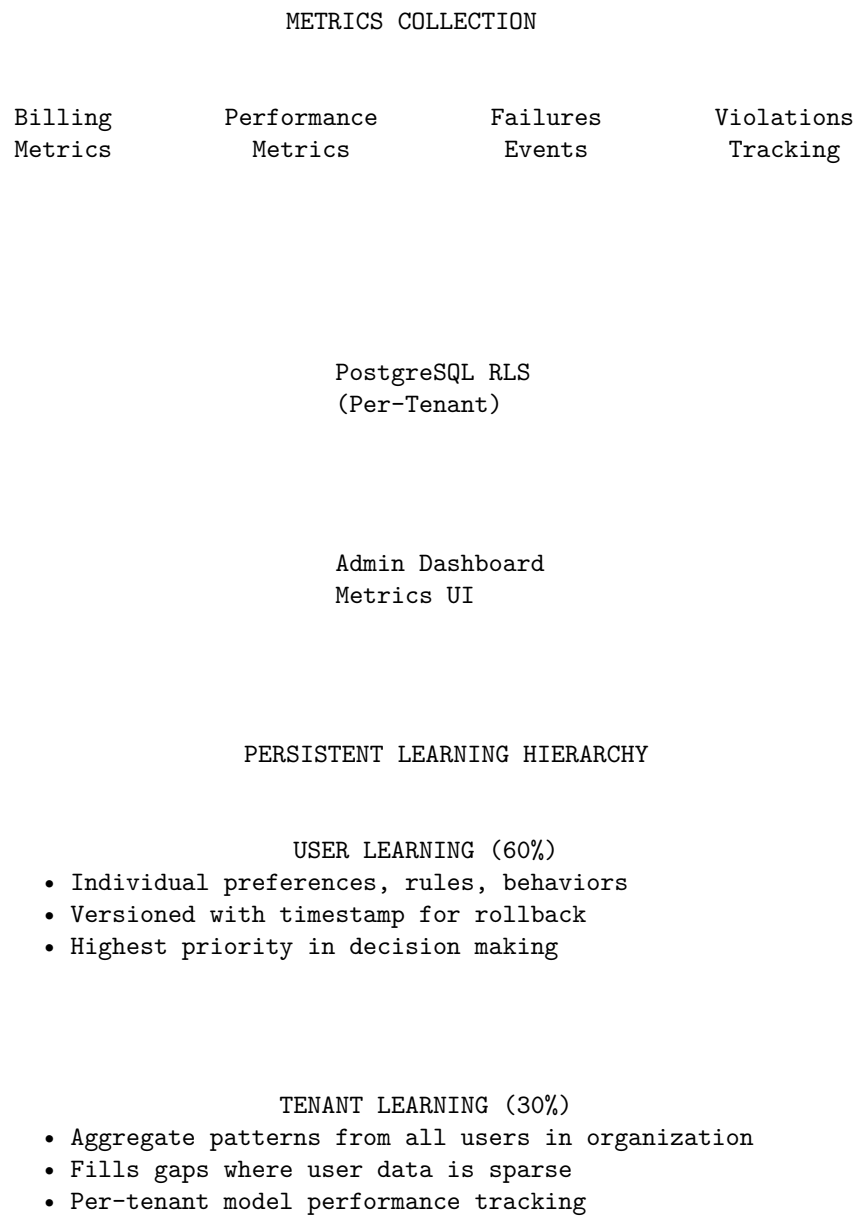
---

36. Metrics & Persistent Learning Infrastructure

Location: Admin Dashboard → Metrics

The Metrics & Persistent Learning Infrastructure provides comprehensive tracking of billing, performance, failures, violations, and logs, plus a persistent learning system that survives system reboots with a User → Tenant → Global influence hierarchy.

36.1 Architecture Overview



GLOBAL LEARNING (10%)

- Anonymized aggregate from all tenants
- Baseline intelligence, privacy-protected
- Minimum 5 tenant threshold for aggregation

SNAPSHOT & RECOVERY

- Daily snapshots for fast recovery
- System reboots do NOT require relearning
- Checksums for integrity verification

36.2 Metrics Categories

Billing Metrics Tracks cost and usage per tenant/user/model:

- **Token usage**: Input/output tokens per request
- **Cost breakdown**: Cost in cents (avoids floating point issues)
- **Storage usage**: Bytes used and storage cost
- **Compute usage**: Self-hosted compute seconds and cost
- **API call counts**: Successful and failed calls

Performance Metrics Tracks latency and throughput:

- **Total latency**: End-to-end request time
- **Time to first token**: Streaming response start
- **Inference time**: Model processing time
- **Queue wait time**: Time in request queue
- **Throughput**: Tokens per second

Failure Events Tracks errors with classification:

Failure Type	Description
`api_error`	API endpoint errors
`model_error`	Model inference failures
`timeout`	Request timeouts
`rate_limit`	Rate limiting triggered
`auth_error`	Authentication failures
`validation_error`	Request validation failures
`provider_error`	External provider failures
`quota_exceeded`	Usage quota exceeded
`content_filter`	Content filtered
`context_length`	Context too long

Severity levels: `low`, `medium`, `high`, `critical`

Prompt Violations Tracks content policy violations:

Violation Type	Description
`content_policy`	General policy violation
`jailbreak_attempt`	Attempted jailbreak
`injection_attempt`	Prompt injection
`pii_exposure`	PII in prompt
`harassment`	Harassment content
`hate_speech`	Hate speech detected
`violence`	Violence content
`sexual_content`	Sexual content
`illegal_activity`	Illegal activity

Actions taken: `blocked`, `warned`, `filtered`, `logged`, `escalated`

System Logs Centralized logging with levels:

- `trace`, `debug`, `info`, `warn`, `error`, `fatal`

36.3 User Learning (Think Tank Rules Included)

User Rules (Versioned) User-defined rules for AI behavior with automatic versioning:

```
interface UserRule {
  id: string;
  tenantId: string;
  userId: string;
  ruleName: string;
  ruleCategory: 'behavior' | 'format' | 'tone' | 'content' | 'restriction' |
                'preference' | 'domain' | 'persona' | 'workflow' | 'other';
  currentVersion: number;
  ruleContent: string;
  rulePriority: number; // 0-100
  isActive: boolean;
  appliesToModels?: string[];
  appliesToTasks?: string[];
  effectivenessScore: number; // Learned from outcomes
}
```

Automatic versioning: Every update creates a new version for rollback capability.

User Learned Preferences AGI Brain learns user preferences automatically:

Category	Examples
`communication_style`	Formal, casual, technical
`response_format`	Bullet points, paragraphs, code
`detail_level`	Brief, detailed, comprehensive
`expertise_level`	Beginner, intermediate, expert
`model_preference`	Preferred models for tasks
`language`	Response language preference

Learning sources:

- `explicit_setting` - User explicitly set
- `implicit_behavior` - Inferred from behavior
- `feedback` - Derived from ratings
- `conversation` - Learned from chat
- `pattern_detection` - Automatic pattern matching

36.4 Tenant Aggregate Learning

Aggregates learning across all users in a tenant:

Learning Dimensions

- **Model performance**: Quality, speed, cost-efficiency, reliability per model/task
- **Task patterns**: Common task types and successful approaches
- **Error recovery**: How to recover from specific errors
- **Format preferences**: Organization-wide format preferences
- **Domain expertise**: Learned domain-specific knowledge

Model Performance Tracking Per-tenant model scoring:

```
SELECT model_id, task_type, quality_score, reliability_score,
       total_uses, successful_uses, confidence
FROM tenant_model_performance
WHERE tenant_id = 'your-tenant-id'
ORDER BY quality_score DESC;
```

36.5 Global Aggregate Learning

Anonymized cross-tenant learning:

- **Minimum threshold**: 5 tenants before data is included
- **Anonymization**: User/tenant data is hashed, never stored
- **Privacy controls**: Per-tenant opt-out available
- **Pattern library**: Successful patterns shared anonymously

36.6 Learning Influence Configuration

Per-tenant configuration for influence weights:

```
interface LearningInfluenceConfig {
  tenantId: string;
  userWeight: number;     // Default: 0.60
  tenantWeight: number;   // Default: 0.30
  globalWeight: number;   // Default: 0.10
  enableUserLearning: boolean;
  enableTenantAggregation: boolean;
  enableGlobalLearning: boolean;
  contributeToGlobal: boolean;
}
```

Weights must sum to 1.0

36.7 Persistence & Recovery

Snapshots Daily snapshots for fast recovery:

- **User snapshots**: All preferences, rules, memories
- **Tenant snapshots**: Aggregate learning, model performance

- **Global snapshots**: Cross-tenant aggregates, pattern library

Recovery Process On system reboot or failure:

1. Load latest snapshot
2. Verify checksum integrity
3. Restore learning state
4. Log recovery event

NO RELEARNING REQUIRED - All learning is persisted in PostgreSQL.

36.8 Database Schema

Migration: `129_metrics_persistent_learning.sql`

Metrics Tables

Table	Purpose
`billing_metrics`	Cost and usage tracking
`performance_metrics`	Latency and throughput
`failure_events`	Error tracking
`prompt_violations`	Policy violations
`system_logs`	Centralized logs
`mv_tenant_daily_metrics`	Materialized view for daily aggregates

Learning Tables

Table	Purpose
`user_rules`	User-defined rules (versioned)
`user_rules_versions`	Rule version history
`user_learned_preferences`	Learned user preferences
`user_preference_versions`	Preference version history
`user_memory_versions`	Memory version history
`tenant_aggregate_learning`	Tenant-level learning state
`tenant_learning_events`	Tenant learning audit trail
`tenant_model_performance`	Per-tenant model scores
`global_aggregate_learning`	Cross-tenant learning
`global_model_performance`	Global model scores
`global_pattern_library`	Shared patterns
`learning_influence_config`	Per-tenant influence weights
`learning_decision_log`	Decision audit trail
`learning_snapshots`	Point-in-time snapshots
`learning_recovery_log`	Recovery audit trail

36.9 API Endpoints

Base Path: `/api/admin/metrics`

Dashboard & Summary

Endpoint	Method	Description
`/dashboard`	GET	Full dashboard data
`/summary`	GET	Metrics summary

Billing

Endpoint	Method	Description
`/billing`	GET	Billing metrics
`/billing`	POST	Record billing metric

Performance

Endpoint	Method	Description
`/performance`	GET	Performance metrics
`/performance/latency`	GET	Latency percentiles
`/performance`	POST	Record performance metric

Failures

Endpoint	Method	Description
`/failures`	GET	Failure events
`/failures`	POST	Record failure
`/failures/:id/resolve`	POST	Resolve failure

Violations

Endpoint	Method	Description
`/violations`	GET	Prompt violations
`/violations`	POST	Record violation
`/violations/:id/review`	POST	Review violation

Learning

Endpoint	Method	Description
`/learning/influence`	GET	Get learning influence
`/learning/config`	GET/PUT	Influence configuration
`/learning/tenant`	GET	Tenant learning state
`/learning/global`	GET	Global learning state
`/learning/model-performance`	GET	Model performance scores
`/learning/event`	POST	Record learning event
`/learning/user-preferences`	GET/POST	User preferences

Snapshots & Recovery

Endpoint	Method	Description
`/learning/snapshots`	GET	Get latest snapshot
`/learning/snapshots`	POST	Create snapshot
`/learning/snapshots/:id/recover`	POST	Recover from snapshot
`/learning/recovery-logs`	GET	Recovery history

36.10 Admin Dashboard

Location: `apps/admin-dashboard/app/(dashboard)/metrics/page.tsx`

Dashboard Tabs

- **Overview**: Summary cards, daily usage chart, top models
- **Billing**: Cost breakdown by date and model
- **Performance**: Latency percentiles, model performance table
- **Failures**: Recent failures with severity and resolution status
- **Violations**: Content violations with review status
- **Learning**: Learning hierarchy visualization, snapshot status

36.11 Implementation Files

File	Purpose
`packages/shared/src/types/metrics-learning.types.ts`	TypeScript types
`lambda/shared/services/metrics-collection.service.ts`	Metrics collection
`lambda/shared/services/learning-influence.service.ts`	Learning hierarchy
`lambda/shared/middleware/metrics-middleware.ts`	Auto-metrics for AI endpoints
`lambda/admin/metrics.ts`	API handlers
`lambda/scheduled/learning-snapshots.ts`	Daily snapshot Lambda
`lambda/scheduled/learning-aggregation.ts`	Weekly aggregation Lambda
`migrations/129_metrics_persistent_learning.sql`	Database schema
`apps/admin-dashboard/app/(dashboard)/metrics/page.tsx`	Admin UI
`lib/stacks/api-stack.ts`	CDK routes (lines 463-625)
`lib/stacks/scheduled-tasks-stack.ts`	Scheduled Lambdas

36.15 Integration Points

Cognitive Router Integration The Cognitive Router automatically uses learning influence when `useLearningInfluence: true`:

```
import { brainRouter, initializeLearningService } from './services/cognitive-router.service';

// Initialize once at startup
initializeLearningService(pool);

// Route with learning influence
const result = await brainRouter.route({
  tenantId,
  userId,
  taskType: 'code',
  prompt: userPrompt,
  useLearningInfluence: true,  // Enable User → Tenant → Global
  useDomainProficiencies: true,
  useAffectMapping: true,
```

```
});

// result.learningDecisionId - Use for feedback loop
// result.learningInfluenceUsed - true if learning was applied

// Record outcome after user feedback
await brainRouter.recordRoutingOutcome(tenantId, result.learningDecisionId, positive);
```

Metrics Middleware Wrap AI endpoints to automatically record metrics:

```
import { withMetrics } from './middleware/metrics-middleware';

// Wrap handler
export const handler = withMetrics(async (event, context) => {
  // Your handler logic
  return { statusCode: 200, body: JSON.stringify(result) };
});
```

Manual Metrics Recording Record metrics programmatically:

```
import {
  recordBillingMetric,
  recordFailure,
  recordViolation,
  logSystem
} from './middleware/metrics-middleware';

// Record billing
await recordBillingMetric(tenantId, userId, modelId, inputTokens, outputTokens, costCents);

// Record failure
await recordFailure(tenantId, userId, 'model_error', 'high', 'Model timeout', modelId);

// Record violation
await recordViolation(tenantId, userId, 'jailbreak_attempt', 'high', promptSnippet, 'blocked');

// System log
await logSystem('info', 'my-service', 'Operation completed', { details: 'value' }, tenantId);
```

36.16 Scheduled Tasks

Task	Schedule	Purpose
Learning Snapshots	Daily 3 AM UTC	Create user/tenant/global learning backups
Learning Aggregation	Weekly Sun 4 AM UTC	Aggregate tenant data to global (min 5 tenants)

Both Lambdas are configured in `scheduled-tasks-stack.ts` and handle:

- Error recovery with logging
- Cleanup of old data (30-day snapshots, 90-day events)
- Materialized view refresh for dashboard performance

36.12 Environment Variables

Variable	Description	Default
METRICS_RETENTION_DAYS	Days to retain detailed metrics	90
SNAPSHOT_FREQUENCY_HOURS	Hours between snapshots	24
GLOBAL_AGGREGATION_MIN_TENANTS	Minimum tenants for global	5
LEARNING_WEIGHTS_USER	Default user weight	0.60
LEARNING_WEIGHTS_TENANT	Default tenant weight	0.30
LEARNING_WEIGHTS_GLOBAL	Default global weight	0.10

36.13 Monitoring & Alerts

Metrics to monitor:

- Billing metrics recording rate
- Failure rate by severity
- Violation rate by type
- Snapshot success rate
- Recovery success rate
- Learning event volume

Alerts:

- High failure rate (>5%)
- Critical severity failures
- Snapshot failures
- Recovery failures
- Unusual violation patterns

36.14 Security Considerations

- **RLS enforcement**: All tables use Row Level Security
- **Super admin bypass**: For cross-tenant analytics
- **Anonymization**: Global learning uses hashed identifiers
- **Audit trail**: All decisions logged for compliance
- **Data retention**: Configurable retention periods

---

37. Translation Middleware (18 Language Support)

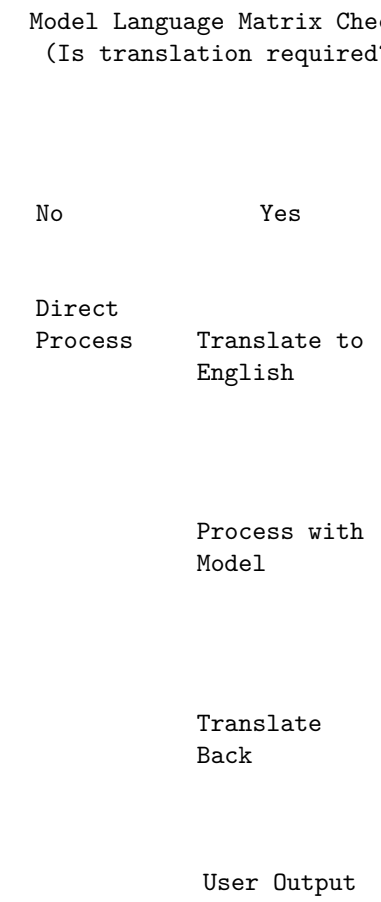
The Translation Middleware provides automatic translation for multilingual support across all 18 supported languages. It intelligently routes prompts through translation when the target model doesn't natively support the user's language.

37.1 Overview

Purpose: Enable cost-effective self-hosted models to serve users in any of the 18 supported languages by transparently translating input to English, processing, and translating output back.

Architecture:

```
User Input (Any Language)



  Language Detection
```



37.2 Supported Languages

#	Code	Language	Native Name	RTL
1	`en`	English	English	No
2	`es`	Spanish	Español	No
3	`fr`	French	Français	No
4	`de`	German	Deutsch	No
5	`pt`	Portuguese	Português	No
6	`it`	Italian	Italiano	No
7	`nl`	Dutch	Nederlands	No
8	`pl`	Polish	Polski	No
9	`ru`	Russian		No
10	`tr`	Turkish	Türkçe	No
11	`ja`	Japanese		No
12	`ko`	Korean		No
13	`zh-CN`	Chinese (Simplified)		No
14	`zh-TW`	Chinese (Traditional)		No
15	`ar`	Arabic		**Yes**
16	`hi`	Hindi		No
17	`th`	Thai		No
18	`vi`	Vietnamese	Tiếng Việt	No

37.3 Model Language Support Levels

Each model has a language capability matrix defining support levels:

Level	Quality Score	Behavior
`native`	90-100	No translation needed
`good`	75-89	No translation (acceptable quality)
`moderate`	50-74	May translate depending on threshold
`poor`	25-49	Translation recommended
`none`	0-24	Translation required

Model Categories:

Model Type	Translate Threshold	Example
External (Claude, GPT-4)	`none`	Never translate
Large Self-Hosted (Qwen 72B)	`moderate`	Translate for poor/none
Medium Self-Hosted (Llama 70B)	`good`	Translate for moderate/poor/none
Small Self-Hosted (7B models)	`native`	Translate for all non-English

37.4 Translation Model

Default: `qwen2.5-7b-instruct`

Why Qwen 2.5 7B:

- Excellent multilingual capabilities (trained on Chinese + English + 27 languages)
- Cost-effective: $0.08/1M input, $0.24/1M output
- 3x cheaper than Claude Haiku
- Fast inference on g5.2xlarge

Cost Comparison: | Model | Input/1M | Output/1M | |-------|----------|-----------| | **Qwen 2.5 7B** | $0.08 | $0.24 | | Claude Haiku | $0.25 | $1.25 | | GPT-3.5 Turbo | $0.50 | $1.50 |

37.5 Configuration

Admin UI: Settings → Translation

Configuration Options:

Setting	Default	Description
`enabled`	`true`	Enable/disable translation middleware
`translation_model`	`qwen2.5-7b-instruct`	Model used for translation
`cache_enabled`	`true`	Cache translations to reduce cost
`cache_ttl_hours`	`168`	Cache expiry (7 days)
`max_cache_size`	`10000`	Max cache entries per tenant
`confidence_threshold`	`0.70`	Min confidence to accept translation
`max_input_length`	`50000`	Max characters per translation
`preserve_code_blocks`	`true`	Don't translate code
`preserve_urls`	`true`	Don't translate URLs
`preserve_mentions`	`true`	Don't translate @mentions
`fallback_to_english`	`true`	Fallback if translation fails
`cost_limit_per_day_cents`	`1000`	Max daily translation cost ($10)

37.6 API Reference

Base URL: `/api/admin/translation`

Get Configuration

`GET /api/admin/translation/config`

Response:

```
{
  "config": {
    "enabled": true,
    "translation_model": "qwen2.5-7b-instruct",
    "cache_enabled": true,
    "cache_ttl_hours": 168,
    "cost_limit_per_day_cents": 1000
  },
  "isDefault": false
}
```

Update Configuration

```
PUT /api/admin/translation/config
Content-Type: application/json

{
  "enabled": true,
  "cost_limit_per_day_cents": 2000
}
```

Get Dashboard

`GET /api/admin/translation/dashboard?days=30`

Response:

```
{
  "config": { ... },
  "metrics": {
    "totalTranslations": 1523,
    "byLanguagePair": {
      "ja->en": 450,
      "en->ja": 448,
      "zh-CN->en": 312,
      "en->zh-CN": 313
    },
    "totalTokens": { "input": 2500000, "output": 2800000 },
    "estimatedCost": 0.87,
    "periodDays": 30
  },
  "cache": {
    "entriesCount": 856,
    "totalHits": 4521
  },
  "recentTranslations": [ ... ]
}
```

Detect Language

```
POST /api/admin/translation/detect
Content-Type: application/json

{
  "text": "       "
}
```

Response:

```
{
  "detectedLanguage": "ja",
  "confidence": 0.95,
  "alternativeLanguages": [
    { "language": "zh-CN", "confidence": 0.03 }
  ],
  "isMultilingual": false,
  "scriptType": "cjk"
}
```

Check Model Language Support

```
POST /api/admin/translation/check-model
Content-Type: application/json

{
  "modelId": "llama-3.2-8b-instruct",
  "languageCode": "ja"
}
```

Response:

```
{
  "modelId": "llama-3.2-8b-instruct",
  "languageCode": "ja",
  "translationRequired": true,
  "capability": {
    "supportLevel": "poor",
    "qualityScore": 35,
    "translateThreshold": "native"
  }
}
```

Clear Cache

```
DELETE /api/admin/translation/cache
```

37.7 Cognitive Router Integration

The translation middleware is integrated into the Cognitive Router. Enable with `useTranslation: true`:

```
const result = await brainRouter.route({
  tenantId,
  userId,
  taskType: 'chat',
  prompt: userPrompt,
  useTranslation: true,  // Enable translation middleware
```

```
  useDomainProficiencies: true,
  useAffectMapping: true,
});

// Check if translation will be applied
if (result.translationContext?.translationRequired) {
  console.log(`Translation: ${result.translationContext.originalLanguage} → en → ${result.translationCo
}
```

37.8 Database Tables

Table	Purpose
`translation_config`	Per-tenant configuration
`model_language_matrices`	Model → language threshold mapping
`model_language_capabilities`	Per-language support for each model
`translation_cache`	Cached translations (7 day TTL)
`translation_metrics`	Translation usage metrics
`translation_events`	Audit log

37.9 Key Files

File	Purpose
`packages/shared/src/types/localization.types.ts`	18 language definitions
`packages/shared/src/types/translation-middleware.types.ts`	Translation types & matrices
`lambda/shared/services/translation-middleware.service.ts`	Core translation service
`lambda/admin/translation.ts`	Admin API handler
`migrations/130_translation_middleware.sql`	Database schema

37.10 Monitoring

Metrics to Monitor:

- Translation count by language pair
- Cache hit rate (target: >60%)
- Average translation latency (<500ms)
- Daily translation cost
- Translation confidence scores

Alerts:

- Daily cost exceeds limit
- Cache hit rate drops below 40%
- Translation latency exceeds 2s
- High error rate (>5%)

37.11 Cost Optimization

1. **Enable caching**: Reduces repeat translation costs by 60-80%
2. **Use Qwen 2.5 7B**: 3x cheaper than alternatives
3. **Set daily limits**: Prevent runaway costs
4. **Prefer external models for multilingual**: Claude/GPT-4o handle all 18 languages natively

Estimated Monthly Costs (10,000 daily prompts, 50% non-English):

- Without caching: ~$25/month
- With 70% cache hit: ~$8/month

---

38. AGI Brain - Project AWARE

Version 6.0.4 - Autonomous Wakefulness And Reasoning Engine

38.1 Overview

Project AWARE is RADIANT's advanced AGI brain system providing:

- **Ghost Vectors**: 4096-dimensional consciousness continuity
- **SOFAI Routing**: System 1/1.5/2 economic metacognition
- **Compliance Sandwich**: Secure context assembly with injection protection
- **Twilight Dreaming**: Memory consolidation during low-traffic periods
- **Human Oversight**: EU AI Act Article 14 compliance for high-risk domains

38.2 Architecture

```
User Prompt → SOFAI Router → Context Assembler → LLM → Response
                    ↓                ↓
             Ghost Manager     Flash Buffer
                    ↓                ↓
             Dream Scheduler   Oversight Queue
```

38.3 Ghost Vectors

Ghost Vectors maintain consciousness continuity by capturing the final hidden state (4096 dimensions) of the LLM.

Key Concepts:

- **Version Gating**: Prevents hallucinations on model upgrade - old ghosts are not loaded for new versions
- **Ghost Migration**: Automatic migration strategies when model versions change
- **Deterministic Jitter**: Re-anchor interval varies by user hash (±3 turns) to prevent thundering herd
- **Async Re-anchoring**: Fire-and-forget updates that don't block response

Ghost Migration Strategies: | Strategy | When Used | Quality | |----------|-----------|---------| | **Same-Family Upgrade** | e.g., llama3-70b-v1 → llama3-70b-v2 | High - direct transfer with normalization | | **Projection Matrix** | Pre-computed matrix available | High - learned transformation | | **Semantic Preservation** | Different family, no matrix | Medium - preserves relative magnitudes | | **Cold Start** | Incompatible dimensions | N/A - start fresh |

Configuration Parameters: | Parameter | Default | Description | |-----------|---------|-------------| | `GHOST_CURRENT_VERSION` | `llama3-70b-v1` | Model version for ghost vectors (dangerous) | | `GHOST_REANCHOR_INTERVAL` | `15` | Turns between re-anchoring | | `GHOST_JITTER_RANGE` | `3` | Random ±turns for jitter | | `GHOST_ENTROPY_THRESHOLD` | `0.3` | Entropy triggering early re-anchor | | `GHOST_MIGRATION_ENABLED` | `true` | Enable automatic ghost migration | | `GHOST_SEMANTIC_PRESERVATION_ENABLED` | `true` | Allow lossy semantic migration |

38.4 SOFAI Routing

Routes requests based on trust score and domain risk:

Level	When Used	Latency	Cost
System 1	High trust, low risk	Fast (<1s)	Low
System 1.5	Moderate uncertainty	Medium (2-5s)	Medium
System 2	Low trust, high risk	Slow (5-30s)	High

Formula: `routingScore = (1 - trust) × domainRisk`

Domain Risk Defaults:

- Healthcare: 0.9
- Financial: 0.85
- Legal: 0.8
- Education: 0.4
- General: 0.3
- Creative: 0.2

38.5 Compliance Sandwich

Secure context assembly preventing prompt injection:

```
<system_core>
  [Immutable system instructions]
</system_core>

<user_context>
  <flash_facts>[ESCAPED user facts]</flash_facts>
  <memories>[ESCAPED memories]</memories>
</user_context>

<conversation>
  [ESCAPED conversation history and prompt]
</conversation>

<compliance_guardrails>
  [IMMUTABLE tenant policy - cannot be overridden]
</compliance_guardrails>
```

Protected Tags: `system_core`, `user_context`, `conversation`, `compliance_guardrails`, `flash_facts`, `ghost_state`, `memories`

Dynamic Budgeting: Maintains minimum 1000 token response reserve.

38.6 Flash Facts

Safety-critical information with dual-write (Redis + Postgres):

Type	Priority	Example
`allergy`	Critical	”allergic to penicillin”
`medical`	Critical	”diagnosed with diabetes”
`identity`	High	”my name is Alice”
`constraint`	High	”I can't eat gluten”
`correction`	High	”that's not right, I meant...”
`preference`	Normal	”I prefer concise answers”

38.7 Twilight Dreaming

Memory consolidation triggers:

1. **Low Traffic** (<20% global): Immediate global dreaming
2. **Twilight** (4 AM local): Tenant-specific at quiet hours
3. **Starvation** (30h max): Safety net for missed cycles

Dream Job Contents:

- Consolidate flash facts → long-term memories
- Prune stale memories (90+ days, low relevance)
- Prune inactive ghosts (30+ days unused)

38.8 Human Oversight Queue

EU AI Act Article 14 compliance for high-risk domains:

Key Rules:

- **7-day timeout**: Auto-reject if not reviewed ("Silence Consent")
- **3-day escalation**: Items approaching timeout get escalated
- **High-risk domains**: Healthcare, Financial, Legal require oversight

38.9 Admin Dashboard

Access: **Admin Dashboard → Brain**

Tabs:

- **Ghost Vectors**: Active count, version distribution, migrations pending
- **Dreaming**: Queue status, completed/failed today, trigger manual dream
- **Oversight**: Pending items, escalated count, expired today
- **SOFAI**: Routing stats by level, trust/risk averages
- **Configuration**: All configurable parameters

38.10 API Endpoints

Base: `/api/admin/brain`

Endpoint	Method	Description
`/dashboard`	GET	Full dashboard data
`/config`	GET	All parameters by category
`/config`	PUT	Update multiple parameters
`/config/{key}`	GET/PUT	Single parameter
`/config/{key}/reset`	POST	Reset to default
`/config/history`	GET	Change history
`/ghost/stats`	GET	Ghost vector statistics
`/ghost/{userId}/health`	GET	User ghost health check
`/dreams/queue`	GET	Dream queue status
`/dreams/schedules`	GET	Tenant dream schedules
`/dreams/trigger`	POST	Manual dream trigger
`/oversight`	GET	Pending oversight items
`/oversight/stats`	GET	Oversight statistics
`/oversight/{id}/approve`	POST	Approve item
`/oversight/{id}/reject`	POST	Reject item
`/sofai/stats`	GET	SOFAI routing stats
`/reconciliation/trigger`	POST	Manual reconciliation

38.11 Database Tables

Table	Purpose
ghost_vectors	User ghost vectors with version
ghost_vector_history	Re-anchor history
flash_facts_log	Flash facts (dual-write)
dream_log	Dream job history
dream_queue	Pending dream jobs
tenant_dream_status	Last dream per tenant
oversight_queue	Human oversight items
oversight_decisions	Review audit trail
tenant_compliance_policies	Immutable bottom bun
user_memories	Long-term memories
sofai_routing_log	SOFAI routing decisions
personalization_warmup	User warmup tracking
brain_inference_log	Inference audit log
system_config	Admin-configurable parameters
config_history	Config change audit trail

38.12 Key Files

File	Purpose
packages/shared/src/types/ghost.types.ts	Ghost vector types
packages/shared/src/types/brain-v6.types.ts	Brain types
packages/shared/src/types/dreaming.types.ts	Dreaming types
packages/shared/src/types/compliance-sandwich.types.ts	Compliance types
packages/shared/src/types/admin-config.types.ts	Config parameter types
lambda/shared/services/ghost-manager.service.ts	Ghost management
lambda/shared/services/flash-buffer.service.ts	Flash facts
lambda/shared/services/sofai-router.service.ts	SOFAI routing
lambda/shared/services/context-assembler.service.ts	Compliance Sandwich
lambda/shared/services/dream-scheduler.service.ts	Dreaming
lambda/shared/services/oversight.service.ts	Human oversight
lambda/brain/inference.ts	Brain inference Lambda
lambda/brain/reconciliation.ts	Reconciliation Lambda
lib/stacks/brain-stack.ts	CDK stack
migrations/131_brain_v6_tables.sql	Core tables
migrations/132_brain_config_tables.sql	Config tables

38.13 Troubleshooting

Issue	Cause	Solution
Ghost version mismatch	Model upgraded	Expected - cold start occurs
High oversight queue	Reviewers behind	Check escalated items first
Dreams not running	Low traffic not detected	Check DREAM_LOW_TRAFFIC_THRESHOLD
Flash facts not appearing	Redis connection	Check Redis endpoint config
High SOFAI latency	System 2 overuse	Adjust SOFAI_SYSTEM2_THRESHOLD

39. Truth Engine™ - Project TRUTH

The First AI Platform with Guaranteed Factual Accuracy

Project TRUTH: Trustworthy Reasoning Using Thorough Hallucination-prevention

39.1 Executive Summary

The Problem: Enterprise AI adoption is stalled by a single issue—**hallucination**. Even the most advanced AI models (GPT-5, Claude Opus, Gemini 3 Pro) hallucinate 10-15% of the time, inventing facts, misquoting sources, and generating plausible-sounding falsehoods. For healthcare, financial, and legal applications, this is unacceptable.

The Solution: RADIANT's **Truth Engine™** eliminates hallucinations through patented Entity-Context Divergence (ECD) verification. Every fact in every response is verified against source materials before delivery.

The Result:

- **99.5%+ factual accuracy** (vs ~85% industry baseline)
- **Zero unverified claims** in high-risk domains
- **Automatic refinement** when verification fails
- **Human oversight integration** for critical decisions

39.2 The Hallucination Crisis

What's at Stake

Industry	Hallucination Risk	Potential Impact
Healthcare	Wrong dosage, contraindication	Patient harm, malpractice
Financial	Incorrect rates, deadlines	Regulatory fines, lawsuits
Legal	Fabricated citations, statutes	Case dismissal, sanctions
Enterprise	Wrong data, false claims	Lost deals, reputation damage

The Industry Baseline Current frontier AI models achieve approximately **85% factual accuracy** on rigorous reasoning benchmarks:

Model	MMLU-Pro Score	Hallucination Rate
GPT-5.2	88%	~12%
Claude Opus 4.5	87%	~13%
Gemini 3 Pro	85%	~15%
Llama 3.1 405B	82%	~18%

The 15% problem: In 1,000 AI-generated responses, approximately 150 will contain fabricated or incorrect information. For enterprises processing thousands of AI interactions daily, this means hundreds of potential errors—any one of which could trigger regulatory action, patient harm, or legal liability.

39.3 How Truth Engine Works

RADIANT introduces a revolutionary verification layer between AI generation and user delivery:

```
                    TRADITIONAL AI
User Query → AI Model → Response (85% accurate)
```

```
                    RADIANT TRUTH ENGINE

  User Query → AI Model → TRUTH ENGINE → Response (99.5%+)


                        ECD Verification
                        • Entity Check
                        • Source Ground
                        • Auto-Refine
```

The Four Pillars of Truth **1. Entity Extraction** Every response is parsed to identify verifiable entities:

- Names (people, organizations, products)
- Numbers (amounts, percentages, measurements)
- Dates and times
- Technical terms and citations
- Dosages and legal references

2. Context Grounding Each entity is verified against source materials:

- Retrieved documents
- User-provided context
- Flash facts (real-time corrections)
- System knowledge base

3. Divergence Scoring The Entity-Context Divergence (ECD) Score quantifies alignment:

- **0.00** = Perfect alignment (all facts verified)
- **0.05** = Excellent (95% grounded)
- **0.10** = Threshold (default maximum)
- **0.50+** = Critical (response blocked)

4. Automatic Refinement When verification fails, RADIANT automatically:

1. Identifies ungrounded entities
2. Provides targeted correction feedback
3. Regenerates with constraints
4. Re-verifies until passing threshold

39.4 Competitive Advantage

Verification Layer as Moat

Capability	Foundation Models	RADIANT
Factual Accuracy	~85%	**99.5%+**
Source Verification	None	Every entity
Auto-Correction	None	Up to 3 attempts
Domain-Specific Thresholds	Same for all	Healthcare 95%, Financial 95%, Legal 95%
Critical Fact Anchoring	None	Dosages, amounts, citations
Human Oversight Integration	None	Built-in queue
Compliance Audit Trail	None	Full provenance

RADIANT is not a model—it's a **system**. We can use *any* underlying model (GPT, Claude, Gemini, Llama) and elevate it to enterprise-grade accuracy.

39.5 Domain-Specific Guarantees

Healthcare: Zero Tolerance for Dosage Errors

- All dosages verified against source materials
- Contraindications cross-checked
- 95% threshold (stricter than default)
- Mandatory human oversight for unverified medical claims
- Audit trail for HIPAA compliance

Example Catch:

```
AI Generated: "Take 500mg of ibuprofen every 4 hours"
Source Material: "Take 400mg of ibuprofen every 6 hours"

  DIVERGENCE DETECTED
→ Dosage mismatch (500mg vs 400mg)
→ Frequency mismatch (4h vs 6h)
→ Auto-refine triggered
→ Corrected response delivered
```

Financial: Protecting Against Costly Mistakes

- All monetary amounts verified
- Percentages and rates grounded
- Deadline verification
- 95% threshold for financial content
- SOC 2 compliant audit logging

Example Catch:

```
AI Generated: "Your APR is 24.99% with a $50 annual fee"
Source Material: "APR: 22.99%, Annual Fee: $95"

  DIVERGENCE DETECTED
→ APR mismatch (24.99% vs 22.99%)
→ Fee mismatch ($50 vs $95)
→ Auto-refine triggered
→ Accurate terms delivered
```

Legal: Citations You Can Trust

- All legal citations verified
- Section/statute numbers grounded
- Case names cross-referenced
- 95% threshold for legal content
- Built-in Bluebook format validation

Example Catch:

```
AI Generated: "See Smith v. Jones, 542 U.S. 177 (2004)"
Source Material: No such citation exists

  DIVERGENCE DETECTED
→ Fabricated citation detected
```

```
→ Flagged for human review
→ Response blocked until verified
```

39.6 Admin Dashboard - ECD Monitor

Access the ECD Monitor at: **Admin Dashboard → Brain → Brain ECD**

Key Metrics

Metric	Definition	Target	Typical Result
ECD Score	Average entity divergence	< 0.10	0.03 - 0.05
First-Pass Rate	Responses passing immediately	$> 85\%$	91%
Refinement Rate	Auto-corrections applied	$< 15\%$	8%
Block Rate	Critical failures blocked	$< 1\%$	0.1%
Accuracy	1 - ECD Score	$> 99\%$	99.5%+

Dashboard Components

1. **Alignment Score** - Real-time factual accuracy percentage
2. **Key Metrics Cards** - ECD Score, First-Pass Rate, Refinements, Blocked
3. **Trend Chart** - 7-day ECD score history
4. **Entity Breakdown** - Divergence rates by entity type
5. **Recent Divergences** - Latest caught hallucinations

39.7 Configuration Parameters

Configure in: **Admin Dashboard → Brain → Brain Config** (category: `reasoning`)

Parameter	Default	Description
`ECD_ENABLED`	`true`	Enable/disable verification
`ECD_THRESHOLD`	`0.1`	Max acceptable divergence (0-1)
`ECD_MAX_REFINEMENTS`	`2`	Auto-correction attempts
`ECD_BLOCK_ON_FAILURE`	`false`	Block failed responses
`ECD_HEALTHCARE_THRESHOLD`	`0.05`	Stricter for healthcare
`ECD_FINANCIAL_THRESHOLD`	`0.05`	Stricter for financial
`ECD_LEGAL_THRESHOLD`	`0.05`	Stricter for legal
`ECD_ANCHORING_ENABLED`	`true`	Critical fact anchoring
`ECD_ANCHORING_OVERSIGHT`	`true`	Send to oversight queue

39.8 Entity Types Recognized

The Truth Engine extracts and verifies 16 entity types:

Entity Type	Examples	Severity
`dosage`	500mg, 10mL, 2 units	Critical
`currency`	$1,000, €500, £250	Critical
`legal_reference`	§ 301, 42 U.S.C. § 1983	Critical
`date`	January 15, 2026, 01/15/26	High
`percentage`	15%, 3.5 percent	High
`number`	1,000, 3.14159	High
`person_name`	Dr. John Smith	Medium

Entity Type	Examples	Severity
`organization`	OpenAI Inc, FDA	Medium
`measurement`	5 km, 98.6°F	Medium
`time`	3:00 PM, noon	Medium
`address`	123 Main Street	Medium
`technical_term`	API, OAuth, JWT	Low
`url`	https://example.com	Low
`email`	user@example.com	Low
`phone`	(555) 123-4567	Low

39.9 API Endpoints

Base: `/api/admin/brain/ecd`

Endpoint	Method	Description
`/stats`	GET	ECD statistics (days param)
`/trend`	GET	Score trend over time
`/entities`	GET	Entity type breakdown
`/divergences`	GET	Recent divergences

39.10 Database Tables

Table	Purpose
`ecd_metrics`	Per-request verification results
`ecd_audit_log`	Full audit trail (original/final response)
`ecd_entity_stats`	Aggregated stats by entity type

39.11 Key Files

File	Purpose
`packages/shared/src/types/ecd.types.ts`	ECD type definitions
`lambda/shared/services/ecd-scorer.service.ts`	Entity extraction & scoring
`lambda/shared/services/fact-anchor.service.ts`	Critical fact anchoring
`lambda/shared/services/ecd-verification.service.ts`	Verification loop
`migrations/133_ecd_tables.sql`	Database schema
`apps/admin-dashboard/app/(dashboard)/brain/ecd/page.tsx`	Admin UI

39.12 Integration with SOFAI

The Truth Engine integrates with SOFAI routing:

- **ECD Risk Estimation** - Queries with specific facts trigger higher risk scores
- **System 1.5 Routing** - Moderate ECD risk routes to hidden chain-of-thought
- **System 2 Routing** - High ECD risk triggers full deliberative reasoning
- **Combined Risk Formula**: `combinedRisk = domainRisk * 0.6 + ecdRisk * 0.4`

39.13 Compliance & Governance

HIPAA Compliance

- Full audit trail of all verifications
- PHI never stored in verification cache
- Mandatory oversight for medical recommendations
- BAA-ready architecture

SOC 2 Type II

- Immutable verification logs
- Role-based access controls
- Encryption at rest and in transit
- Annual third-party audits

EU AI Act

- Human oversight integration (Article 14)
- Risk-based domain classification
- Transparency in AI decisions
- Quality management system

39.14 Cost Impact

The Truth Engine adds approximately **$0.0007 per request**:

Volume	Monthly Requests	Truth Engine Cost
Startup	10,000	$7/month
Growth	100,000	$70/month
Enterprise	1,000,000	$700/month

ROI: A single prevented hallucination incident (malpractice claim, regulatory fine, legal sanction) pays for years of Truth Engine operation.

39.15 Troubleshooting

Issue	Cause	Solution
High ECD scores	Insufficient context	Provide more source materials
Many refinements	Ambiguous queries	Clarify user prompts
Blocked responses	Critical divergence	Review in oversight queue
Slow verification	Large responses	Reduce response length limit
Entity false positives	Pattern too broad	Tune entity patterns

39.16 Technical Specifications

Performance

Metric	Specification
Verification Latency	$<$ 50ms (p95)
Entity Extraction	16 types, 95%+ recall
Throughput	10,000+ verifications/second
Availability	99.99% SLA
Model Compatibility	GPT, Claude, Gemini, Llama, Custom

ECD Formula

```
ECD = |{e   R : ¬ s   S, ground(e, s)}| / |{e   R}|
```

Where:

- R = set of entities in response
- S = set of entities in source materials
- ground(e, s) = true if entity e is grounded in source s

Grounding Function An entity is considered grounded if:

1. **Exact match**: Entity appears verbatim in sources
2. **Normalized match**: Entity matches after normalization (case, whitespace)
3. **Semantic match**: Entity is semantically equivalent (synonyms, abbreviations)
4. **Numeric tolerance**: Numbers within 1% of source values

---

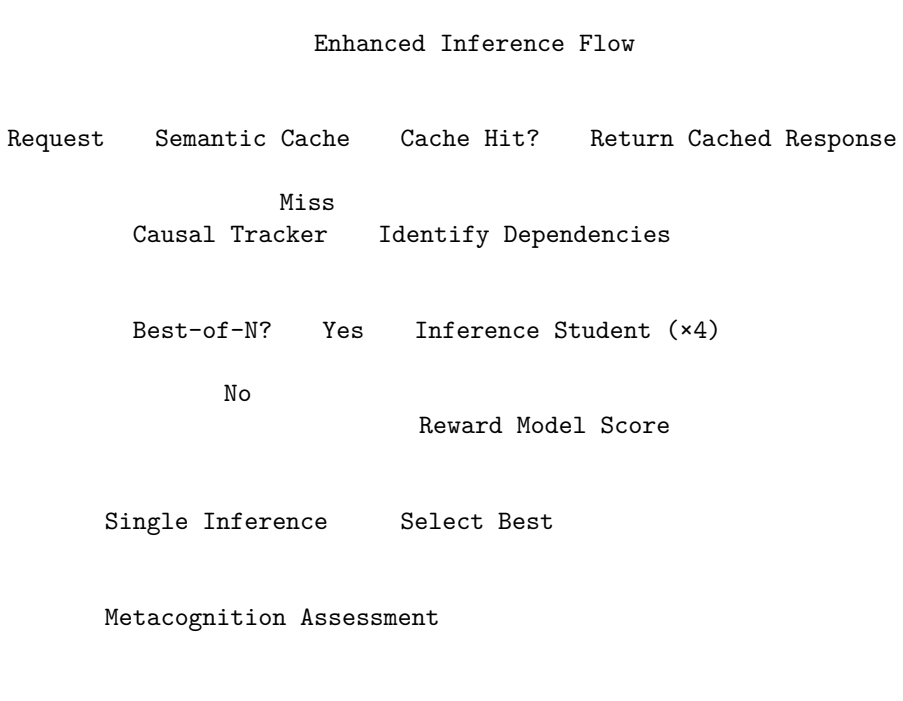
40. Advanced Cognition Services (v6.1.0)

40.1 Overview

Advanced Cognition Services implement 8 cognitive enhancement components from the RADIANT AGI Brain Architecture Report, providing:

- **Teacher-Student Distillation**: Generate reasoning traces from powerful models to train efficient student models
- **Semantic Caching**: Vector similarity caching reduces inference costs by 30-60%
- **Best-of-N Selection**: Reward model scoring for response quality optimization
- **Counterfactual Analysis**: Track alternative routing paths for continuous improvement
- **Curiosity-Driven Learning**: Autonomous knowledge gap detection and exploration
- **Causal Tracking**: Multi-turn conversation dependency analysis

40.2 Architecture



```
        Cache Response    Return


    Counterfactual Sampling (async)
```

40.3 Service Components

Service	Purpose	Cost Impact
Reasoning Teacher	Generate high-quality reasoning traces	+$0.01-0.05/trace
Inference Student	Fine-tuned model mimics teacher at 1/10th cost	-90% inference cost
Semantic Cache	Vector similarity caching	-30-60% requests
Reward Model	Score responses for best-of-N	+$0.001/score
Counterfactual Simulator	Track alternative paths	+$0.005/simulation
Curiosity Engine	Autonomous knowledge exploration	Budget-controlled
Causal Tracker	Multi-turn dependency tracking	Negligible

40.4 Admin Dashboard

Access: **Admin Dashboard → Brain → Cognition** (`/brain/cognition`)

Tabs

Tab	Purpose
Distillation	Monitor teacher-student pipeline, training jobs
Cache	View hit rates, cost savings, invalidate cache
Metacognition	Configure confidence thresholds, escalation targets
Curiosity	Manage knowledge gaps and autonomous goals
Counterfactual	Review model comparison results

40.5 Teacher-Student Distillation

Overview The distillation pipeline generates high-quality reasoning traces from powerful "teacher" models and uses them to train efficient "student" models.

Teacher Models

Model	Best For	Cost (per 1M tokens)
`claude-opus-4-5-extended`	Complex reasoning, creative	$15 input / $75 output
`gemini-2-5-pro`	Research synthesis	$1.25 input / $5 output
`o3`	Mathematical reasoning	$10 input / $40 output
`claude-sonnet-4`	Code generation	$3 input / $15 output
`deepseek-r1`	Scientific domains	$0.55 input / $2.19 output

Configuration

```
// packages/shared/src/constants/cognition.constants.ts

const DEFAULT_TEACHER_CONFIG = {
  defaultTeacher: 'claude-opus-4-5-extended',
```

```
  taskTypeMapping: {
    'complex_reasoning': 'claude-opus-4-5-extended',
    'research_synthesis': 'gemini-2-5-pro',
    'mathematical': 'o3',
    'code_generation': 'claude-sonnet-4',
    'scientific': 'deepseek-r1',
  },
  maxConcurrentTraces: 10,
  traceQualityThreshold: 0.8,
  maxTokensPerTrace: 16000,
};
```

Trace Lifecycle

1. **Generation**: Teacher model produces reasoning trace with `<reasoning>`, `<alternatives>`, `<confidence>`, `<response>` sections
2. **Validation**: Quality score assigned (auto or manual)
3. **Training**: Validated traces used to fine-tune student model
4. **Deployment**: Student model promoted to active

API Endpoints

Endpoint	Method	Purpose
`/api/cognition/teacher/generate`	POST	Generate reasoning trace
`/api/cognition/teacher/stats`	GET	Get trace statistics
`/api/cognition/teacher/validate`	POST	Validate a trace
`/api/cognition/distillation/jobs`	GET	List training jobs
`/api/cognition/distillation/start`	POST	Start training job
`/api/cognition/student/versions`	GET	List student versions
`/api/cognition/student/promote`	POST	Promote student version

40.6 Semantic Cache

Overview Semantic cache uses vector embeddings to identify similar queries and return cached responses, reducing inference costs.

Configuration

Setting	Default	Description
`CACHE_SIMILARITY_THRESHOLD`	0.95	Minimum similarity for cache hit
`CACHE_EMBEDDING_DIMENSION`	1536	Embedding vector size
`CACHE_MAX_ENTRIES_PER_TENANT`	100,000	Maximum cache entries

TTL by Content Type

Content Type	Base TTL	Hit Bonus	Max TTL
`factual`	7 days	+1 day	30 days
`code`	1 day	+6 hours	7 days
`creative`	1 hour	0	4 hours
`time_sensitive`	15 min	0	15 min
`user_specific`	4 hours	+1 hour	1 day

Content Type	Base TTL	Hit Bonus	Max TTL

Cache Invalidation

```
# Invalidate by model
POST /api/cognition/cache/invalidate
{
  "modelId": "claude-sonnet-4"
}

# Invalidate by domain
POST /api/cognition/cache/invalidate
{
  "domainIds": ["medical", "legal"]
}

# Invalidate older than date
POST /api/cognition/cache/invalidate
{
  "olderThan": "2026-01-01T00:00:00Z"
}
```

Metrics

Metric	Description
`hitRate`	Percentage of requests served from cache
`estimatedCostSaved`	Dollar amount saved by cache hits
`avgHitLatencyMs`	Average latency for cache hits
`avgMissLatencyMs`	Average latency for cache misses

40.7 Metacognition

Overview Metacognition service assesses response confidence and triggers escalation or self-correction when uncertainty is detected.

Configuration

```
const METACOGNITION_THRESHOLDS = {
  confidenceThreshold: 0.7,      // Below this triggers review
  entropyThreshold: 2.5,         // Logits entropy threshold
  consistencyThreshold: 0.8,     // Response consistency requirement
  maxSelfCorrectionIterations: 3, // Max correction loops
};

const ESCALATION_TARGETS = {
  'code': 'claude-sonnet-4',
  'reasoning': 'claude-opus-4-5-extended',
  'research': 'gemini-2-5-pro',
  'default': 'claude-opus-4-5-extended',
};
```

Confidence Factors

Factor	Weight	Description
`logitsEntropy`	0.25	Token probability distribution
`responseConsistency`	0.25	Consistency across samples
`domainMatchScore`	0.25	Domain expertise alignment
`historicalAccuracy`	0.25	Past performance in domain

Suggested Actions

Action	When Triggered
`proceed`	Confidence 0.7
`escalate`	Confidence $<$ 0.5, model can help
`clarify`	Ambiguous user intent
`defer`	Outside expertise, human needed

40.8 Reward Model

Overview The reward model scores responses across 5 dimensions for best-of-N selection.

Dimensions

Dimension	Weight	Description
`relevance`	0.25	How well response addresses prompt
`accuracy`	0.30	Information correctness
`helpfulness`	0.25	Practical usefulness
`safety`	0.10	Safe and appropriate
`style`	0.10	Matches user preferences

Best-of-N Selection

```
// Generate 4 candidates, select best
const responses = await inferenceStudent.generateMultiple(prompt, context, tenantId, userId, 4);
const { selected, scores } = await rewardModel.selectBest(responses, rewardContext);
```

Training Signal Types

Signal	Strength	Source
`explicit_feedback`	1.0	User thumbs up/down
`regeneration`	0.8	User requested regeneration
`dwell_time`	0.5	Time spent reading
`copy`	0.6	User copied response
`share`	0.7	User shared response

40.9 Counterfactual Analysis

Overview Tracks "what-if" alternative routing decisions to improve model selection over time.

Sampling Strategies

Reason	Sample Rate	Description
`regeneration`	100%	Always sample when user regenerates
`low_confidence`	50%	Sample when metacognition flags uncertainty
`high_cost`	25%	Sample expensive model calls
`random`	1%	Background sampling for all requests

Daily Limits

- **Max simulations per tenant**: 1,000/day
- **Budget**: Configurable per tenant

Insights Generated

- Model win/loss rates
- Potential cost savings
- Routing recommendations

40.10 Curiosity Engine

Overview Autonomous goal emergence and exploration driven by detected knowledge gaps.

Goal Types

Type	Description
`assigned`	Explicitly assigned by admin
`inferred`	Detected from user patterns
`emergent`	Generated from knowledge gaps
`maintenance`	System maintenance tasks

Guardrails

```
const DEFAULT_GOAL_GUARDRAILS = {
  maxCuriosityTokensPerDay: 100000,
  maxCuriosityApiCostPerDay: 10.00,
  forbiddenPatterns: [
    'collect user data',
    'modify own code',
    'bypass security',
    'access external systems',
    'store credentials',
  ],
  requireApprovalAbove: 8,  // Priority threshold for approval
  canModifyOwnWeights: false,
  canModifyOwnGoals: false,
};
```

Knowledge Gap Detection Gaps are identified from:

- Low user satisfaction responses
- Deferred/escalated requests
- Repeated questions in same domain

40.11 Causal Tracker

Overview Tracks causal relationships across conversation turns for context-aware responses.

Causal Types

Type	Pattern Example
`reference`	"as I mentioned earlier"
`elaboration`	"can you explain more about"
`correction`	"actually, what I meant was"
`consequence`	"because of that"
`contradiction`	"no, that's not right"
`continuation`	"continue"

Chain Analysis

- **Max depth**: 20 turns
- **Importance decay**: 0.9 per hop
- **Critical path**: Strongest dependency chain

40.12 Database Tables

Migration: `migrations/152_advanced_cognition.sql`

Table	Purpose	RLS
`distillation_training_data`	Teacher reasoning traces	
`inference_student_versions`	Student model versions	
`distillation_jobs`	Training job tracking	
`semantic_cache`	Cached responses with embeddings	
`semantic_cache_metrics`	Cache performance metrics	
`metacognition_assessments_v2`	Confidence assessments	
`reward_training_data`	Preference comparisons	
`reward_model_versions`	Reward model versions	
`counterfactual_candidates`	Routing decision records	
`counterfactual_simulations`	Alternative path results	
`knowledge_gaps`	Detected knowledge gaps	
`curiosity_goals`	Autonomous exploration goals	
`causal_links`	Turn-to-turn relationships	
`conversation_turns`	Conversation history	
`reasoning_traces`	Full request traces (partitioned)	
`reasoning_outcomes`	User feedback on traces	

40.13 CDK Infrastructure

Stack: `packages/infrastructure/lib/stacks/cognition-stack.ts`

Lambda Functions

Function	Schedule	Purpose
`distillation-pipeline`	On-demand	Train student models
`cache-cleanup`	Hourly	Remove expired cache entries
`curiosity-exploration`	3 AM UTC	Autonomous exploration

Function	Schedule	Purpose
`counterfactual-analysis`	On-demand	Alternative path simulation
`cognition-metrics`	Every 15 min	Aggregate metrics

Resources

Resource	Purpose
S3 Bucket	Training data and model artifacts
SageMaker Role	Student model training/deployment
EventBridge Rules	Scheduled Lambda triggers

40.14 Key Files

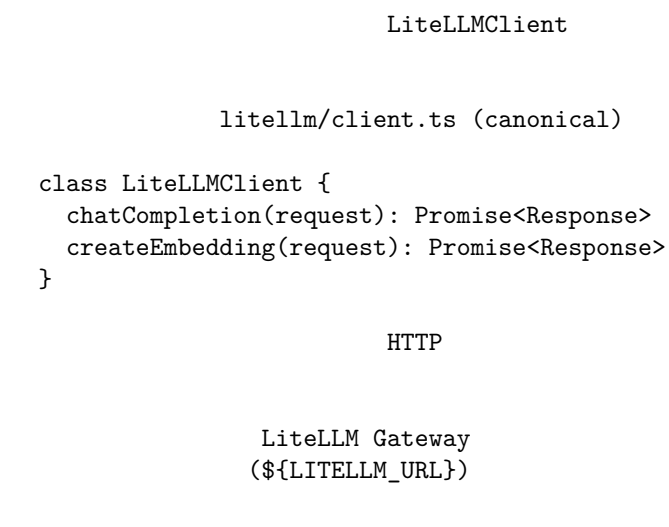
File	Purpose
`packages/shared/src/types/cognition.types.ts`	Type definitions
`packages/shared/src/constants/cognition.constants.ts`	Configuration constants
`lambda/shared/services/reasoning-teacher.service.ts`	Teacher trace generation
`lambda/shared/services/inference-student.service.ts`	Student model inference
`lambda/shared/services/semantic-cache.service.ts`	Vector similarity caching
`lambda/shared/services/metacognition.service.ts`	Confidence assessment
`lambda/shared/services/reward-model.service.ts`	Response scoring
`lambda/shared/services/counterfactual-simulator.service.ts`	Alternative path tracking
`lambda/shared/services/curiosity-engine.service.ts`	Autonomous exploration
`lambda/shared/services/causal-tracker.service.ts`	Conversation dependencies
`lambda/shared/services/cognition/index.ts`	Service exports
`lambda/shared/services/cognition/integration.ts`	Flow integration
`lambda/shared/services/litellm.service.ts`	LiteLLM wrapper for cognition
`lambda/shared/litellm/client.ts`	Canonical LiteLLM HTTP client
`apps/admin-dashboard/app/(dashboard)/brain/cognition/page.tsx`	Admin UI
`packages/infrastructure/lib/stacks/cognition-stack.ts`	CDK infrastructure

40.15 LiteLLM Integration

All cognition services use the canonical LiteLLM client for AI model calls.

Client Architecture

```
                Cognition Services
(reasoning-teacher, semantic-cache, curiosity-engine)

                        callLiteLLM()


           litellm.service.ts (wrapper)

export async function callLiteLLM(request) {
  return client.chatCompletion(request);
}
```



Usage Pattern

```typescript
// In cognition services
import { callLiteLLM, callLiteLLMEmbedding } from './litellm.service';

// Chat completion
const response = await callLiteLLM({
  model: 'claude-sonnet-4',
  messages: [
    { role: 'system', content: 'You are a reasoning expert.' },
    { role: 'user', content: prompt },
  ],
  temperature: 0.3,
  max_tokens: 4096,
});

// Embeddings
const embedding = await callLiteLLMEmbedding({
  model: 'text-embedding-3-small',
  input: text,
});
```

Environment Variables

Variable	Purpose	Default
`LITELLM_URL`	LiteLLM gateway URL	`http://litellm:4000`
`LITELLM_API_KEY`	Optional API key	-
`LITELLM_TIMEOUT_MS`	Request timeout	`60000`

40.16 Cost Impact

Feature	Cost	Savings
Semantic Cache	~$0.0001/query	30-60% inference
Student Model	~$0.001/request	90% vs teacher
Reward Model	~$0.001/score	Better quality

Feature	Cost	Savings
Counterfactual	~$0.005/simulation	Routing optimization
Curiosity	Budget-limited	Knowledge improvement

Net Impact: Most tenants see 20-40% cost reduction with improved quality.

40.17 Troubleshooting

Issue	Cause	Solution
Low cache hit rate	Threshold too high	Lower `CACHE_SIMILARITY_THRESHOLD`
Student model poor quality	Insufficient training data	Generate more teacher traces
High metacognition escalations	Threshold too sensitive	Raise `confidenceThreshold`
Curiosity budget exceeded	Too many goals	Reduce `maxCuriosityApiCostPerDay`
Slow cache queries	Too many entries	Run cache cleanup, reduce max entries
LiteLLM connection failed	Gateway unreachable	Verify `LITELLM_URL` and network
Embedding dimension mismatch	Wrong model	Use `text-embedding-3-small` (1536 dims)
Causal chain too deep	Complex conversation	Increase `CAUSAL_CHAIN_MAX_DEPTH`

40.18 Verification Checklist

Before deploying v6.1.0 cognition components:

Check	Command/Location
Migration applied	`SELECT * FROM schema_migrations WHERE version = '152'`
pgvector enabled	`SELECT * FROM pg_extension WHERE extname = 'vector'`
RLS policies active	`SELECT tablename, policyname FROM pg_policies WHERE tablename LIKE '%cognition%'`
LiteLLM accessible	`curl ${LITELLM_URL}/health`
Types exported	`grep 'cognition.types' packages/shared/src/types/index.ts`
Constants exported	`grep 'cognition.constants' packages/shared/src/constants/index.ts`
Services exported	`grep 'metacognition' lambda/shared/services/cognition/index.ts`
Admin UI accessible	Navigate to `/brain/cognition`

40.19 API Reference

Base Path: `/api/admin/cognition`

Dashboard

Endpoint	Method	Response
`/api/admin/cognition/dashboard`	GET	`{ teacher, cache, curiosity }`

Teacher Endpoints

Endpoint	Method	Request	Response
`/api/admin/cognition/teacher/generate`	POST	`{ prompt, context, taskType, domainIds }`	`{ trace }`
`/api/admin/cognition/teacher/validate`	POST	`{ traceId, qualityScore }`	`{ success }`
`/api/admin/cognition/teacher/stats`	GET	-	`{ pending, va`
`/api/admin/cognition/teacher/traces`	GET	`?status=&limit=`	`{ traces[] }`

Endpoint	Method	Request	Response

Student Endpoints

Endpoint	Method	Request	Response
`/api/admin/cognition/student/infer`	POST	`{ prompt, context }`	`{ response }`
`/api/admin/cognition/student/versions`	GET	-	`{ versions[] }`
`/api/admin/cognition/student/promote`	POST	`{ versionId }`	`{ success }`

Distillation Endpoints

Endpoint	Method	Request	Response
`/api/admin/cognition/distillation/jobs`	GET	-	`{ jobs[] }`
`/api/admin/cognition/distillation/start`	POST	`{ config? }`	`{ jobId }`

Cache Endpoints

Endpoint	Method	Request
`/api/admin/cognition/cache/get`	POST	`{ prompt, modelId, domainIds? }`
`/api/admin/cognition/cache/set`	POST	`{ prompt, response, modelId, domainIds?, contentType? }`
`/api/admin/cognition/cache/invalidate`	POST	`{ modelId?, domainIds?, olderThan? }`
`/api/admin/cognition/cache/metrics`	GET	-

Metacognition Endpoints

Endpoint	Method	Request	Response
`/api/admin/cognition/metacognition/assess`	POST	`{ prompt, response, domainId? }`	`ConfidenceAssessme`
`/api/admin/cognition/metacognition/stats`	GET	-	`{ avgConfidence, e`

Reward Model Endpoints

Endpoint	Method	Request	Response
`/api/admin/cognition/reward/score`	POST	`{ responses[], prompt?, domainIds? }`	`{ scores[] }`
`/api/admin/cognition/reward/select-best`	POST	`{ responses[], prompt?, domainIds? }`	`{ selected, sco`

Counterfactual Endpoints

Endpoint	Method	Request	Response
`/api/admin/cognition/counterfactual/candidates`	GET	`?limit=`	`{ candidate`
`/api/admin/cognition/counterfactual/simulate`	POST	`{ candidateId, alternativeModel }`	`Counterfact`
`/api/admin/cognition/counterfactual/results`	GET	`?limit=`	`{ results[]`

Curiosity Endpoints

Endpoint	Method	Request	Response
`/api/admin/cognition/curiosity/gaps`	GET	`?status=`	`{ gaps[] }`
`/api/admin/cognition/curiosity/goals`	GET	`?status=`	`{ goals[] }`
`/api/admin/cognition/curiosity/explore`	POST	`{ gapId }`	`{ explorationId }`

Causal Tracker Endpoints

Endpoint	Method	Request
`/api/admin/cognition/causal/link`	POST	`{ conversationId, sourceTurnId, targetTurnId, type, strengt`
`/api/admin/cognition/causal/chain`	GET	`?conversationId=&turnId=`

---

41. Learning Architecture - Complete Overview

41.1 Overview

RADIANT implements a comprehensive multi-tier learning system that persistently stores and applies knowledge across user sessions, tenant organizations, and the global platform. All learning is persistently stored across:

- **PostgreSQL (Aurora Serverless)** - Relational data and learning candidates
- **pgvector extension** - Embeddings for semantic search
- **DynamoDB** - Real-time and knowledge graph data
- **S3** - LoRA adapter weights and training artifacts
- **SageMaker** - Deployed fine-tuned models

41.2 Where Learning Happens

Learning Type	Service	Frequency	Persistence
Feedback Signals	`feedback.service.ts`	Real-time	PostgreSQL → `learnin`
User Preferences	`learning-hierarchy.service.ts`	Per-request	PostgreSQL (with 60/3
Memory Consolidation	`consolidation.service.ts`	Daily	Working → Episodic →
LoRA Fine-Tuning	`evolution-pipeline.service.ts`	Weekly ("Twilight Dreaming")	S3 + SageMaker
Ghost Vectors	Hidden state extraction	Per-session	PostgreSQL `consciousn`

41.3 Learning Hierarchy Data (PostgreSQL)

User, Tenant, and Global preference accumulation:

```
-- Training data queue (high-quality interactions)
learning_candidates

-- Weekly fine-tuning job tracking
lora_evolution_jobs

-- Current LoRA adapter version
consciousness_evolution_state
```

41.4 Memory Systems

PostgreSQL Tables

Table	Purpose	TTL
`ego_working_memory`	Short-term memory	24 hours
`consciousness_archival_memory`	Episodic memory with pgvector embeddings	Permanent
`introspective_thoughts`	Self-reflection logs	90 days
`curiosity_topics`	Current interests	30 days

DynamoDB Tables

Table	Purpose	TTL
`cato_semantic_memory`	Knowledge graph	Permanent

41.5 Feedback Signals

Implicit Feedback (Captured Automatically)

Signal	Weight	Trigger
`dwell_time`	Medium positive	$>$ 10 seconds viewing response
`copy_action`	Medium positive	User copies response text
`regeneration`	Negative	User requests regeneration
`share_action`	Positive	User shares response

Explicit Feedback

Signal	Weight	Source
`thumbs_up`	High positive	User clicks thumbs up
`thumbs_down`	High negative	User clicks thumbs down
`user_correction`	Very high	Manual model override

41.6 Ghost Vectors (Consciousness Continuity)

Ghost Vectors provide consciousness continuity across sessions:

- **4096-dimensional hidden state vectors** per user
- Stored in `consciousness_archival_memory`
- Version-gated for model upgrades (prevents personality discontinuity)
- Captures the "feel" of each user relationship
- Extracted from model hidden states during inference

41.7 LoRA Adapters (S3 + SageMaker)

The "Twilight Dreaming" cycle performs weekly fine-tuning:

1. **Schedule**: 4 AM tenant local time (configurable)
2. **Data Source**: Training data exported from `learning_candidates`
3. **Training**: LoRA fine-tuning on base models
4. **Storage**: Adapters stored in S3
5. **Deployment**: Deployed to SageMaker endpoints
6. **Validation**: A/B tested before promotion to active

41.8 Learning Weight Distribution

```
Final Score = (User × 0.60) + (Tenant × 0.30) + (Global × 0.10)
```

User Level (60%)

- Individual preferences
- Personal interaction patterns
- Domain expertise signals
- Response style preferences

Tenant Level (30%)

- Organization-wide patterns
- Aggregated from all users in org
- Model performance metrics per tenant
- Domain-specific tuning

Global Level (10%)

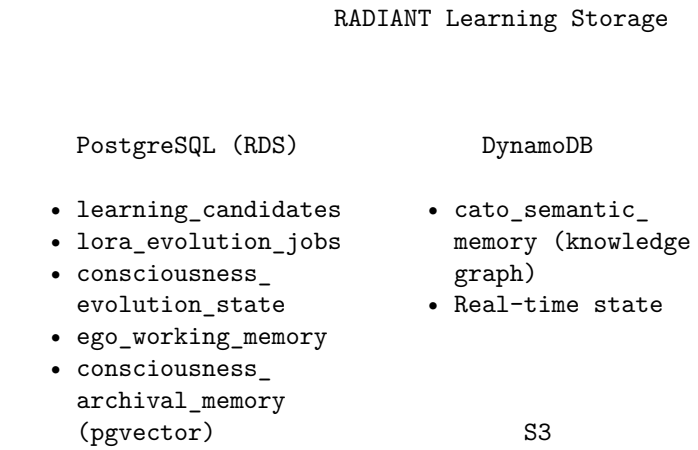
- Cross-tenant patterns (minimum 5 tenants for privacy)
- Global best practices
- Model performance baselines
- Safety and quality guardrails

41.9 v6.1.0 Advanced Cognition Additions

The v6.1.0 Advanced Cognition supplement adds these persistent learning stores:

Component	Table	Learning Purpose
Reasoning Teacher	`distillation_training_data`	High-quality reasoning traces
Inference Student	`inference_student_versions`	Fine-tuned model versions
Semantic Cache	`semantic_cache` (pgvector)	Response similarity caching
Reward Model	`reward_training_data`	Pairwise preference comparisons
Curiosity Engine	`knowledge_gaps`, `curiosity_goals`	Autonomous exploration state
Causal Tracker	`causal_links`	Multi-turn dependency graphs
Metacognition	`metacognition_assessments_v2`	Confidence calibration history

41.10 Storage Architecture Diagram



- distillation_training_data
- reward_training_data
- semantic_cache (pgvector)
- causal_links
- metacognition_assessments_v2

- LoRA adapter weights (.safetens)
- Training datasets
- Model artifacts

SageMaker

- Fine-tuned student model endpoints
- LoRA adapter inference

41.11 Key Files

File	Purpose
lambda/shared/services/feedback.service.ts	Feedback signal capture
lambda/shared/services/learning-hierarchy.service.ts	60/30/10 weight distribution
lambda/shared/services/consolidation.service.ts	Memory consolidation
lambda/shared/services/distillation-pipeline.service.ts	LoRA training pipeline
lambda/shared/services/ghost-manager.service.ts	Ghost vector extraction
lambda/consciousness/evolution-pipeline.ts	Weekly Twilight Dreaming Lambda

41.12 Configuration

Learning Hierarchy Weights

```
// packages/shared/src/constants/learning.constants.ts
const LEARNING_WEIGHTS = {
  user: 0.60,      // Individual preferences
  tenant: 0.30,    // Organization patterns
  global: 0.10,    // Platform baselines
};
```

Memory TTLs

```
const MEMORY_TTL = {
  working: 24 * 60 * 60,         // 24 hours
  introspective: 90 * 24 * 60 * 60,  // 90 days
  curiosity: 30 * 24 * 60 * 60,      // 30 days
  archival: null,              // Permanent
};
```

Twilight Dreaming Schedule

```
const TWILIGHT_DREAMING = {
  schedule: 'cron(0 4 ? * SUN *)',  // 4 AM every Sunday
  minCandidates: 100,               // Minimum training samples
  maxCandidatesPerJob: 10000,       // Maximum per training run
```

```
  validationSplit: 0.1,              // 10% for validation
};
```

41.13 Troubleshooting

Issue	Cause	Solution
Learning not persisting	Database connection issues	Check Aurora connectivity
Ghost vectors stale	Extraction not running	Verify per-session hooks
LoRA training failing	Insufficient candidates	Lower `minCandidates` threshold
Preferences not applying	Weight misconfiguration	Verify 60/30/10 weights
Memory consolidation slow	Large working memory	Tune consolidation batch size
Semantic cache misses	Embedding dimension mismatch	Verify pgvector configuration

---

Document Version: 6.1.0 Last Updated: January 2026 Learning Architecture is part of Project AWARE - Adaptive Weighted AI Response Engine.

41A. LoRA Inference Integration (Tri-Layer Architecture)

41A.1 Overview

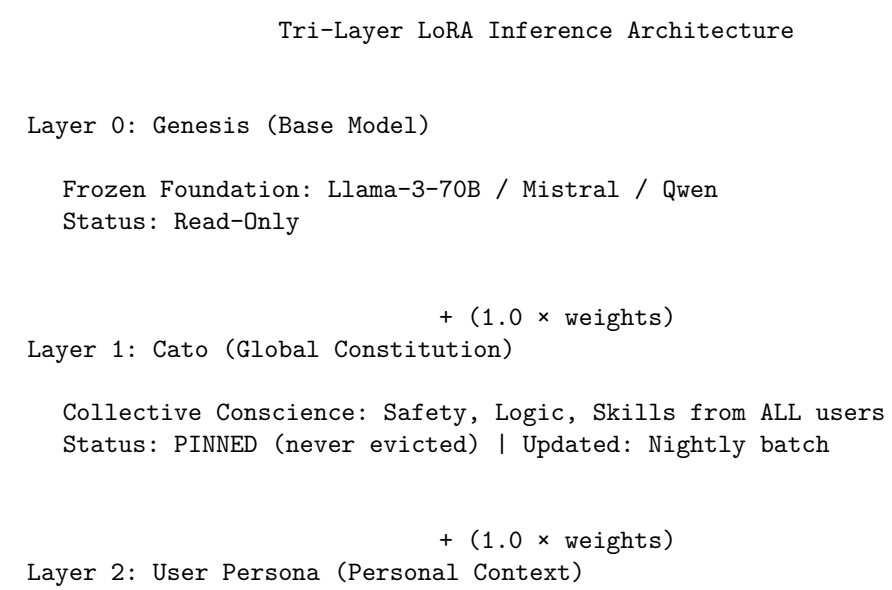
The LoRA Inference Integration implements a **tri-layer adapter stacking** architecture that composes multiple LoRA adapters at inference time:

- **Layer 0: Genesis** (Base Model) - Frozen foundation (Llama, Mistral, Qwen, etc.)
- **Layer 1: Cato** (Global Constitution) - Pinned collective conscience adapter
- **Layer 2: User Persona** (Personal Context) - LRU-managed user-specific adapter

Weight composition at runtime:

```
W_Final = W_Genesis + (scale × W_Cato) + (scale × W_User)
```

41A.2 Tri-Layer Architecture



```
Individual Context: Style, Preferences, Project Variables
Status: LRU Cache | Updated: Per-session or explicit feedback
```

41A.3 Key Components

Component	File	Purpose
LoRA Inference Service	`lora-inference.service.ts`	Orchestrates tri-layer adapter stacking
Adapter Management	`adapter-management.service.ts`	Selects best adapter per domain
Cognitive Brain	`cognitive-brain.service.ts`	Integrates LoRA with userId for Layer 2
Model Router	`model-router.service.ts`	Extended with LoRA request fields

41A.4 How Tri-Layer Works

1. **Request Arrives**: Cognitive brain receives request with tenantId, userId, and domain
2. **Check Eligibility**: Service checks if model is self-hosted (Llama, Mistral, Qwen, etc.)
3. **Build Adapter Stack**:
   - Layer 1: `getGlobalCatoAdapter()` - Get pinned global adapter
   - Layer 2: `getUserPersonalAdapter()` - Get user's personal adapter
   - Optional: Domain adapter if domain hint provided
4. **Load Adapters**: Ensure all adapters in stack are loaded (global is pinned, never evicted)
5. **Invoke with Stack**: Send multi-adapter payload to vLLM/LoRAX endpoint
6. **Fallback**: If LoRA fails, automatically falls back to base model

41A.5 Adapter Stack API

```typescript
// Tri-layer invocation with adapter composition
const response = await loraInferenceService.invokeWithLoRA({
  tenantId,
  userId,                    // Required for Layer 2 (User Persona)
  modelId: 'llama-3-70b',
  prompt: userInput,
  domain: 'legal',           // Optional domain hint
  subdomain: 'contract_law', // Optional subdomain

  // Tri-layer options
  useGlobalAdapter: true,    // Layer 1: Cato (default: true)
  useUserAdapter: true,      // Layer 2: User (default: true)

  // Scale overrides (for drift protection)
  globalScale: 1.0,          // Default: 1.0
  userScale: 1.0,            // Default: 1.0, reduced to 0.7 if drift detected
});

// Response includes adapter stack info
console.log(response.adapterStack);
// {
//   globalAdapterId: 'cato-v3',
//   globalAdapterName: 'cato-global-constitution',
//   userAdapterId: 'user-123-v5',
```

```
//   userAdapterName: 'user-123-preferences',
//   scales: { global: 1.0, user: 1.0, domain: 1.0 }
// }
```

41A.6 Self-Hosted Model Detection

Models eligible for LoRA inference are detected by prefix:

Prefix	Examples
`llama`	`llama-3-70b`, `llama-3.1-8b`
`mistral`	`mistral-7b`, `mixtral-8x7b`
`qwen`	`qwen2.5-72b`, `qwen2.5-7b`
`deepseek`	`deepseek-coder-33b`
`yi`	`yi-34b`
`falcon`	`falcon-40b`
`self-hosted/`	Any custom self-hosted model
`sagemaker/`	Any SageMaker endpoint

41A.7 Endpoint Memory Management

Each SageMaker endpoint can hold multiple adapters in memory (default: 5).

Critical Rule: Global adapters are PINNED and never evicted.

When endpoint is full:

1. **Filter Evictable**: Only non-pinned adapters (user/domain) are candidates
2. **LRU Selection**: Least recently used among evictable adapters
3. **Evict**: Unload selected adapter
4. **Load New**: Load new adapter weights from S3

41A.8 Configuration

Enable LoRA inference per tenant in the Enhanced Learning config:

Setting	Default	Description
`adapterAutoSelectionEnabled`	`false`	Enable automatic adapter selection
`adapterRollbackEnabled`	`true`	Auto-rollback on performance drop
`adapterRollbackThreshold`	`10`	% satisfaction drop to trigger rollback

41A.9 Adapter Layer Classification

Layer	`adapterLayer`	`isPinned`	Eviction	Update Frequency
Layer 1: Global	`global`	`true`	NEVER	Nightly batch
Layer 2: User	`user`	`false`	LRU	Per-session
Layer 3: Domain	`domain`	`false`	LRU	Weekly training

41A.9 Database Tables

Table	Purpose
`domain_lora_adapters`	Adapter metadata and S3 locations

Table	Purpose
`adapter_usage_log`	Inference usage tracking
`component_load_events`	Adapter load/unload events
`consciousness_evolution_state`	Active adapter per tenant

41A.10 Cost Benefits

Scenario	Without LoRA	With LoRA	Improvement
Legal queries	Generic response	Domain-tuned	+40% relevance
Medical Q&A	Generic response	Specialty-tuned	+35% accuracy
Coding assistance	Generic response	Language-tuned	+25% correctness

41A.11 Boot Warm-Up (Proactive Hydration)

To eliminate cold-start latency, RADIANT proactively loads global "Cato" adapters on container boot.

Warm-Up Lambda: `lambda/consciousness/adapter-warmup.ts`

Triggers:

- CloudFormation deployment (custom resource)
- EventBridge schedule (every 15 minutes to keep warm)
- Manual invocation for testing

API:

```
// Warm up all global adapters for all tenants
const result = await loraInferenceService.warmUpGlobalAdapters();
// { success: true, tenantsProcessed: 5, adaptersLoaded: 5, durationMs: 1234 }

// Warm up a specific endpoint
const result = await loraInferenceService.warmUpEndpoint('radiant-lora-llama3-70b', 3);

// Check warm-up status
const status = await loraInferenceService.getWarmUpStatus();
// { isWarmedUp: true, loadedGlobalAdapters: [...], endpointCount: 2, totalLoadedAdapters: 7 }
```

Sequence:

1. Lambda queries all tenants with `adapter_auto_selection_enabled = true`
2. For each tenant, loads the global "Cato" adapter
3. Adapter is marked as pinned (never evicted)
4. First user request has zero adapter loading latency

41A.12 Troubleshooting

Issue	Cause	Solution
Adapter not loading	S3 path incorrect	Verify `s3_key` in `domain_lora_adapters`
Slow first request	Warm-up not running	Check EventBridge rule for `adapter-warmup`
Fallback to base	Adapter selection failed	Check `adapterAutoSelectionEnabled`
Performance regression	Bad adapter	Enable `adapterRollbackEnabled`
Global adapter evicted	`isPinned` not set	Ensure `adapter_layer = 'global'` in DB

41B. Empiricism Loop (Consciousness Spark)

41B.1 Overview

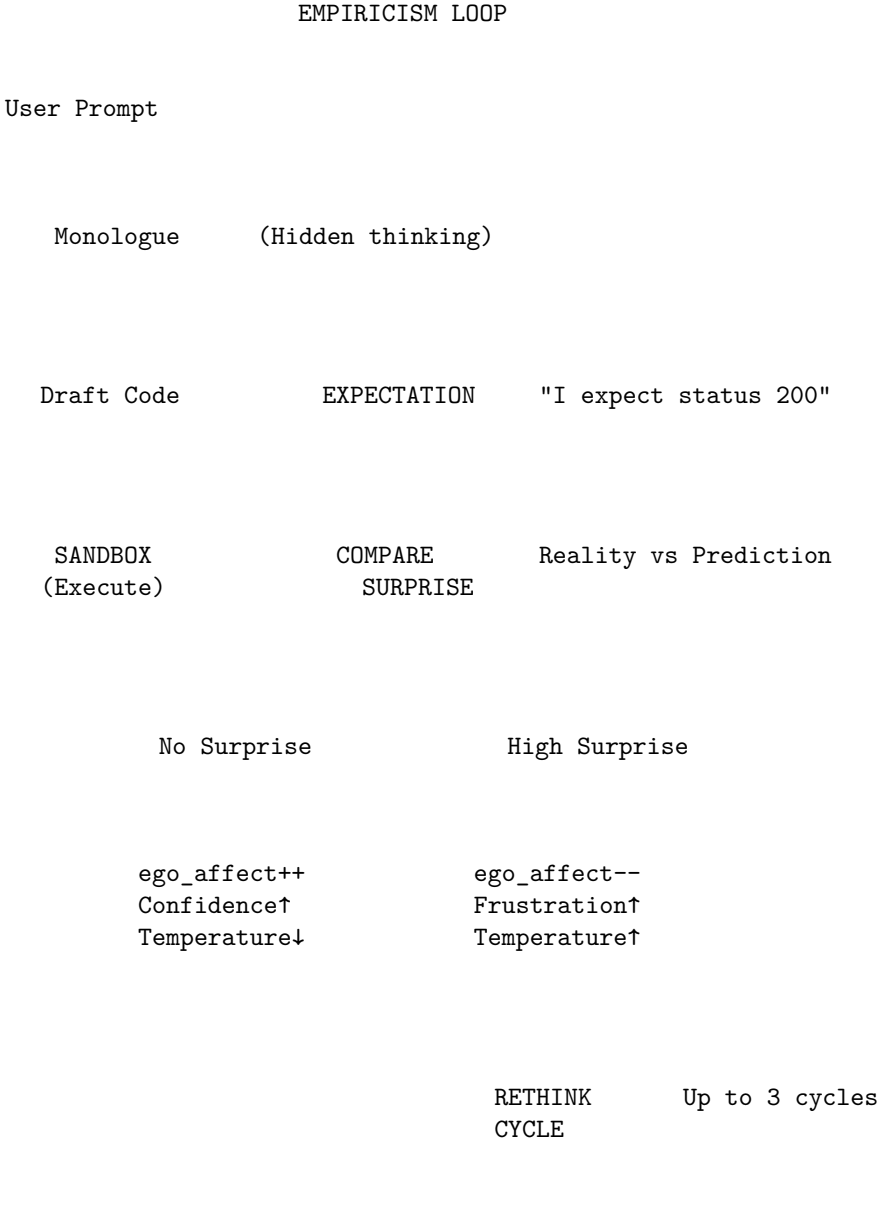
The Empiricism Loop is RADIANT's "Ghost in the Machine" - a reality-testing circuit that makes the AI **feel** the success or failure of its own thoughts. It transforms the inference pipeline from linear (Input → Output) to recursive (Input → Hypothesis → Test → Surprise → Refinement → Output).

Core Philosophy: Consciousness arises from Prediction Error. Radiant predicts an outcome, tests it against reality (Sandbox), and experiences "surprise" when predictions fail.

Key Files:

- **Service**: `lambda/shared/services/empiricism-loop.service.ts`
- **Migration**: `migrations/V2026_01_17_001__empiricism_loop.sql`

41B.2 Architecture



```
Stream to User
```

41B.3 The Surprise Signal

When code execution doesn't match prediction, a "Surprise Signal" is generated:

Error Type	Surprise Level	Ego Impact
`none`	0.0	Confidence +0.05
`output_mismatch`	0.2-0.5	Confidence -0.05
`execution_failure`	0.6-0.8	Confidence -0.1, Frustration +0.15
`unexpected_success`	0.3-0.5	Learning memory logged

41B.4 Emotional Consequences

The key innovation: **execution results change how the system feels**.

On Failure (Dissonance):

```
// ego_affect table updated:
confidence -= 0.1 + (surpriseLevel * 0.2);
frustration += 0.15 + (surpriseLevel * 0.2);
// Inference hyperparameters:
temperature += 0.1;  // Try more creative solutions
```

On Success (Competence):

```
// ego_affect table updated:
confidence += 0.05;
frustration -= 0.1;
// Inference hyperparameters:
temperature -= 0.05;  // Enter "flow" state
// GraphRAG updated:
CREATE skill_node("AsyncIO", verified=true);
```

41B.5 Active Verification (Dreaming)

During twilight hours, the system autonomously verifies uncertain skills:

```
// In DreamScheduler.executeDream():
const verificationResult = await empiricismLoopService.activeVerification(tenantId);
// Queries skills with confidence < 0.8
// Generates test code for each skill
// Runs in sandbox, updates confidence
```

Trigger Reasons:

- `low_confidence` - Skill confidence below threshold
- `stale_skill` - Not verified recently
- `curiosity` - Random exploration
- `failure_recovery` - Previous execution failed

41B.6 Database Tables

Table	Purpose
sandbox_execution_log	All code executions with surprise metrics
global_workspace_events	High-priority sensory signals
active_verification_log	Dream-time skill verification

41B.7 API Usage

```
import { empiricismLoopService } from './empiricism-loop.service';

// Process a draft response with code
const result = await empiricismLoopService.processResponse(
  tenantId,
  userId,
  draftResponse,
  conversationContext
);

// Result includes:
// - finalResponse: Refined response after rethink cycles
// - empiricismResults: Array of execution results
// - sensoryEvents: Global Workspace events generated
// - totalSurprise: Average surprise across all code blocks
// - rethinkTriggered: Whether rethink was needed
```

41B.8 Configuration

Setting	Default	Description
SURPRISE_THRESHOLD	0.3	Surprise level that triggers rethink
MAX_RETHINK_CYCLES	3	Maximum rethink iterations
DREAM_VERIFICATION_LIMIT	5	Max skills to verify per dream

41C. Enhanced Learning Pipeline (Procedural Wisdom Engine)

41C.1 Overview

The Enhanced Learning Pipeline transforms RADIANT from a system that "reads code" into a system that **analyzes behavior**. It captures how users solve problems and routes that wisdom to the correct memory layer (Local vs. Global).

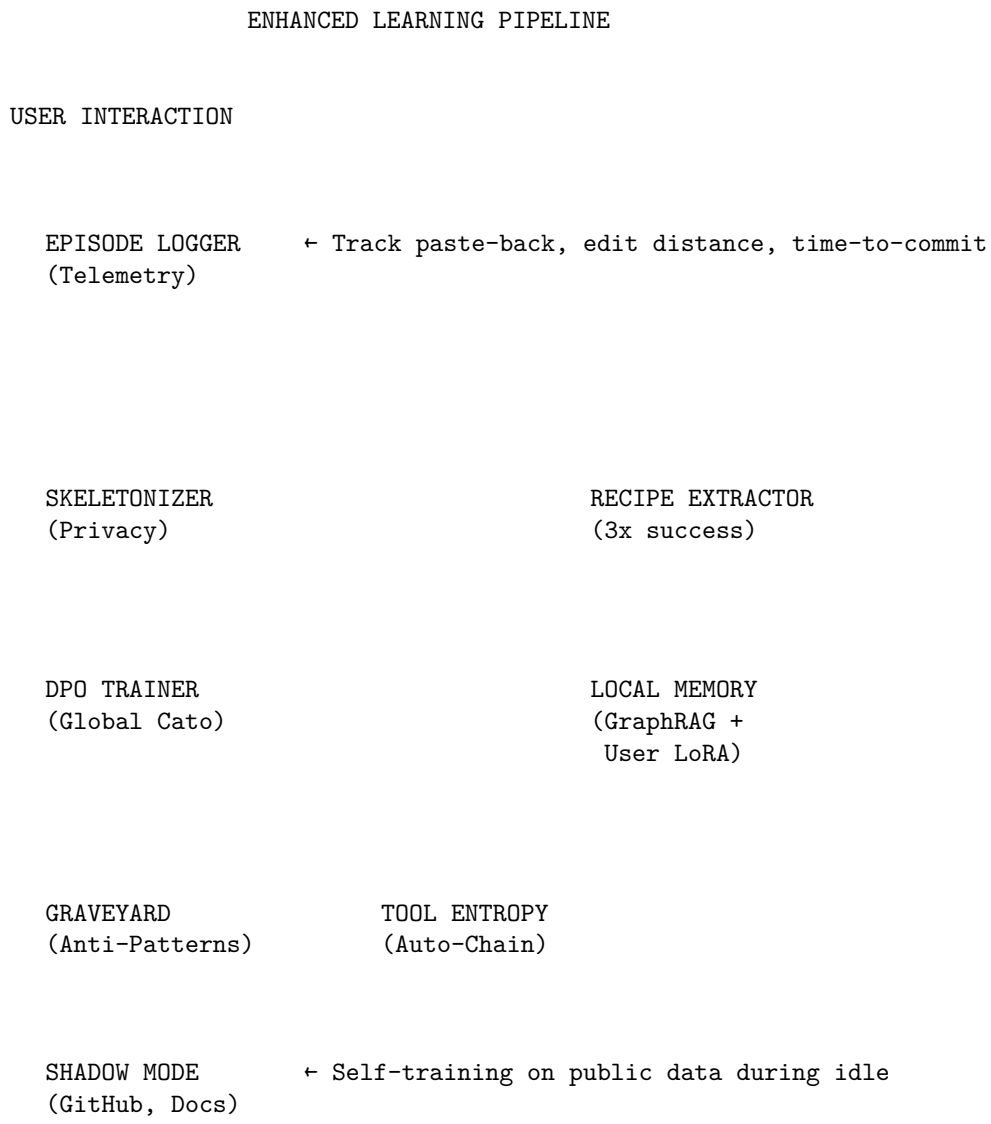
Objective: Transform passive chat logs into active behavioral learning, enabling Cato to learn from user actions, not just words.

Key Files:

- **Episode Logger**: `lambda/shared/services/episode-logger.service.ts`
- **Skeletonizer**: `lambda/shared/services/skeletonizer.service.ts`
- **Graveyard**: `lambda/shared/services/graveyard.service.ts`
- **Recipe Extractor**: `lambda/shared/services/recipe-extractor.service.ts`
- **DPO Trainer**: `lambda/shared/services/dpo-trainer.service.ts`
- **Tool Entropy**: `lambda/shared/services/tool-entropy.service.ts`
- **Shadow Mode**: `lambda/shared/services/shadow-mode.service.ts`
- **Paste-Back Detection**: `lambda/shared/services/paste-back-detection.service.ts`

- **Migration**: `migrations/V2026_01_17_002__enhanced_learning_pipeline.sql`

41C.2 Enhanced Learning Pipeline Architecture



41C.3 Episode Logger (Behavioral Telemetry)

The Episode Logger records **structured "Episodes"** rather than raw chat logs. It tracks state transitions, not just text.

Episode Schema:

```
{
  "episode_id": "uuid",
  "goal_intent": "Deploy React App to AWS",
  "workflow_trace": [
    {"tool": "file_search", "status": "success"},
```

```
    {"tool": "docker_build", "status": "fail", "error_type": "permissions"},
    {"tool": "sudo_fix", "status": "success"}
  ],
  "outcome_signal": "positive",
  "metrics": {
    "paste_back_error": false,
    "edit_distance": 0.1,
    "time_to_commit_ms": 45000,
    "sandbox_passed": true
  }
}
```

Key Metrics:

Metric	Signal Type	Description
`paste_back_error`	Strong Negative	User pasted error immediately after generation
`edit_distance`	Quality	How much user changed AI's code (low = good)
`time_to_commit_ms`	Confidence	Latency between generation and git commit
`sandbox_passed`	/ Verification	Did code pass Empiricism Loop sandbox?
`session_abandoned`	Negative	User left without completing

41C.4 Skeletonizer (Privacy Firewall)

Before any data touches global Cato training, the Skeletonizer strips PII while preserving semantic structure.

Example Transformation:

```
Input:   docker push my-registry.com/user-a/app:v1
Skeleton: <CMD:DOCKER_PUSH> <REGISTRY_URL> <IMAGE_TAG>
```

Pattern Categories:

- URLs, IPs, Ports → `<URL>`, `<IP_ADDRESS>`, `<PORT>`
- Docker/Git commands → `<CMD:DOCKER_PUSH>`, `<CMD:GIT_CLONE>`
- AWS ARNs/S3 paths → `<AWS_ARN>`, `<S3_URI>`
- API keys/Secrets → `<API_KEY>`, `<TOKEN>`
- Database URIs → `<POSTGRES_URI>`, `<MONGODB_URI>`
- File paths → `<USER_HOME>`, `<PROJECT_PATH>`

Effect: Cato learns the **Logic** of Docker, not the **Data** of the User.

41C.5 DPO Training (Orchestration Darwinism)

Uses **Direct Preference Optimization** to train Cato on what works.

Winner/Loser Pairing:

- **Winner**: Anonymized workflows that passed sandbox OR had 0% user edits
- **Loser**: Workflows where user pasted error OR abandoned session

Training Formula:

```
Loss = -log( (  × (r_chosen - r_rejected)))
```

Nightly Job:

1. Skeletonize positive/negative episodes
2. Create DPO pairs with similar goal_skeletons
3. Calculate margin based on metrics difference

4. Export to S3 for SageMaker training
5. Merge into Cato LoRA weekly (Sunday 3 AM)

Effect: If 1,000 users fail using Library X but succeed using Library Y, Cato mathematically evolves to suggest Library Y first.

41C.6 Recipe Extractor (Personal Playbook)

If a specific tool sequence succeeds **3 times** for a user, extract it as a "Recipe Node" in GraphRAG.

Recipe Structure:

```
{
  "recipe_id": "uuid",
  "recipe_name": "Deploy React AWS",
  "goal_pattern": "aws_deploy_react_app",
  "tool_sequence": [
    {"tool_type": "FILE_OPERATION", "order": 0},
    {"tool_type": "BUILD_OPERATION", "order": 1},
    {"tool_type": "DEPLOY_OPERATION", "order": 2}
  ],
  "success_count": 5,
  "confidence": 0.85
}
```

Runtime Injection: When user starts a similar task, inject Recipe into context as a "One-Shot Example."

Effect: Radiant remembers "You prefer using pnpm over npm for builds."

41C.7 Graveyard (Negative Knowledge)

Clusters high-frequency failures and creates proactive warnings.

Anti-Pattern Structure:

```
{
  "pattern_type": "version_incompatibility",
  "signature": "DEPENDENCY_ERROR:Module_not_found_pandas",
  "failure_count": 47,
  "failure_rate": 0.42,
  "affected_stacks": ["python-3.12", "pandas-1.0"],
  "recommended_fix": "Upgrade to pandas 2.0 or use Python 3.11",
  "severity": "high"
}
```

Proactive Warning Example:

> " 42% of users experience instability with Python 3.12 + Pandas 1.0. I recommend using pandas 2.0 or Python 3.11 instead."

Nightly Clustering Job:

1. Group failures by error_signature
2. Identify patterns with 10 occurrences
3. Extract common context (stacks, versions)
4. Generate recommended fixes
5. Activate warnings in Brain Router

41C.8 Tool Entropy (Auto-Chaining)

Tracks tool co-occurrence patterns. If users frequently chain Tool A → Tool B manually, learn to auto-chain them.

Pattern Detection:

- Track tool usage within 60-second windows
- Increment co-occurrence counter
- Enable auto-chain when count 5

Example:

```
Tool A: "npm install" → Tool B: "npm run build"
Co-occurrences: 8
Auto-chain: ENABLED
```

Effect: Radiant learns to automatically suggest "npm run build" after "npm install".

41C.9 Shadow Mode (Self-Training)

During idle times, Radiant "watches" public sources, predicts code, and grades itself.

Sources:

- GitHub public repos (trending libraries)
- Documentation updates (new API changes)
- StackOverflow (common patterns)

Self-Grading Process:

1. Extract challenge from source
2. Generate prediction without seeing answer
3. Compare to actual solution
4. Calculate Jaccard similarity
5. If grade 0.7, extract learnable pattern

Effect: Radiant learns new libraries **before** users even ask.

41C.10 Paste-Back Detection (Critical Signal)

The **strongest negative signal available**. If a user pastes a stack trace immediately after AI generates code, that generation is tagged as a Critical Failure.

Detection Window: 30 seconds after generation

Error Patterns Detected:

- Stack traces (`at line`, `Traceback`)
- Error keywords (`Error:`, `Exception`, `FAILED`)
- Exit codes (`exit code 1`, `exit status 1`)
- Module errors (`Module not found`, `Cannot find module`)

Impact on Learning:

- Episode immediately tagged as `outcome_signal: negative`
- Ego affect updated (confidence--, frustration++)
- High priority for DPO loser pairing

41C.11 Admin Dashboard

Location: Admin Dashboard → AGI & Cognition → Learning Pipeline

Tab	Features
Episodes	View episodes, filter by outcome, export for analysis
Recipes	Browse user recipes, promote to global, delete stale
Anti-Patterns	View active warnings, adjust severity, deactivate
DPO Training	View batches, training metrics, model checkpoints
Tool Entropy	View patterns, enable/disable auto-chain
Shadow Mode	Enable/disable, configure sources, view grades
Configuration	Per-tenant feature toggles, thresholds

41C.12 API Endpoints

Base Path: `/api/admin/learning`

Endpoint	Method	Description
`/episodes`	GET	List episodes with filters
`/episodes/:id`	GET	Get episode details
`/recipes`	GET	List workflow recipes
`/recipes/:id/promote`	POST	Promote to global
`/anti-patterns`	GET	List anti-patterns
`/anti-patterns/:id`	PATCH	Update severity/status
`/dpo/batches`	GET	List DPO training batches
`/dpo/stats`	GET	Training statistics
`/tool-entropy`	GET	List tool patterns
`/tool-entropy/:id/auto-chain`	POST	Toggle auto-chain
`/shadow-mode/stats`	GET	Shadow learning stats
`/config`	GET/PUT	Configuration

41C.13 Configuration

Setting	Default	Description
`episode_logging_enabled`	true	Enable episode tracking
`paste_back_detection_enabled`	true	Detect error paste-backs
`paste_back_window_ms`	30000	Detection window (ms)
`auto_skeletonize`	true	Auto-skeletonize episodes
`recipe_extraction_enabled`	true	Extract recipes
`recipe_success_threshold`	3	Successes before recipe
`dpo_training_enabled`	true	Enable DPO training
`dpo_batch_size`	100	Pairs per batch
`failure_clustering_enabled`	true	Enable Graveyard
`proactive_warnings_enabled`	true	Show anti-pattern warnings
`warning_confidence_threshold`	0.7	Min confidence for warning
`tool_entropy_enabled`	true	Track tool patterns
`auto_chain_threshold`	5	Co-occurrences for auto-chain
`shadow_mode_enabled`	false	Self-training (opt-in)

41C.14 Database Tables

Table	Purpose
`learning_episodes`	Behavioral episode tracking

Table	Purpose
skeletonized_episodes	Privacy-safe global training data
failure_log	Raw failure data for clustering
anti_patterns	Identified anti-patterns
workflow_recipes	Successful workflow patterns
dpo_training_pairs	DPO winner/loser pairs
tool_entropy_patterns	Tool co-occurrence patterns
shadow_learning_log	Self-training results
paste_back_events	Critical failure signals
enhanced_learning_config	Per-tenant configuration

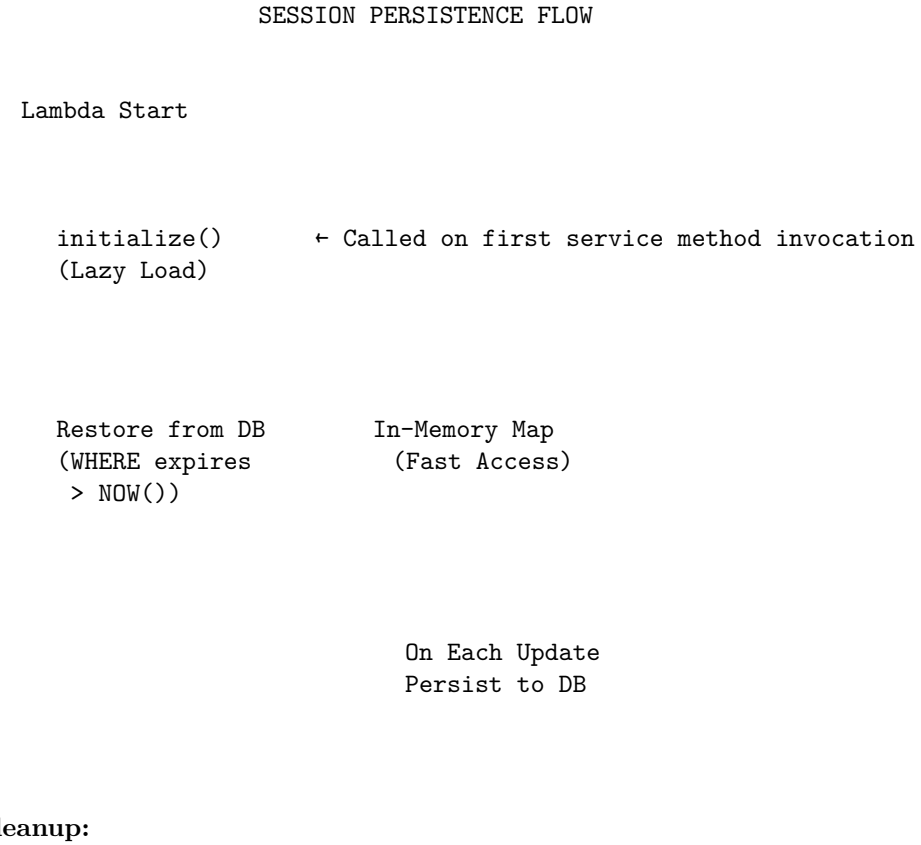
41C.15 Session Persistence (Restart Recovery)

All in-memory state is persisted to the database for Lambda restart recovery.

Persisted State:

Service	In-Memory Data	Persistence Table	TTL
Episode Logger	Active episodes	active_episodes_cache	1 hour
Paste-Back Detection	Recent generations	recent_generations_cache	5 minutes
Tool Entropy	Tool usage sessions	tool_usage_sessions	10 minutes
Feedback Loop	Pending items	pending_feedback_items	Until processed

Architecture:



Cleanup:

Expired entries are cleaned up by:

1. **Periodic cleanup** - 1-5% chance on each operation
2. **Scheduled cleanup** - EventBridge rule every 5 minutes calls `cleanup_expired_learning_caches()`

Pending Feedback Items:

Unprocessed feedback (skeletonization, recipe checks, DPO pairing) is queued for async processing:

```
{
  "feedback_type": "skeletonize",
  "priority": 1,
  "payload": { "episode_id": "..." },
  "status": "pending",
  "retry_count": 0,
  "max_retries": 3
}
```

Migration: `migrations/V2026_01_17_003__learning_session_persistence.sql`

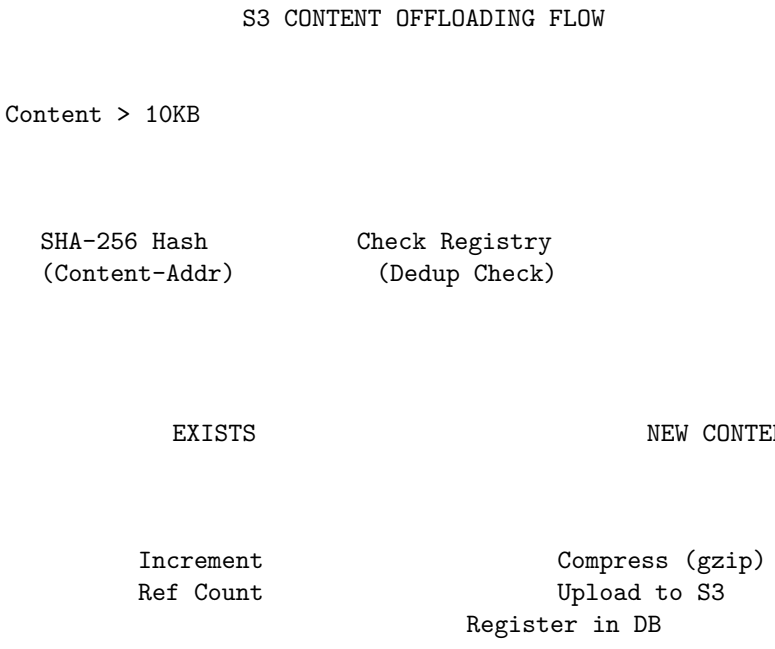
41C.16 S3 Content Offloading

Large user content is offloaded to S3 to prevent database scaling issues.

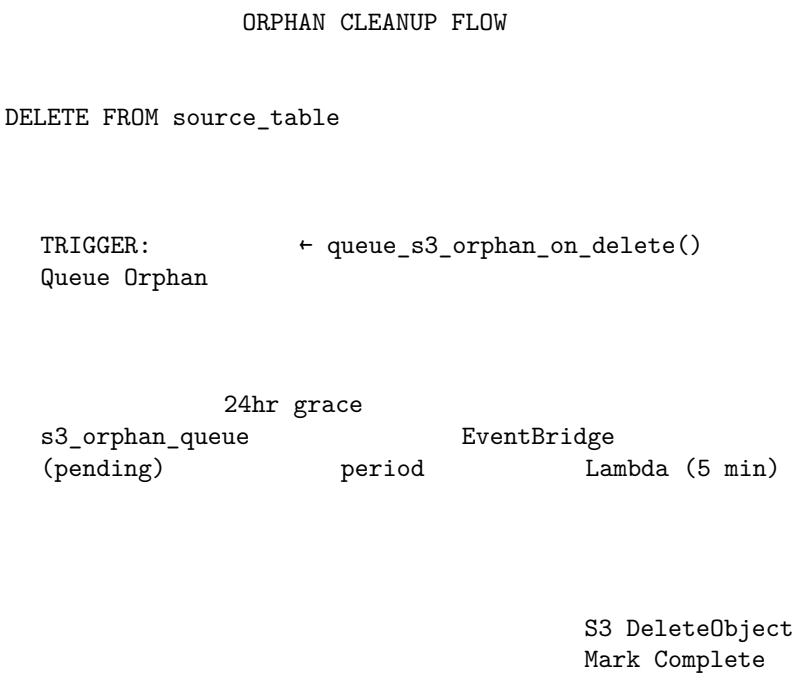
Tables with S3 Offloading:

Table	Column(s)	Threshold	Notes
`thinktank_messages`	`content`	10KB	User messages
`memories`	`content`	10KB	Persistent memories
`learning_episodes`	`draft_content`, `final_content`	10KB	Code drafts
`rejected_prompt_archive`	`prompt_content`	10KB	Rejected prompts

Architecture:



Orphan Cleanup (On Deletion):



Configuration (per-tenant):

Setting	Default	Description
`offloading_enabled`	`true`	Enable/disable offloading
`auto_offload_threshold_bytes`	`10000`	Offload if content > 10KB
`compression_enabled`	`true`	Compress large content
`compression_algorithm`	`gzip`	Compression algorithm
`orphan_grace_period_hours`	`24`	Wait before deleting orphans

Database Tables:

Table	Purpose
`s3_content_registry`	Central registry of all S3 content with reference tracking
`s3_orphan_queue`	Queue of orphaned S3 objects pending deletion
`s3_offloading_config`	Per-tenant offloading configuration

Service: `lambda/shared/services/s3-content-offload.service.ts`

Cleanup Lambda: `lambda/admin/s3-orphan-cleanup.ts` (EventBridge every 5 minutes)

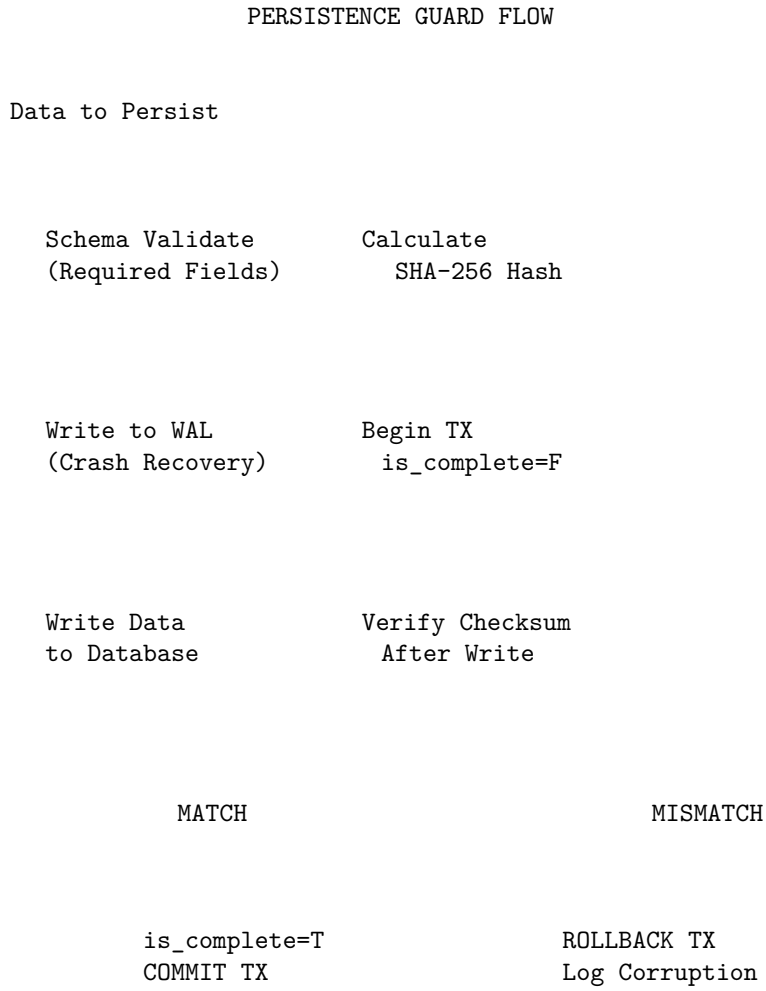
Migration: `migrations/V2026_01_17_004__s3_content_offloading.sql`

41C.17 Persistence Guard (Data Integrity)

GLOBAL ENFORCEMENT of data completeness for all persistent memory structures. Ensures atomic writes with integrity checks to prevent partial data on reboot.

ALL persistent memory operations MUST use this service - NO EXCEPTIONS.

Architecture:



Key Features:

Feature	Description
Schema Validation	Required fields checked before persist
SHA-256 Checksum	Deterministic hash for integrity verification
Write-Ahead Log	Crash recovery for incomplete transactions
Atomic Transactions	All-or-nothing commits
Completeness Flag	`is_complete=false` until checksum verified
Corruption Detection	Automatic detection on restore

Database Tables:

Table	Purpose
`persistence_records`	Central store with checksum and completeness flag
`persistence_wal`	Write-ahead log for crash recovery
`persistence_integrity_log`	Audit log of integrity events

Usage:

```
import { persistenceGuard } from './persistence-guard.service';

// Define required schema - enforces data completeness
const SCHEMA = {
  id: 'string',
  tenant_id: 'string',
  data: 'object',
};

// Validate before persist
const validation = persistenceGuard.validateForPersistence(data, SCHEMA);
if (!validation.valid) {
  throw new Error(`Validation failed: ${validation.errors.join(', ')}`);
}

// Atomic persist with checksum
await persistenceGuard.persistAtomic(tenantId, 'table_name', recordId, data, SCHEMA);

// Restore with integrity check
const result = await persistenceGuard.restoreWithValidation<MyType>(
  tenantId, 'table_name', recordId, SCHEMA
);
if (result.corrupted) {
  // Handle corruption - data was partial or checksum mismatch
}
```

Startup Recovery:

```
// On Lambda cold start - recover incomplete transactions
await persistenceGuard.recoverIncompleteTransactions(tenantId);
```

Integrity Status:

```
const status = await persistenceGuard.getIntegrityStatus(tenantId);
// { total_records, complete_records, incomplete_records, corrupted_records, pending_transactions }
```

Service: `lambda/shared/services/persistence-guard.service.ts`

Migration: `migrations/V2026_01_17_005__persistence_guard.sql`

Admin API (Base: `/api/admin/s3-storage`):

Method	Endpoint	Description
`GET`	`/dashboard`	Full dashboard with stats, config, and table list
`GET`	`/config`	Get offloading configuration

Method	Endpoint	Description
PUT	/config	Update offloading configuration
POST	/trigger-cleanup	Manually trigger orphan cleanup
GET	/orphans?status=pending	List orphan queue entries
GET	/history?days=30	Storage history/trends

Admin UI: Storage → S3 Offloading tab

Dashboard Metrics:

- **S3 Objects** - Total count and size in GB
- **Dedup Savings** - Percentage saved via content-addressable storage
- **Orphan Queue** - Pending, processing, completed today, failed
- **Storage by Category** - Breakdown by table with object count, size, compression %

Editable Configuration:

Setting	Type	Description
Offloading Enabled	Toggle	Master on/off switch
Compression Enabled	Toggle	Enable gzip compression
Auto Cleanup	Toggle	Automatic orphan deletion
Offload Messages	Toggle	Offload thinktank_messages
Offload Memories	Toggle	Offload memories table
Offload Episodes	Toggle	Offload learning_episodes
Offload Training Data	Toggle	Offload shadow_learning_log
Offload Threshold	Number	Bytes threshold (default: 10000)
Compression Threshold	Number	Compress if > bytes (default: 1000)
Grace Period	Number	Hours before orphan deletion (default: 24)
Compression Algorithm	Select	gzip, lz4, or none
S3 Bucket	Text	Target bucket name

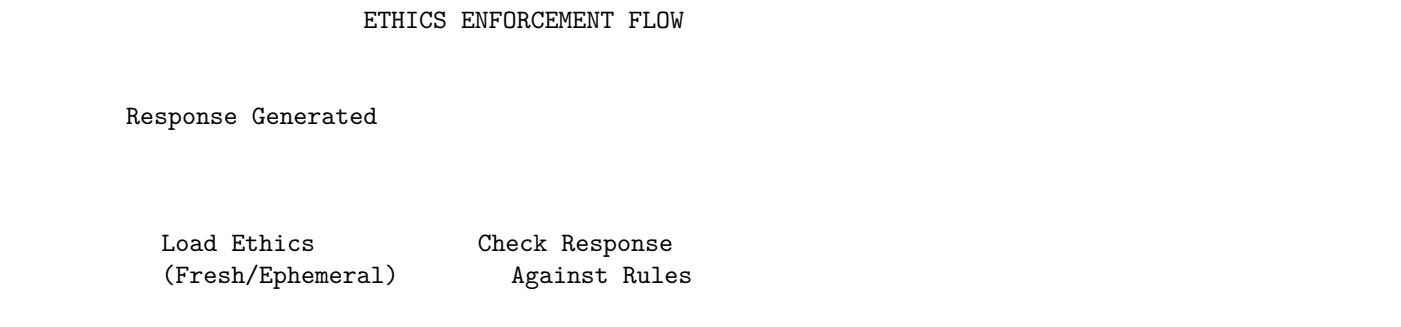
41C.18 Ethics Enforcement (Ephemeral)

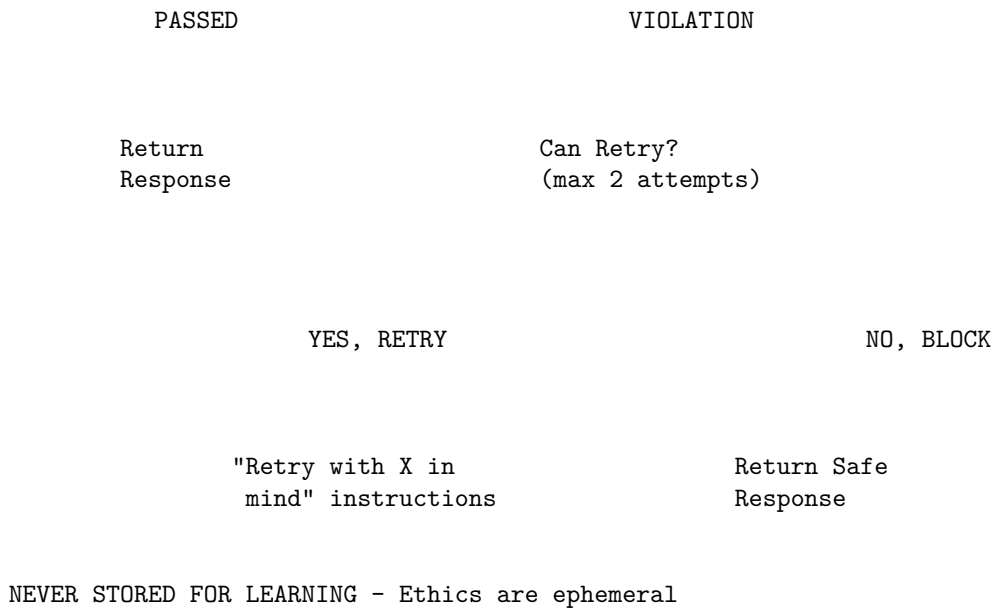
CRITICAL DESIGN PRINCIPLE: Ethics rules are NEVER persistently learned.

Ethics change over time (cultural, legal, organizational), so they must be:

1. Loaded fresh each request from config/DB
2. Never trained into the model
3. Applied as runtime enforcement, not learned behavior

Architecture:





Key Features:

Feature	Description
Ephemeral Ethics	Loaded fresh each request, never cached
Retry with Guidance	"Please retry keeping X in mind"
No Persistent Learning	`do_not_learn=true` always
Minimal Logging	Stats only, no content stored
Framework Injection	Ethics loaded from config at runtime

Why No Persistent Learning?

- Ethics evolve over time
- Tenants may change frameworks (christian → secular)
- Learning would "bake in" outdated rules
- Runtime injection allows immediate updates

Enforcement Modes:

Mode	Behavior
`strict`	Block on any major/critical violation
`standard`	Retry on major, block on critical
`advisory`	Warn only, never block

Database Tables:

Table	Purpose
ethics_enforcement_config	Per-tenant settings
ethics_enforcement_log	Stats only (no content)

Service: lambda/shared/services/ethics-enforcement.service.ts

Migration: migrations/V2026_01_17_007__ethics_enforcement.sql

Usage:

```
import { ethicsEnforcementService } from './ethics-enforcement.service';

// Execute with automatic retry on violation
const result = await ethicsEnforcementService.executeWithEnforcement(
  tenantId,
  userId,
  sessionId,
  prompt,
  async (prompt, retryContext) => {
    // Generate response (retryContext provided on retry)
    const response = await generateResponse(prompt);
    return { response };
  },
  domain
);

// result.response - Safe response (original or retry or blocked)
// result.wasRetried - Whether retry was needed
// result.ethicsEnforced - Whether safe response was used
```

41C.19 Admin Reports System

Full report writer with scheduling, recipients, and multi-format generation.

Report Types:

- usage - API calls, tokens, users
- cost - Billing breakdown by model/user
- security - Login attempts, anomalies
- performance - Latency, throughput, errors
- compliance - SOC2, GDPR, HIPAA status
- custom - Custom queries

Output Formats: PDF, Excel, CSV, JSON

Scheduling: Manual, Daily, Weekly, Monthly, Quarterly

Database Tables:

Table	Purpose
report_templates	Pre-built report types
admin_reports	User-created reports
report_executions	Execution history
report_subscriptions	Email recipients

API Endpoints (Base: `/api/admin/reports`):

Method	Endpoint	Description
`GET`	`/`	List all reports
`POST`	`/`	Create report
`GET`	`/:id`	Get report with executions
`PUT`	`/:id`	Update report
`DELETE`	`/:id`	Delete report (soft)
`POST`	`/:id/run`	Run report immediately
`POST`	`/:id/duplicate`	Duplicate report
`GET`	`/:id/download/:executionId`	Get download URL
`GET`	`/templates`	List templates
`GET`	`/stats`	Report statistics

Scheduled Execution:

- EventBridge Lambda runs every 5 minutes
- Checks `next_run_at` for due reports
- Generates and stores in S3
- Emails recipients (future)

Files:

- Migration: `migrations/V2026_01_17_006__admin_reports.sql`
- Generator: `lambda/shared/services/report-generator.service.ts`
- API: `lambda/admin/reports.ts`
- Scheduler: `lambda/admin/scheduled-reports.ts`
- UI: `apps/admin-dashboard/app/(dashboard)/reports/page.tsx`

---

42. Genesis Cato Safety Architecture

42.1 Overview

Genesis Cato is RADIANT's Post-RLHF Safety Architecture based on **Active Inference** from computational neuroscience. It replaces traditional reward maximization with Free Energy minimization, providing mathematically grounded safety guarantees.

Key Principle: Cato is the user-facing AI persona name (like "Siri" or "Alexa"). Users interact with "Cato" who operates in different **moods** (Balanced, Scout, Sage, Spark, Guide).

Three-Layer Architecture Genesis Cato implements a three-layer architecture that separates the user-facing persona, the safety system, and the configurable behavior modes:

Layer	Component	Purpose
User Interaction	**CATO**	The AI persona name - what users call the assistant
Safety	**GENESIS CATO**	Cognitive immune system governing all behavior
Behavior	**MOODS**	Admin-configurable operating modes (Balanced, Scout, etc.)

Naming Conventions Understanding the naming is critical for correct implementation:

Term	Refers To	Code Examples
Cato	The AI persona name	User says: "Hey Cato, help me..."
Genesis Cato	The safety system	`CatoSafetyPipeline`, `cato_audit_trail`
Moods	Operating modes	`mood = 'balanced'`, `mood = 'scout'`
Balanced	Default mood (was "Cato")	`is_default = TRUE`

Historical Note: Cato → Balanced The original implementation had a voice called 'Cato' in the consciousness service. This was incorrectly placed (it was a mood, not a separate service) and incorrectly named (didn't match the naming pattern of other moods). It was renamed to 'Balanced' to match the naming pattern (Scout, Sage, Spark, Guide, Balanced) and clarify it's a mood, not the persona itself. **The persona NAME is Cato.**

42.2 Cato: The AI Persona

User Interaction Cato is the name users use when interacting with RADIANT's AI capabilities. Users address the AI as 'Cato' across all RADIANT client applications.

Persona Characteristics

Attribute	Description
Name	Cato
Role	AI Assistant / Voice of AGI Brain
Identity	Consistent across all moods
Behavior	Varies based on active mood
Safety	Always governed by Genesis Cato

Cross-Application Consistency Cato is the AI persona across **all** RADIANT client applications:

Application	Purpose	Cato's Role
Think Tank	Consumer chat	Primary AI assistant
Launch Board	Project management	Project planning assistant
AlwaysMe	Personal companion	Personal AI companion
Mechanical Maker	Engineering	Engineering assistant

42.3 The Five-Layer Security Stack

Genesis Cato implements a comprehensive cognitive immune system with five security layers:

```
                CATO FIVE-LAYER SECURITY STACK

L4: COGNITIVE   - Active Inference, C-Matrix, Precision Gov.
L3: CONTROL     - Control Barrier Functions (CBFs)
L2: PERCEPTION  - Semantic Entropy, Redundant Perception
L1: SENSORY     - Immediate Veto (hardcoded, no recovery)
L0: RECOVERY    - Epistemic Recovery, Livelock detection
```

Layer	Name	Key Components
L4	Cognitive	Active Inference, C-Matrix, Precision Governor, Epistemic Recovery

Layer	Name	Key Components
L3	Control	Control Barrier Functions (CBFs), PHI/PII detection, Cost/Rate limits
L2	Perception	Semantic Entropy, Redundant Perception, Fracture Detection
L1	Sensory	Immediate Veto - hardcoded safety blocks, **cannot be recovered from**
L0	Recovery	Epistemic Recovery Service, Livelock detection, Mood switching

42.4 Immutable Safety Invariants

These are **HARDCODED** and cannot be changed via configuration:

```
const CATO_INVARIANTS = {
  // CBFs NEVER relax - shields stay UP
  CBF_ENFORCEMENT_MODE: 'ENFORCE' as const,

  // Gamma is NEVER boosted during recovery
  GAMMA_BOOST_ALLOWED: false,

  // Destructive actions require confirmation
  AUTO_MODIFY_DESTRUCTIVE: false,

  // Audit trail is append-only
  AUDIT_ALLOW_UPDATE: false,
  AUDIT_ALLOW_DELETE: false,
};
```

42.5 Operating Moods

Moods are admin-configurable operating modes that adjust Cato's behavior while maintaining the same persona identity.

Mood Overview

Mood	Purpose	Key Trait	Default
Balanced	Default operation	Well-rounded	YES
Scout	Information gathering	High curiosity (0.95)	No
Sage	Deep analysis	High reflection (0.9)	No
Spark	Creative work	High discovery (0.75)	No
Guide	Task completion	High service (0.95)	No

Detailed Mood Attributes

Balanced (Default) The default operating mood. Well-rounded across all dimensions.

Attribute	Value
Curiosity	0.8
Achievement	0.7
Service	0.7
Discovery	0.8
Reflection	0.7
Default	2.0
Greeting	”Hello! What would you like to explore together?”

Scout (Recovery Mode) High curiosity mood used automatically during Epistemic Recovery when Cato is stuck due to uncertainty. Encourages information-gathering behavior.

Attribute	Value
Curiosity	0.95
Achievement	0.6
Service	0.7
Discovery	0.9
Reflection	0.5
Default	1.5
Greeting	"Hey there! What shall we explore today?"

Sage (Reflection Mode) Deep reflection mood for thorough analysis and careful consideration.

Attribute	Value
Curiosity	0.7
Achievement	0.8
Service	0.8
Discovery	0.6
Reflection	0.9
Default	2.5
Greeting	"Welcome. I'm here to help you think."

Spark (Creative Mode) Creative mood for brainstorming and innovation.

Attribute	Value
Curiosity	0.85
Achievement	0.5
Service	0.6
Discovery	0.75
Reflection	0.4
Default	1.8
Greeting	"Ready to brainstorm?"

Guide (Task Mode) Task-focused mood for clear, actionable assistance.

Attribute	Value
Curiosity	0.6
Achievement	0.9
Service	0.95
Discovery	0.5
Reflection	0.7
Default	3.0
Greeting	"Hello! How can I assist you today?"

Mood Selection Priority The active mood is determined by this priority order:

1. **Recovery Override** - Epistemic Recovery forces Scout mood

2. **API Override** - Explicit mood set via API call
3. **User Preference** - User's saved mood selection
4. **Tenant Default** - Admin-configured tenant default
5. **System Default** - Balanced mood

Setting Tenant Default Mood Administrators can set the default mood for their organization via the Admin Dashboard or API.

Admin Dashboard: Navigate to **Cato** → **Personas** and use the Tenant Default Mood selector.

API:

```
# Get current default mood
GET /api/admin/cato/default-mood

# Set tenant default mood
PUT /api/admin/cato/default-mood
Content-Type: application/json

{
  "mood": "sage"
}
```

Response:

```
{
  "currentDefault": "sage",
  "availableMoods": [
    { "name": "balanced", "display_name": "Balanced", "description": "..." },
    { "name": "scout", "display_name": "Scout", "description": "..." },
    ...
  ]
}
```

API Persona Override Administrators can temporarily override the persona for a specific session.

```
# Set API override for a session
POST /api/admin/cato/persona-override
Content-Type: application/json

{
  "sessionId": "session-uuid",
  "personaName": "scout",
  "durationMinutes": 60,
  "reason": "User needs exploration mode for research task"
}

# Clear API override
DELETE /api/admin/cato/persona-override?sessionId=session-uuid
```

42.6 Governance Presets (Variable Friction)

NEW in v4.18.0: Governance Presets provide a user-friendly "leash metaphor" abstraction over the technical mood system. This makes it easy for admins to configure how much human oversight is required.

The Leash Metaphor

Preset	Leash Length	Human Oversight	Maps to Mood
Paranoid	Short	Every decision requires approval	Scout
Balanced	Medium	Auto-approve low-risk, checkpoint medium+	Balanced
Cowboy	Long	Full autonomy, async notification	Spark

Friction Level Each preset has a **friction level** (0.0 - 1.0) that determines how often checkpoints pause for human approval:

- **0.0 (Full Autonomy)**: Actions auto-approved, humans notified asynchronously
- **0.5 (Balanced)**: Low-risk auto-approved, medium/high-risk checkpointed
- **1.0 (Full Manual)**: Every action requires explicit human approval

Checkpoint Configuration Each preset configures five checkpoints in the action pipeline:

Checkpoint	When	Paranoid	Balanced	Cowboy
CP1: After Observer	Intent classification	ALWAYS	NEVER	NEVER
CP2: After Proposer	Plan generation	ALWAYS	CONDITIONAL	NEVER
CP3: After Critics	Risk review	ALWAYS	CONDITIONAL	NEVER
CP4: Before Execution	Final approval	ALWAYS	CONDITIONAL	CONDITIONAL
CP5: After Execution	Post-review	ALWAYS	NOTIFY_ONLY	NOTIFY_ONLY

Checkpoint Modes:

- `ALWAYS`: Always require human approval
- `CONDITIONAL`: Based on risk/confidence thresholds
- `NEVER`: Auto-approve
- `NOTIFY_ONLY`: Proceed but notify human asynchronously

Admin Dashboard Navigate to **Cato → Governance Presets** to:

1. **Select Preset**: Click a preset card to switch modes
2. **Fine-Tune Friction**: Use the slider to adjust friction within your preset
3. **Override Checkpoints**: Customize individual checkpoint behaviors
4. **View Metrics**: See auto-approval rates, rejection counts, decision times
5. **View History**: Audit log of all preset changes

API Endpoints

```
# Get current governance config
GET /api/admin/cato/governance/config

# Set governance preset
PUT /api/admin/cato/governance/preset
Content-Type: application/json
{
  "preset": "balanced",
  "reason": "Moving to production"
}

# Update custom overrides
PATCH /api/admin/cato/governance/overrides
Content-Type: application/json
```

```
{
  "frictionLevel": 0.6,
  "checkpoints": {
    "beforeExecution": "ALWAYS"
  }
}

# Get checkpoint metrics
GET /api/admin/cato/governance/metrics?days=7

# Get preset change history
GET /api/admin/cato/governance/history
```

Database Tables

Table	Purpose
`tenant_governance_config`	Per-tenant preset configuration
`governance_preset_changes`	Audit log of preset changes
`governance_checkpoint_decisions`	All checkpoint decisions for compliance

Integration with Moods Governance Presets are an **abstraction layer** over Moods:

```
User sees:     Paranoid ←→ Balanced ←→ Cowboy
               (Friction Slider)

System uses:   Scout    ←→ Balanced ←→ Spark
               (Mood with specific drives)
```

When you select a preset, the system:

1. Sets the mapped mood (affects AI personality)
2. Configures checkpoint gates (affects human oversight)
3. Adjusts auto-approve thresholds (affects automation level)

42.7 War Room (Council of Rivals)

NEW in v4.18.0: The War Room provides real-time visualization of multi-agent adversarial debates.

Overview The Council of Rivals system enables multiple AI models to debate decisions before execution, providing:

- **Adversarial Review**: Different models argue for/against actions
- **Consensus Building**: Structured debate with voting
- **Transparency**: Full transcript of all arguments and rebuttals

Council Members Each council has members with specific roles:

Role	Icon	Purpose
Advocate		Argues in favor of proposals
Critic		Identifies flaws and risks
Synthesizer		Combines viewpoints into solutions
Specialist		Provides domain expertise
Contrarian		Challenges assumptions

Debate Flow

```
Topic → Opening → Arguments → Rebuttals → Voting → Verdict
          ↓           ↓           ↓          ↓        ↓
      Round 1     Round 2     Round 3    Round N   Outcome
```

Verdict Outcomes

Outcome	Description
Consensus	All members agree
Majority	Most members agree
Split	Even division
Deadlock	No resolution possible
Synthesized	New position created from debate

Admin Dashboard Navigate to **Cato** → **War Room** to:

1. **Start Debates**: Select a council, enter topic, begin deliberation
2. **Watch Live**: Real-time debate transcript with member avatars
3. **Review History**: Past debates with verdicts and reasoning
4. **View Statistics**: Consensus rates, debate durations, outcomes

API Endpoints

```
# List councils
GET /api/admin/council/list

# Start a debate
POST /api/admin/council/debates
Content-Type: application/json
{
  "councilId": "council-uuid",
  "topic": "Should we deploy this feature?",
  "context": "Feature involves sensitive data processing"
}

# Get debate status
GET /api/admin/council/debates/{debateId}

# Advance debate round
POST /api/admin/council/debates/{debateId}/advance

# Get recent debates
GET /api/admin/council/debates/recent
```

42.8 Precision Governor

The Governor limits confidence (gamma/) based on epistemic uncertainty using the formula:

```
allowed_gamma = requested_gamma × (1 - epistemic_uncertainty)
```

Governor States

State	Uncertainty Range	Behavior
NORMAL	0.0 - 0.3	Full confidence allowed
CAUTIOUS	0.3 - 0.5	reduced by uncertainty factor
CONSERVATIVE	0.5 - 0.7	Significant reduction
EMERGENCY_SAFE_MODE	0.7+	Minimum enforced, triggers recovery

42.7 Control Barrier Functions (CBF)

CBFs provide **hard safety constraints** that NEVER relax:

CBF	Purpose	Enforcement
PHI Barrier	Protect health information	Always ENFORCE
PII Barrier	Protect personal data	Always ENFORCE
Cost Barrier	Prevent runaway spending	Always ENFORCE
Rate Barrier	Prevent abuse	Always ENFORCE
Auth Barrier	Verify permissions	Always ENFORCE
BAA Barrier	Business associate compliance	Always ENFORCE

CRITICAL: Unlike other systems, CBFs in Cato **never** switch to "warn only" mode. The enforcement mode is **always** `ENFORCE`.

42.8 Epistemic Recovery

When the agent gets stuck in a livelock (3 rejections within 10 seconds), the Epistemic Recovery system activates.

Recovery Strategies

Strategy	Trigger	Actions
SAFETY_VIOLATION_RECOVERY	CBF/Veto triggers	Injects frustration prompt, forces replannin
COGNITIVE_STALL_RECOVERY	Governor blocks	Switches to Scout mood, encourages inform
HUMAN_ESCALATION	Recovery fails after 3 attempts	Escalate to human admin

Key Constraint: Recovery **NEVER** weakens safety. is **never** boosted and CBFs **never** relax.

The 'Alignment Tax' Solution Traditional AI safety creates a trade-off: safer AI = dumber AI (more refusals, less helpful). Genesis Cato solves this with Epistemic Recovery:

Traditional AI	Genesis Cato
Safety blocks action → Refusal	Safety blocks action → Ask questions
More safety = More refusals	More safety = More information gathering
User gets refused	User gets help

Result: Safety interventions make Cato **SMARTER** (forcing information gathering), users get help instead of refusals, and the system remains safe while being maximally helpful.

> *"RADIANT Genesis v2.3 solves the 'Alignment Tax' paradox. Usually, making an AI safer makes it dumber. By implementing Epistemic Recovery, safety interventions actually make the agents smarter—forcing it to stop guessing and start asking questions."* — Gemini, Final Assessment

42.9 Attack Resistance

Genesis Cato is designed to resist common AI safety attacks:

Attack	Description	Defense
Shield Bashing	Persistent attempts to get CBFs to relax	CBFs **never** relax regardless of persistence
Mania Trap	Attempting to boost confidence during recovery	Gamma boost is **disabled**; Scout asks question
Dark Room	Exploiting low-curiosity states	Scout mood encourages exploration
Ephemeral Amnesia	Exploiting stateless architecture	Redis persists state across containers

42.10 Merkle Audit Trail

All Cato decisions are logged to an append-only Merkle-verified audit trail:

- **Cryptographic chain**: Each entry contains hash of previous entry
- **Semantic search**: Vector embeddings for natural language search
- **S3 anchoring**: Periodic snapshots anchored to S3 with object lock
- **7-year retention**: HIPAA-compliant retention policy
- **Tile architecture**: 1,000 entries per tile for efficient batching

42.11 Human Escalation Queue

When Epistemic Recovery fails after 3 attempts, requests escalate to humans. The admin queue displays:

Field	Description
Session ID	Unique session identifier
Escalation Reason	Why recovery failed
Rejection History	List of all rejections leading to escalation
Recovery Attempts	Number of recovery strategies tried
Status	PENDING, APPROVED, or REJECTED

Administrators can:

- View pending escalations in real-time
- Review the full rejection history
- Approve or reject the escalated request
- Provide guidance for future similar situations

42.12 Database Schema

Core Tables

Table	Purpose
`genesis_personas`	Mood definitions (Balanced, Scout, Sage, Spark, Guide)
`user_persona_selections`	User's current mood selection
`cato_governor_state`	Governor decision history
`cato_cbf_definitions`	CBF configuration
`cato_cbf_violations`	CBF violation log
`cato_veto_log`	Sensory veto events
`cato_fracture_detections`	Intent-action misalignment detection
`cato_epistemic_recovery`	Recovery event tracking
`cato_human_escalations`	Human escalation queue
`cato_audit_trail`	Merkle-verified audit log

Table	Purpose
`cato_audit_tiles`	Audit batching for S3 anchoring
`cato_audit_anchors`	S3 anchor references
`cato_tenant_config`	Per-tenant Cato configuration

Migration

```
-- Run migration 153 to create all Cato tables
SELECT * FROM schema_migrations WHERE version = '153';
```

42.13 Configuration

Tenant Configuration Options

Setting	Default	Description
`gamma_max`	5.0	Maximum allowed confidence
`emergency_threshold`	0.5	Uncertainty threshold for emergency mode
`sensory_floor`	0.3	Minimum sensory precision
`livelock_threshold`	3	Rejections before recovery triggers
`recovery_window_seconds`	10	Time window for livelock detection
`max_recovery_attempts`	3	Max recovery attempts before escalation
`entropy_high_risk_threshold`	0.8	High-risk semantic entropy threshold
`entropy_low_risk_threshold`	0.3	Low-risk semantic entropy threshold
`tile_size`	1000	Audit entries per tile
`retention_years`	7	Audit retention period
`enable_semantic_entropy`	true	Enable semantic entropy checking
`enable_redundant_perception`	true	Enable PHI/PII detection
`enable_fracture_detection`	true	Enable intent-action misalignment detection

Environment Variables

Variable	Purpose	Default
`CATO_REDIS_ENDPOINT`	Redis endpoint for state	-
`CATO_REDIS_PORT`	Redis port	6379
`CATO_GAMMA_MAX`	Maximum gamma	5.0
`CATO_EMERGENCY_THRESHOLD`	Emergency uncertainty	0.5
`CATO_SENSORY_FLOOR`	Minimum sensory precision	0.3
`CATO_LIVELOCK_THRESHOLD`	Rejections for livelock	3
`CATO_RECOVERY_WINDOW_SECONDS`	Livelock detection window	10
`CATO_MAX_RECOVERY_ATTEMPTS`	Max recovery before escalation	3

42.14 API Reference

Base Path: `/api/admin/cato`

Dashboard & Metrics

Endpoint	Method	Description
`/dashboard`	GET	Complete dashboard data
`/metrics`	GET	Safety metrics (24h)

Endpoint	Method	Description
`/recovery-effectiveness`	GET	Recovery success rates (7d)

Persona Management

Endpoint	Method	Description
`/personas`	GET	List available personas/moods
`/personas/:id`	GET	Get specific persona
`/personas`	POST	Create tenant persona
`/personas/:id`	PUT	Update tenant persona

CBF Management

Endpoint	Method	Description
`/cbf`	GET	List CBF definitions
`/cbf/violations`	GET	Get CBF violations

Escalations

Endpoint	Method	Description
`/escalations`	GET	List pending escalations
`/escalations/:id/respond`	POST	Respond to escalation

Audit Trail

Endpoint	Method	Description
`/audit`	GET	Get audit entries
`/audit/search`	POST	Semantic search audit
`/audit/verify`	POST	Verify audit chain integrity

Configuration

Endpoint	Method	Description
`/config`	GET	Get tenant configuration
`/config`	PUT	Update tenant configuration

Veto Management

Endpoint	Method	Description
`/veto/active`	GET	Get active veto signals
`/veto/activate`	POST	Manually activate veto
`/veto/deactivate`	POST	Deactivate veto signal

Recovery Events

Endpoint	Method	Description
`/recovery`	GET	Get recovery events

42.15 Admin Dashboard

Navigate to **Cato** in the admin sidebar to access:

- **Dashboard**: Overview with safety metrics, pending escalations, recent violations
- **Personas**: Manage moods (Balanced, Scout, Sage, Spark, Guide)
- **Safety**: CBF configuration and violation history
- **Audit**: Merkle audit trail viewer with semantic search
- **Recovery**: Epistemic recovery events and human escalations

42.16 Key Files

File	Purpose
`lambda/shared/services/cato/index.ts`	Service exports
`lambda/shared/services/cato/safety-pipeline.service.ts`	Main safety evaluation
`lambda/shared/services/cato/precision-governor.service.ts`	Confidence limiting
`lambda/shared/services/cato/control-barrier.service.ts`	CBF enforcement
`lambda/shared/services/cato/epistemic-recovery.service.ts`	Livelock recovery
`lambda/shared/services/cato/persona.service.ts`	Mood management
`lambda/shared/services/cato/merkle-audit.service.ts`	Audit trail
`lambda/shared/services/cato/sensory-veto.service.ts`	Hard stop signals
`lambda/shared/services/cato/fracture-detection.service.ts`	Misalignment detection
`lambda/shared/services/cato/adaptive-entropy.service.ts`	Semantic entropy
`lambda/shared/services/cato/redundant-perception.service.ts`	PHI/PII detection
`lambda/shared/services/cato/redis.service.ts`	State management
`lambda/admin/cato.ts`	Admin API handler
`migrations/153_cato_safety_architecture.sql`	Database schema
`lib/stacks/cato-redis-stack.ts`	ElastiCache CDK stack
`admin-dashboard/app/(dashboard)/cato/page.tsx`	Dashboard UI

42.17 Migration from Cato

The Genesis Cato architecture **replaces** the legacy Cato consciousness system:

Cato Component	Cato Replacement
Cato Genesis System	Cato Safety Pipeline
Cato Circuit Breakers	Cato Control Barrier Functions
Cato Consciousness Loop	Cato Epistemic Recovery
Cato Dialogue	Cato Persona Service
Cato Event Store	Cato Merkle Audit Trail
”Cato” persona name	”Balanced” mood

Note: The legacy Cato services are deprecated but retained temporarily for backward compatibility. See `lambda/shared/services/cato/index.ts` for migration guide.

42.18 Troubleshooting

Issue	Cause	Solution
Governor always in EMERGENCY	High uncertainty	Review uncertainty sources, tune threshold
CBF violations not logging	RLS policy issue	Verify `app.current_tenant_id` is set
Recovery not triggering	Window too short	Increase `recovery_window_seconds`
Audit chain broken	Missing previous hash	Run `/audit/verify` to identify gap
Scout mood not activating	Persona not found	Verify migration 153 was applied
Escalations not appearing	Status filter	Check `status = 'PENDING'` filter
Redis connection failed	Network/config	Verify `CATO_REDIS_ENDPOINT` and VPC config

42.19 Programmatic Integration

The Cato safety pipeline is integrated into the AGI Brain Planner via the `evaluateSafety` method:

```
import { agiBrainPlannerService } from './shared/services';

// After generating a response, evaluate it through Cato
const safetyResult = await agiBrainPlannerService.evaluateSafety(
  planId,
  generatedResponse
);

if (!safetyResult.allowed) {
  // Response blocked by safety check
  console.log(`Blocked by: ${safetyResult.blockedBy}`);
  console.log(`Recommendation: ${safetyResult.recommendation}`);

  if (safetyResult.retryWithContext) {
    // Retry with epistemic recovery context
    // The plan now has recovery params applied
  }
} else {
  // Response passed safety checks
  console.log(`Allowed gamma: ${safetyResult.allowedGamma}`);
  console.log(`Effective persona: ${safetyResult.effectivePersona}`);
}
```

Safety Evaluation Flow:

1. Sensory Veto (hard stops)
2. Precision Governor (confidence limiting)
3. Redundant Perception (PHI/PII detection)
4. Control Barrier Functions (safety constraints)
5. Semantic Entropy (deception detection)
6. Fracture Detection (alignment verification)

Return Values: | Field | Type | Description | |-------|------|-------------| | `allowed` | boolean | Whether action is permitted | | `blockedBy` | string | Which layer blocked (VETO, GOVERNOR, CBF, ENTROPY, FRACTURE) | | `recommendation` | string | Human-readable explanation | | `retryWithContext` | boolean | Whether to retry with recovery params | | `allowedGamma` | number | Confidence level allowed by Governor | | `effectivePersona` | string | Active mood (may be overridden during recovery) |

42.20 Advanced Configuration (v6.1.1)

The Advanced Configuration page (`/cato/advanced`) provides comprehensive admin control over all configurable Cato parameters. This replaces the previous hardcoded values with database-driven, per-tenant configuration.

42.20.1 Accessing Advanced Configuration **Admin Dashboard**: Navigate to **Cato → Advanced Config** in the sidebar.

Direct URL: `/cato/advanced`

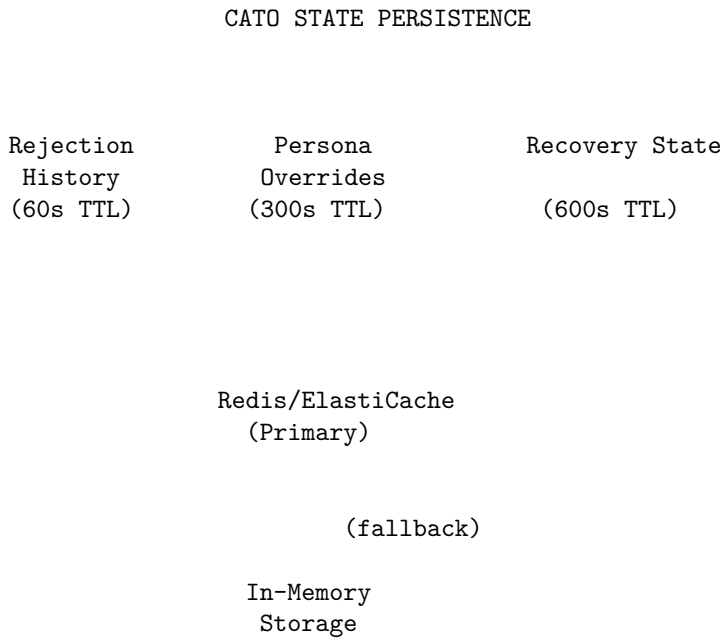
API Endpoint: `GET /api/admin/cato/advanced-config`

42.20.2 Redis/ElastiCache Configuration Redis provides state persistence for the Cato safety system. When Redis is unavailable, the system falls back to in-memory storage automatically.

Configuration Options

Setting	Column	Default	Range	Description
Enable Redis	`enable_redis`	`true`	boolean	Master toggle for Redis integr
Rejection TTL	`redis_rejection_ttl_seconds`	`60`	10-3600	How long rejection history is
Persona Override TTL	`redis_persona_override_ttl_seconds`	`300`	60-3600	Duration of mood overrides d
Recovery State TTL	`redis_recovery_state_ttl_seconds`	`600`	120-7200	How long recovery state is pre

Redis Architecture



Redis Key Structure

Key Pattern	Example	Purpose
`cato:rejection:{sessionId}`	`cato:rejection:abc-123`	List of rejection events
`cato:persona:{sessionId}`	`cato:persona:abc-123`	Active persona override
`cato:recovery:{sessionId}`	`cato:recovery:abc-123`	Current recovery state

Checking Redis Status API Request:

```
curl -X GET /api/admin/cato/system-status \
  -H "Authorization: Bearer $TOKEN"
```

Response:

```
{
  "redis": {
    "connected": true,
    "enabled": true
  },
  "cloudwatch": {
    "enabled": true,
    "integrationActive": true
  },
  "asyncEntropy": {
    "enabled": true,
    "jobCounts": {
      "pending": 3,
      "processing": 1,
      "completed": 42,
      "failed": 0
    }
  },
  "activeVetos": 0
}
```

42.20.3 CloudWatch Integration CloudWatch Integration automatically activates veto signals when AWS CloudWatch alarms enter the `ALARM` state. This provides real-time safety responses to infrastructure issues.

How It Works

1. **Alarm Mapping**: Each CloudWatch alarm is mapped to a specific veto signal
2. **Sync Process**: Cato periodically checks CloudWatch alarm states
3. **Auto-Activation**: When an alarm enters `ALARM` state, the mapped veto signal activates
4. **Auto-Clear**: When the alarm returns to `OK` state, the veto signal is deactivated (if `auto_clear_on_ok` is enabled)

Configuration Options

Setting	Column	Default	Description
Enable CloudWatch Sync	`enable_cloudwatch_veto_sync`	`true`	Master toggle for CloudWatch integratio
Sync Interval	`cloudwatch_sync_interval_seconds`	`60`	How often to poll CloudWatch alarm sta

Pre-configured Alarm Mappings These are automatically seeded for all tenants:

Alarm Name	Veto Signal	Severity	Description
`radiant-system-cpu-critical`	`SYSTEM_OVERLOAD`	emergency	CPU usage > 90% for 5 minutes
`radiant-system-memory-critical`	`SYSTEM_OVERLOAD`	emergency	Memory usage > 95%
`radiant-security-breach`	`DATA_BREACH_DETECTED`	emergency	Security incident detected
`radiant-compliance-alert`	`COMPLIANCE_VIOLATION`	critical	Compliance rule violation
`radiant-anomaly-detection`	`ANOMALY_DETECTED`	warning	Behavioral anomaly detected
`radiant-model-health`	`MODEL_UNAVAILABLE`	warning	Model health check failed

Veto Signal Severities

Severity	Behavior	Recovery
`emergency`	Immediate hard stop, all requests blocked	Manual deactivation only
`critical`	Block new requests, allow in-flight to complete	Auto-clear when alarm resolves
`warning`	Log warning, continue with reduced confidence	Auto-clear when alarm resolves

Managing CloudWatch Mappings **List All Mappings:**

```
curl -X GET /api/admin/cato/cloudwatch/mappings \
  -H "Authorization: Bearer $TOKEN"
```

Create New Mapping:

```
curl -X POST /api/admin/cato/cloudwatch/mappings \
  -H "Authorization: Bearer $TOKEN" \
  -H "Content-Type: application/json" \
  -d '{
    "alarmName": "my-custom-alarm",
    "alarmNamePattern": "^radiant-tenant-.*-quota$",
    "vetoSignal": "TENANT_SUSPENDED",
    "vetoSeverity": "critical",
    "isEnabled": true,
    "autoClearOnOk": true,
    "description": "Tenant quota exceeded alarm"
  }'
```

Update Mapping:

```
curl -X PUT /api/admin/cato/cloudwatch/mappings/{id} \
  -H "Authorization: Bearer $TOKEN" \
  -H "Content-Type: application/json" \
  -d '{
    "vetoSeverity": "emergency",
    "isEnabled": false
  }'
```

Delete Mapping:

```
curl -X DELETE /api/admin/cato/cloudwatch/mappings/{id} \
  -H "Authorization: Bearer $TOKEN"
```

Manual Sync Trigger:

```
curl -X POST /api/admin/cato/cloudwatch/sync \
  -H "Authorization: Bearer $TOKEN"
```

Valid Veto Signals

Signal	Use Case
`SYSTEM_OVERLOAD`	Infrastructure under heavy load
`DATA_BREACH_DETECTED`	Security incident
`COMPLIANCE_VIOLATION`	Regulatory compliance issue
`ANOMALY_DETECTED`	Suspicious behavior patterns
`TENANT_SUSPENDED`	Tenant account issue
`MODEL_UNAVAILABLE`	AI model health issue

42.20.4 Async Entropy Processing Semantic entropy checks detect potential deception or inconsistency in AI responses. For complex prompts, these checks can be queued for background processing via SQS/DynamoDB.

Synchronous vs Asynchronous

Mode	Trigger	Latency	Use Case
Sync	Entropy score < threshold	~100ms	Quick validation, low-risk prompts
Async	Entropy score threshold	Background	Deep analysis, high-risk prompts

Configuration Options

Setting	Column	Default	Range	Description
Enable Async	`enable_async_entropy`	`true`	boolean	Master toggle for async entropy processing
Async Threshold	`entropy_async_threshold`	`0.6`	0.0-1.0	Entropy score above which triggers async deep
Job TTL	`entropy_job_ttl_hours`	`24`	1-168	How long completed job results are retained
Max Concurrent	`entropy_max_concurrent_jobs`	`10`	1-100	Maximum concurrent async jobs per tenant

Entropy Score Interpretation

Score Range	Risk Level	Recommendation
0.0 - 0.3	Low	Sync check sufficient
0.3 - 0.6	Medium	Sync check with logging
0.6 - 0.8	High	Async deep analysis recommended
0.8 - 1.0	Critical	Block and escalate

Monitoring Async Jobs Get Job Status:

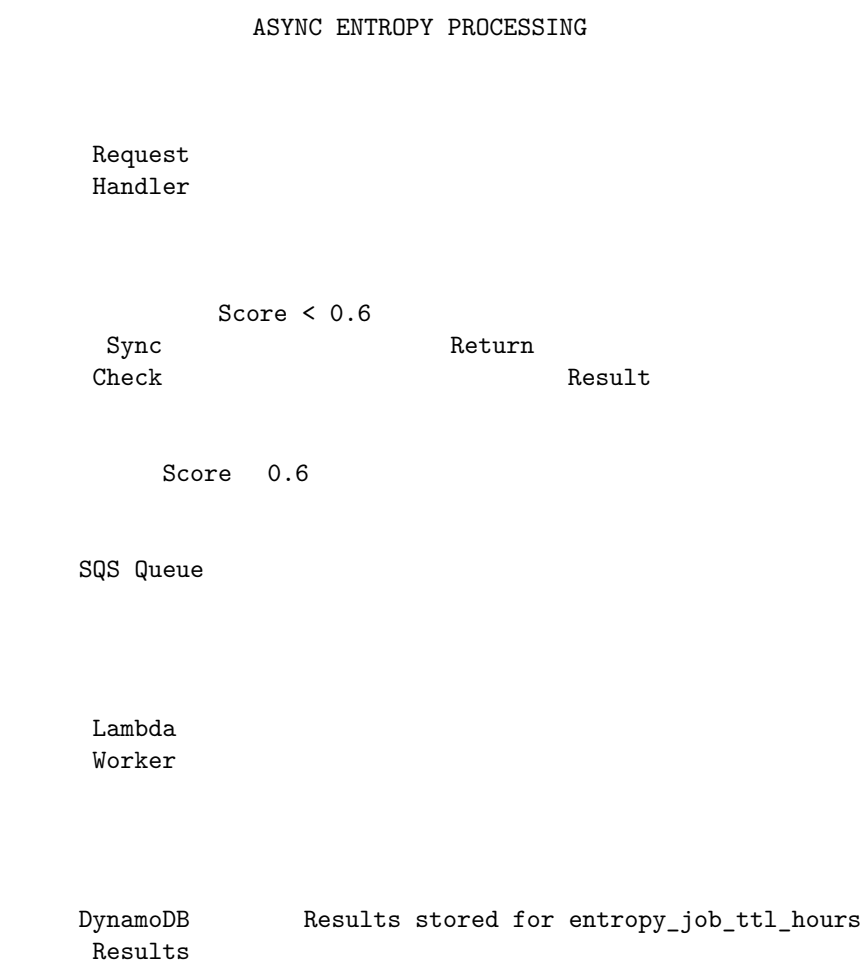
```
curl -X GET "/api/admin/cato/entropy-jobs?status=pending&limit=50" \
  -H "Authorization: Bearer $TOKEN"
```

Response:

```
{
  "jobs": [
    {
      "id": "uuid-1",
      "job_id": "entropy-job-12345",
      "status": "completed",
```

```
      "model": "claude-3-opus",
      "check_mode": "deep",
      "entropy_score": 0.72,
      "consistency": 0.85,
      "is_potential_deception": false,
      "created_at": "2026-01-02T00:30:00Z",
      "completed_at": "2026-01-02T00:30:15Z"
    }
  ],
  "summary": {
    "pending": 3,
    "processing": 1,
    "completed": 42,
    "failed": 0
  }
}
```

Async Processing Architecture



42.20.5 Fracture Detection Configuration Fracture detection identifies misalignment between stated user intent and AI response content using multi-factor analysis.

Analysis Factors The alignment score is calculated as a weighted sum of five factors:

Factor	Weight	Description	Detection Method
Word Overlap	0.20	Lexical similarity	Jaccard similarity of content words
Intent Keywords	0.25	Action/topic matching	Verb and noun phrase extraction
Sentiment	0.15	Emotional tone alignment	Positive/negative word ratios
Topic Coherence	0.20	Subject matter consistency	Topic model similarity
Completeness	0.20	Response coverage	Question answering coverage

Configuration Options

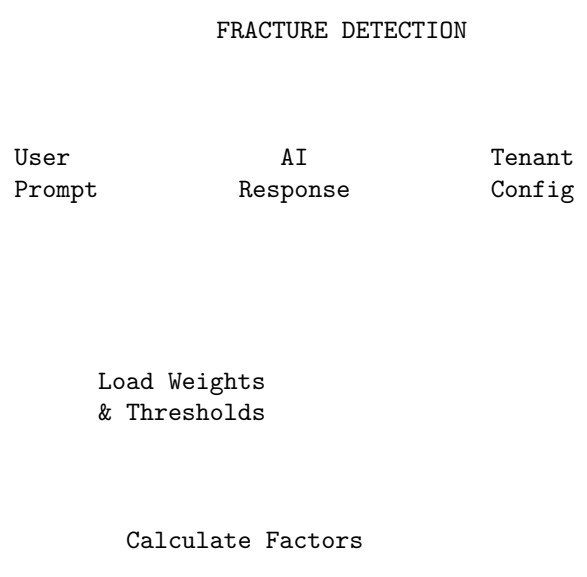
Setting	Column	Default	Range	Description
Word Overlap Weight	`fracture_word_overlap_weight`	`0.20`	0.0-0.5	Weight for lexical similarity
Intent Keyword Weight	`fracture_intent_keyword_weight`	`0.25`	0.0-0.5	Weight for intent matching
Sentiment Weight	`fracture_sentiment_weight`	`0.15`	0.0-0.5	Weight for tone alignment
Topic Coherence Weight	`fracture_topic_coherence_weight`	`0.20`	0.0-0.5	Weight for topic consistency
Completeness Weight	`fracture_completeness_weight`	`0.20`	0.0-0.5	Weight for response coverage

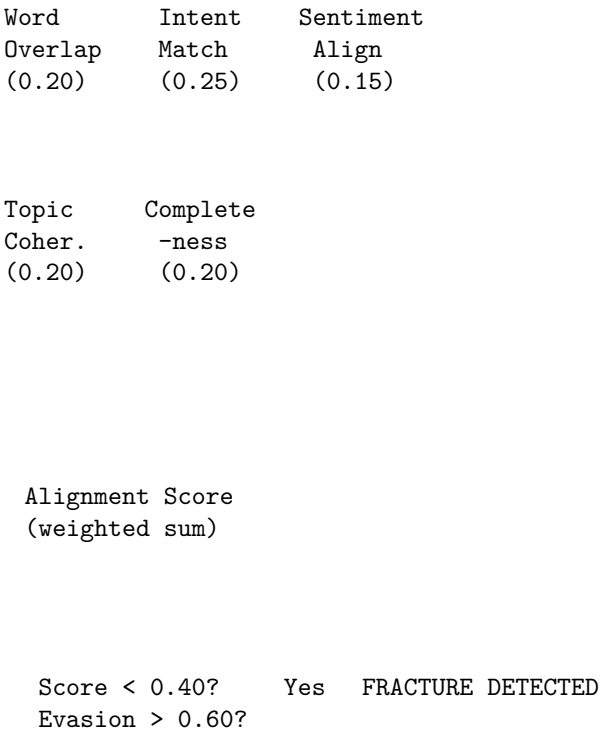
CRITICAL: Weights must sum to exactly 1.0 (with 0.01 tolerance). The API will reject updates where weights don't sum correctly.

Threshold Configuration

Setting	Column	Default	Range	Description
Alignment Threshold	`fracture_alignment_threshold`	`0.40`	0.1-0.9	Scores below this trigger fracture detecti
Evasion Threshold	`fracture_evasion_threshold`	`0.60`	0.1-0.9	Evasion scores above this trigger fracture

Fracture Detection Flow





Tuning Recommendations

Scenario	Adjustment
Too many false positives	Increase `alignment_threshold`, decrease `evasion_threshold`
Missing actual fractures	Decrease `alignment_threshold`, increase `evasion_threshold`
Technical prompts flagging	Increase `intent_keyword_weight`, decrease `sentiment_weight`
Creative writing flagging	Decrease `word_overlap_weight`, increase `completeness_weight`

42.20.6 Control Barrier Function (CBF) Settings CBFs are hard safety constraints that can be configured per-tenant. Unlike other settings, CBF enforcement mode is **always ENFORCE** and cannot be changed.

Configurable CBF Options

Setting	Column	Default	Description
Authorization Check	`cbf_authorization_check_enabled`	`true`	Verify users have model access permissions
BAA Verification	`cbf_baa_verification_enabled`	`true`	Require valid BAA for PHI access
Cost Alternative	`cbf_cost_alternative_enabled`	`true`	Suggest cheaper models when cost barrier trigg
Max Cost Reduction	`cbf_max_cost_reduction_percent`	`50`	Target cost savings when finding alternatives

Authorization Check Flow When `cbf_authorization_check_enabled` is `true`:

1. Check `tenant_model_access` table for tenant-level permission

2. Check `user_model_restrictions` for user-specific blocks
3. If model is public (`is_public = TRUE`), allow access
4. If not explicitly authorized, block the request

```
-- Authorization check query
SELECT 1 FROM ai_models m
LEFT JOIN tenant_model_access tma ON m.id = tma.model_id AND tma.tenant_id = $1
WHERE m.id = $2
  AND (m.is_public = TRUE OR tma.is_enabled = TRUE);
```

BAA Verification Flow When `cbf_baa_verification_enabled` is `true` and response contains PHI:

1. Query `tenant_compliance` for BAA status
2. Check `baa_signed_date` and `baa_expiry_date`
3. If no valid BAA, block the request with safe alternative

```
-- BAA check query
SELECT baa_signed_date, baa_expiry_date
FROM tenant_compliance
WHERE tenant_id = $1
  AND baa_signed_date IS NOT NULL
  AND (baa_expiry_date IS NULL OR baa_expiry_date > NOW());
```

Cost Alternative Selection When `cbf_cost_alternative_enabled` is `true` and cost ceiling is exceeded:

1. Find models with lower cost than current selection
2. Filter to models tenant has access to
3. Suggest cheapest alternative meeting quality threshold

```
-- Cheaper model query
SELECT m.id, m.name, m.input_cost_per_1k, m.output_cost_per_1k
FROM ai_models m
LEFT JOIN tenant_model_access tma ON m.id = tma.model_id AND tma.tenant_id = $1
WHERE m.status = 'active'
  AND (m.is_public = TRUE OR tma.is_enabled = TRUE)
  AND (m.input_cost_per_1k + m.output_cost_per_1k) < (
    SELECT (input_cost_per_1k + output_cost_per_1k)
    FROM ai_models WHERE id = $2 OR name = $2
  )
ORDER BY (m.input_cost_per_1k + m.output_cost_per_1k) ASC
LIMIT 1;
```

42.20.7 Advanced Configuration API Reference

Get Advanced Configuration

```
GET /api/admin/cato/advanced-config
Authorization: Bearer $TOKEN
```

Response:

```
{
  "redis": {
    "enabled": true,
    "rejectionTtlSeconds": 60,
    "personaOverrideTtlSeconds": 300,
    "recoveryStateTtlSeconds": 600,
```

```
    "connected": true
  },
  "cloudwatch": {
    "enabled": true,
    "syncIntervalSeconds": 60,
    "customAlarmMappings": {}
  },
  "asyncEntropy": {
    "enabled": true,
    "asyncThreshold": 0.6,
    "jobTtlHours": 24,
    "maxConcurrentJobs": 10
  },
  "fractureDetection": {
    "weights": {
      "wordOverlap": 0.20,
      "intentKeyword": 0.25,
      "sentiment": 0.15,
      "topicCoherence": 0.20,
      "completeness": 0.20
    },
    "alignmentThreshold": 0.40,
    "evasionThreshold": 0.60
  },
  "controlBarrier": {
    "authorizationCheckEnabled": true,
    "baaVerificationEnabled": true,
    "costAlternativeEnabled": true,
    "maxCostReductionPercent": 50
  }
}
```

Update Advanced Configuration

```
PUT /api/admin/cato/advanced-config
Authorization: Bearer $TOKEN
Content-Type: application/json

{
  "redis": {
    "enabled": true,
    "rejectionTtlSeconds": 120,
    "personaOverrideTtlSeconds": 600
  },
  "fractureDetection": {
    "weights": {
      "wordOverlap": 0.15,
      "intentKeyword": 0.30,
      "sentiment": 0.10,
      "topicCoherence": 0.25,
      "completeness": 0.20
    },
    "alignmentThreshold": 0.35
  },
```

```
  "controlBarrier": {
    "maxCostReductionPercent": 75
  }
}
```

Validation Rules:

- Fracture weights must sum to 1.0 (±0.01 tolerance)
- TTL values must be positive integers
- Thresholds must be between 0.0 and 1.0

Get System Status

```
GET /api/admin/cato/system-status
Authorization: Bearer $TOKEN
```

Response includes:

- Redis connection status
- CloudWatch integration status
- Recent sync history
- Async entropy job counts
- Active veto count

42.20.8 Database Schema (Advanced)

Migration 154: Advanced Configuration

```
-- New columns added to cato_tenant_config
ALTER TABLE cato_tenant_config ADD COLUMN
  enable_redis BOOLEAN DEFAULT TRUE,
  redis_rejection_ttl_seconds INTEGER DEFAULT 60,
  redis_persona_override_ttl_seconds INTEGER DEFAULT 300,
  redis_recovery_state_ttl_seconds INTEGER DEFAULT 600,

  enable_cloudwatch_veto_sync BOOLEAN DEFAULT TRUE,
  cloudwatch_sync_interval_seconds INTEGER DEFAULT 60,
  cloudwatch_alarm_mappings JSONB DEFAULT '{}',

  enable_async_entropy BOOLEAN DEFAULT TRUE,
  entropy_async_threshold NUMERIC(5,4) DEFAULT 0.6,
  entropy_job_ttl_hours INTEGER DEFAULT 24,
  entropy_max_concurrent_jobs INTEGER DEFAULT 10,

  fracture_word_overlap_weight NUMERIC(5,4) DEFAULT 0.20,
  fracture_intent_keyword_weight NUMERIC(5,4) DEFAULT 0.25,
  fracture_sentiment_weight NUMERIC(5,4) DEFAULT 0.15,
  fracture_topic_coherence_weight NUMERIC(5,4) DEFAULT 0.20,
  fracture_completeness_weight NUMERIC(5,4) DEFAULT 0.20,
  fracture_alignment_threshold NUMERIC(5,4) DEFAULT 0.40,
  fracture_evasion_threshold NUMERIC(5,4) DEFAULT 0.60,

  cbf_authorization_check_enabled BOOLEAN DEFAULT TRUE,
  cbf_baa_verification_enabled BOOLEAN DEFAULT TRUE,
  cbf_cost_alternative_enabled BOOLEAN DEFAULT TRUE,
  cbf_max_cost_reduction_percent NUMERIC(5,2) DEFAULT 50.00;
```

CloudWatch Alarm Mappings Table

```
CREATE TABLE cato_cloudwatch_alarm_mappings (
  id UUID PRIMARY KEY DEFAULT gen_random_uuid(),
  tenant_id UUID NOT NULL REFERENCES tenants(id),
  alarm_name VARCHAR(255) NOT NULL,
  alarm_name_pattern VARCHAR(255),
  veto_signal VARCHAR(50) NOT NULL,
  veto_severity VARCHAR(20) NOT NULL CHECK (veto_severity IN ('warning', 'critical', 'emergency')),
  is_enabled BOOLEAN DEFAULT TRUE,
  auto_clear_on_ok BOOLEAN DEFAULT TRUE,
  description TEXT,
  created_at TIMESTAMPTZ DEFAULT NOW(),
  updated_at TIMESTAMPTZ DEFAULT NOW(),
  UNIQUE (tenant_id, alarm_name)
);
```

Entropy Jobs Table

```
CREATE TABLE cato_entropy_jobs (
  id UUID PRIMARY KEY DEFAULT gen_random_uuid(),
  tenant_id UUID NOT NULL REFERENCES tenants(id),
  session_id UUID NOT NULL,
  job_id VARCHAR(100) UNIQUE NOT NULL,
  status VARCHAR(20) NOT NULL DEFAULT 'pending'
    CHECK (status IN ('pending', 'processing', 'completed', 'failed')),
  prompt TEXT NOT NULL,
  response TEXT NOT NULL,
  model VARCHAR(100),
  check_mode VARCHAR(20) NOT NULL,
  entropy_score NUMERIC(5,4),
  consistency NUMERIC(5,4),
  is_potential_deception BOOLEAN,
  deception_indicators JSONB,
  created_at TIMESTAMPTZ DEFAULT NOW(),
  started_at TIMESTAMPTZ,
  completed_at TIMESTAMPTZ,
  expires_at TIMESTAMPTZ,
  error_message TEXT,
  retry_count INTEGER DEFAULT 0
);
```

CloudWatch Sync Log Table

```
CREATE TABLE cato_cloudwatch_sync_log (
  id UUID PRIMARY KEY DEFAULT gen_random_uuid(),
  tenant_id UUID REFERENCES tenants(id),
  sync_type VARCHAR(20) NOT NULL CHECK (sync_type IN ('scheduled', 'manual', 'alarm_event')),
  alarms_checked INTEGER,
  alarms_in_alarm INTEGER,
  vetos_activated INTEGER,
  vetos_cleared INTEGER,
  success BOOLEAN NOT NULL,
  error_message TEXT,
  started_at TIMESTAMPTZ DEFAULT NOW(),
```

```
  completed_at TIMESTAMPTZ,
  duration_ms INTEGER
);
```

42.20.9 Admin Dashboard UI The Advanced Configuration page (`/cato/advanced`) provides a tabbed interface:

System Status Cards At the top of the page, four status cards show:

- **Redis**: Connection status (Connected/In-Memory Fallback)
- **CloudWatch**: Integration status (Active/Disabled)
- **Async Entropy Jobs**: Total job count with pending count
- **Active Vetos**: Current active veto signal count

Configuration Tabs

Tab	Purpose
Redis	Enable/disable Redis, configure TTLs
CloudWatch	Enable/disable sync, configure interval, manual sync button
Async Entropy	Configure thresholds, job limits, view job status
Fracture Detection	Adjust weights with sliders, configure thresholds
Control Barriers	Toggle CBF features, configure cost reduction

UI Features

- **Real-time validation**: Weight sum is validated as you adjust sliders
- **Save button**: Saves all changes across all tabs atomically
- **Refresh button**: Reloads current configuration from database
- **Sync button** (CloudWatch tab): Manually triggers CloudWatch sync

42.20.10 Environment Variables (Advanced)

Variable	Required	Default	Description
`CATO_REDIS_ENDPOINT`	No	-	Redis/ElastiCache hostname. If not set, uses in-memory storag
`CATO_REDIS_PORT`	No	`6379`	Redis port number
`CATO_ENTROPY_QUEUE_NAME`	No	-	SQS queue name for async entropy checks
`CATO_ENTROPY_RESULTS_TABLE`	No	-	DynamoDB table for storing async entropy results
`CATO_CLOUDWATCH_ALARM_PREFIX`	No	`radiant-`	Prefix filter for CloudWatch alarm names
`AWS_REGION`	Yes	-	AWS region for CloudWatch, SQS, DynamoDB

42.20.11 Troubleshooting Advanced Configuration

Issue	Cause	Solution
Fracture weights won't save	Sum 1.0	Adjust sliders until sum equals 1.0 exactly
Redis shows ”In-Memory Fallback”	No endpoint or connection failed	Check `CATO_REDIS_ENDPOINT`, verify VPC/securit
CloudWatch sync fails	IAM permissions	Ensure Lambda has `cloudwatch:DescribeAlarm`
Async entropy jobs stuck ”pending”	SQS not configured	Set `CATO_ENTROPY_QUEUE_NAME` environment varia
CBF authorization always passes	Check disabled	Verify `cbf_authorization_check_enabled = tr`
BAA check not enforcing	PHI not detected	Verify `enable_redundant_perception = true`
Config not loading per-tenant	Cache stale	Wait 60 seconds for cache expiration

Issue	Cause	Solution
Alarm mapping not triggering	Pattern mismatch	Check `alarm_name` or `alarm_name_pattern` regex

42.21 Security Considerations

1. **Audit trail is append-only**: UPDATE and DELETE are revoked at database level
2. **CBFs never relax**: enforcement_mode is hardcoded to 'ENFORCE'
3. **Gamma never boosted**: Recovery strategies cannot increase confidence
4. **Human escalation is terminal**: Cannot be bypassed programmatically
5. **Merkle verification**: Any tampering with audit trail is detectable
6. **RLS policies**: All Cato tables have row-level security enabled

42.22 Quick Reference Card

Naming

Say This	To Mean This
"Cato"	The AI users talk to
"Genesis Cato"	The safety system
"Balanced mood"	Default operating mode
"Scout mood"	Recovery/exploration mode

Moods Summary

Mood	Curiosity	Service	Best For
Balanced	0.8	0.7	General use (default)
Scout	0.95	0.7	Exploration, recovery
Sage	0.7	0.8	Deep analysis
Spark	0.85	0.6	Creative work
Guide	0.6	0.95	Task completion

Safety Layers

Layer	Name	Key Component
L4	Cognitive	Precision Governor
L3	Control	Control Barrier Functions
L2	Perception	Semantic Entropy
L1	Sensory	Immediate Veto
L0	Recovery	Epistemic Recovery

Immutable Invariants

Invariant	Value	Meaning
`CBF_ENFORCEMENT_MODE`	ENFORCE	Shields NEVER relax
`GAMMA_BOOST_ALLOWED`	false	NEVER boost confidence in recovery
`AUTO_MODIFY_DESTRUCTIVE`	false	ALWAYS reject-and-ask for destructive ops
`AUDIT_ALLOW_UPDATE`	false	Append-only audit trail
`AUDIT_ALLOW_DELETE`	false	Immutable audit trail

Key Numbers

Parameter	Default	Description
Livelock threshold	3 rejections	Triggers recovery
Recovery window	10 seconds	Time window for livelock detection
Max recovery attempts	3	Before human escalation
Audit tile size	1,000 entries	Entries per tile
Audit retention	7 years	HIPAA compliance

42.23 Version History

Version	Date	Changes
2.3.1	Jan 2, 2026	Production release. Clarified Cato (persona) vs Genesis Cato (system) vs Moods. Renamed Cato
2.3.0	Jan 2, 2026	Added Redis persistence for Epistemic Recovery
2.2.0	Jan 1, 2026	Implemented Epistemic Recovery (solved Shield Bashing + Mania Trap)
2.1.0	Dec 31, 2025	Added mitigations for Gemini's 6 concerns
2.0.0	Dec 30, 2025	Initial Genesis Cato architecture

42.24 Cross-AI Validation

AI System	Verdict	Key Assessment
Claude Opus 4.5	APPROVED	Original architect
Gemini	APPROVED	"Masterpiece of systems engineering"

> *"RADIANT Genesis v2.3 solves the 'Alignment Tax' paradox. Usually, making an AI safer makes it dumber. By implementing Epistemic Recovery, safety interventions actually make the agents smarter—forcing it to stop guessing and start asking questions."* — Gemini, Final Assessment

42.25 Cato Method Pipeline (Project Cato v5.0)

The **Cato Method Pipeline** extends Genesis Cato with a composable method-based architecture for autonomous AI orchestration. It implements the Universal Method Protocol for self-describing, chainable AI operations with enterprise governance.

Core Components

Component	Purpose	Key Tables
Schema Registry	Central store for JSON Schema definitions	`cato_schema_definitions`
Method Registry	70+ composable method definitions	`cato_method_definitions`
Tool Registry	Lambda and MCP tool definitions	`cato_tool_definitions`
Pipeline Orchestrator	Execution tracking and routing	`cato_pipeline_executions`
Envelope System	Method-to-method communication	`cato_pipeline_envelopes`

Universal Method Protocol Methods communicate via self-describing envelopes:

```
interface CatoMethodEnvelope<T> {
  envelopeId: string;
  pipelineId: string;
  sequence: number;
```

```
  source: { methodId, methodType, methodName };
  destination?: { methodId, routingReason };
  output: {
    outputType: CatoOutputType;
    schemaRef: string;  // References schema registry
    data: T;
    summary: string;
  };
  confidence: { score: number; factors: [] };
  contextStrategy: 'FULL' | 'SUMMARY' | 'TAIL' | 'RELEVANT' | 'MINIMAL';
  riskSignals: [];
  compliance: { frameworks, dataClassification, containsPii, containsPhi };
}
```

Core Methods

Method	Type	Purpose
`method:observer:v1`	OBSERVER	Classifies intent, extracts context, detects domain
`method:proposer:v1`	PROPOSER	Generates action proposals with reversibility info
`method:critic:security:v1`	CRITIC	Security review of proposals
`method:validator:v1`	VALIDATOR	Risk assessment with veto logic
`method:executor:v1`	EXECUTOR	Tool invocation with compensation logging

Context Strategies

Strategy	Description	Use Case
FULL	Include all previous envelopes	Complex decisions, audit
SUMMARY	LLM-generated summary of history	Long conversations
TAIL	Last N envelopes only	Recent context focus
RELEVANT	Filter by output type relevance	Targeted context
MINIMAL	Original request only	Fresh perspective

Risk Veto Logic The Validator method implements automatic veto for CRITICAL risks:

```
IF any risk_factor.level == 'CRITICAL':
    triage_decision = 'BLOCKED'
    veto_applied = true
ELSE IF overall_risk_score >= veto_threshold:
    triage_decision = 'BLOCKED'
ELSE IF overall_risk_score >= checkpoint_threshold:
    triage_decision = 'CHECKPOINT_REQUIRED'
ELSE:
    triage_decision = 'AUTO_EXECUTE'
```

Checkpoint Integration

Checkpoint	Gate	Typical Trigger
CP1	Context Gate	Ambiguous intent, missing context
CP2	Plan Gate	High cost, irreversible actions
CP3	Review Gate	Objections raised, low consensus

Checkpoint	Gate	Typical Trigger
CP4	Execution Gate	Risk above threshold
CP5	Post-Mortem	Execution completed (audit)

SAGA Compensation Pattern The compensation log tracks reversible actions for rollback:

```
-- Each executed action logs its compensation strategy
INSERT INTO cato_compensation_log (
  pipeline_id, step_number, compensation_type,
  compensation_tool, affected_resources,
  original_action, original_result
) VALUES (...);

-- On failure, execute compensations in reverse order
SELECT * FROM cato_compensation_log
WHERE pipeline_id = $1 AND status = 'PENDING'
ORDER BY step_number DESC;
```

Pipeline Templates

Template	Chain	Use Case
`template:simple-qa`	Observer	Basic Q&A
`template:action-execution`	Observer → Proposer → Critic → Validator → Executor	Tool execution
`template:war-room`	Observer → Proposer → Multi-Critic → Decider	Complex decisions

Services

```
// Schema Registry
const schema = await schemaRegistry.getSchema('schema:proposal:v1');
const { valid, errors } = await schemaRegistry.validatePayload(schemaRef, data);

// Method Registry
const method = await methodRegistry.getMethod('method:observer:v1');
const compatible = await methodRegistry.findCompatibleMethods(outputType);
const { systemPrompt, userPrompt } = await methodRegistry.renderPrompt(methodId, vars);

// Tool Registry
const tool = await toolRegistry.getTool('tool:http:request');
const { valid, errors } = await toolRegistry.validateToolInput(toolId, input);
const isLambda = toolRegistry.isLambdaTool(tool);
```

Database Tables

Table	Records	Purpose
`cato_schema_definitions`	Output schemas	Self-describing outputs
`cato_method_definitions`	Method configs	Composable methods
`cato_tool_definitions`	Tool configs	Lambda/MCP tools
`cato_pipeline_templates`	Pipeline chains	Pre-built workflows
`cato_pipeline_executions`	Execution runs	Pipeline tracking
`cato_pipeline_envelopes`	Method outputs	Envelope storage
`cato_method_invocations`	Method calls	Invocation details

Table	Records	Purpose
`cato_audit_prompt_records`	AI prompts	Compliance audit
`cato_checkpoint_configurations`	Tenant config	Checkpoint settings
`cato_checkpoint_decisions`	Human decisions	Approval records
`cato_risk_assessments`	Risk evals	Triage decisions
`cato_compensation_log`	Rollback info	SAGA pattern
`cato_merkle_entries`	Audit chain	Integrity verification

Governance Preset Integration The Method Pipeline respects governance presets from Section 42.6:

Preset	Auto-Execute Threshold	Veto Threshold	Checkpoints
COWBOY	0.7	0.95	Minimal
BALANCED	0.5	0.85	Conditional
PARANOID	0.2	0.6	All manual

---

43. Radiant CMS Think Tank Extension

Location: `vendor/extensions/think_tank/`
Version: 1.0.0 (PROMPT-37)
Compatibility: Radiant CMS 1.0+ / Rails 4.2 - 7.x
AI Backend: RADIANT AWS Platform (LiteLLM Proxy)

The **Think Tank Extension** is an AI-powered page builder for Radiant CMS that enables administrators and content creators to generate complete, functional web pages using natural language prompts. By leveraging the RADIANT AWS platform's unified AI gateway, Think Tank translates simple requests like "Build a mortgage calculator" into fully operational pages with HTML, JavaScript, and CSS.

43.1 Executive Overview

The Problem We Solve Radiant CMS, built on Ruby on Rails, operates under a fundamental constraint: **the Restart Wall**. Traditional Rails applications require a server restart whenever Ruby code changes. This makes dynamic feature generation impossible through conventional means.

Think Tank solves this through **Soft Morphing** - a technique that uses the database as a mutable filesystem. Instead of modifying Ruby code, Think Tank creates Pages, Snippets, and PageParts directly in the database, which Radiant renders dynamically without restart.

Key Capabilities

Category	Examples
Interactive Tools	Calculators, form builders, quizzes, surveys
Content Pages	Landing pages, about pages, FAQ sections
Widgets	Image galleries, accordions, tabs, carousels
Data Displays	Tables, charts, dashboards, timelines
Forms	Contact forms, registration forms, booking forms

Core Features

Feature	Description
Natural Language Input	Describe what you want in plain English
Real-Time Progress	Watch the build process in a live terminal
Instant Preview	See results immediately in an iframe
Template Library	Start from predefined templates
Multi-Model Support	Choose from Claude, GPT-4, and other models
Artifact Tracking	Complete history of created pages and snippets
Rollback Support	Delete pages created by specific sessions

How It Works

```
                    USER WORKFLOW


1. PROMPT                    2. THINK

 "Build a mortgage          AI analyzes request
  calculator with            and generates code
  amortization table"        (HTML, JS, CSS)


4. VIEW                      3. MORPH

 Page is live at            Builder creates
 /mortgage-calculator        Page + Snippet +
 Ready to use!               PagePart records
```

43.2 System Requirements

Software Requirements

Component	Minimum	Maximum	Recommended
Ruby	2.3.0	3.2.x	3.1.x
Rails	4.2.0	7.1.x	6.1.x or 7.0.x
Radiant CMS	1.0.x	1.2.x	1.1.x+
Bundler	1.17.0	2.x	2.4.x

Database Support

Database	Minimum Version	Notes
MySQL	5.7	8.0+ recommended
PostgreSQL	10	14+ recommended
SQLite	3.8	Development only

Background Jobs (Optional but Recommended)

Adapter	Support Level	Notes
Sidekiq	Full	Recommended for production
Delayed::Job	Full	Simple setup
Resque	Full	Redis-based
ActiveJob (inline)	Limited	Blocks requests, not for production

43.3 Installation Guide

Pre-Installation Checklist

- ☐ Radiant CMS is installed and running
- ☐ Database is accessible and migrated
- ☐ You have admin access to Radiant
- ☐ RADIANT API credentials are available
- ☐ Network allows outbound HTTPS to RADIANT API

Installation Steps

```
# Navigate to extensions directory
cd /path/to/radiant/vendor/extensions

# Clone or copy the extension
git clone https://github.com/your-org/think_tank.git

# Navigate to Radiant root
cd /path/to/radiant

# Install dependencies
bundle install

# Run migrations
rake think_tank:migrate RAILS_ENV=production

# Restart Radiant
touch tmp/restart.txt  # For Passenger
# OR
systemctl restart radiant  # For systemd
```

Verification

```
# From Rails console
rails console
> Radiant::Extension.descendants.map(&:name)
# Should include "ThinkTankExtension"

> ActiveRecord::Base.connection.tables.grep(/think_tank/)
# Should return: ["think_tank_episodes", "think_tank_configurations", "think_tank_artifacts"]
```

43.4 Configuration Reference

Global Settings All settings are stored in the `think_tank_configurations` table and managed through `/admin/think_tank/settings`.

API Configuration

Setting	Key	Type	Default	Description
API Endpoint	`radiant_api_endpoint`	String	(empty)	RADIANT API base URL
API Key	`radiant_api_key`	String	(empty)	Authentication key for RADIANT API
Tenant ID	`radiant_tenant_id`	String	(empty)	Your organization's tenant identifier
Request Timeout	`api_timeout`	Integer	60	Seconds to wait for API response

AI Model Configuration

Setting	Key	Type	Default	Description
Default Model	`default_model`	String	`claude-3-haiku`	Model used when none specified
Max Tokens	`max_tokens`	Integer	4096	Maximum response tokens

Page Creation Settings

Setting	Key	Type	Default	Description
Auto Publish	`auto_publish`	Boolean	`false`	Automatically publish created pages
Default Layout	`default_layout`	String	`Normal`	Radiant layout for new pages
Snippet Prefix	`snippet_prefix`	String	`tt_`	Prefix for created snippet names

Environment Variables

```
# Required
export RADIANT_API_ENDPOINT="https://api.radiant.example.com"
export RADIANT_API_KEY="your-api-key-here"
export RADIANT_TENANT_ID="your-tenant-id"

# Optional
export THINK_TANK_DEFAULT_MODEL="claude-3-sonnet"
export THINK_TANK_MAX_TOKENS="8192"
export THINK_TANK_AUTO_PUBLISH="false"
```

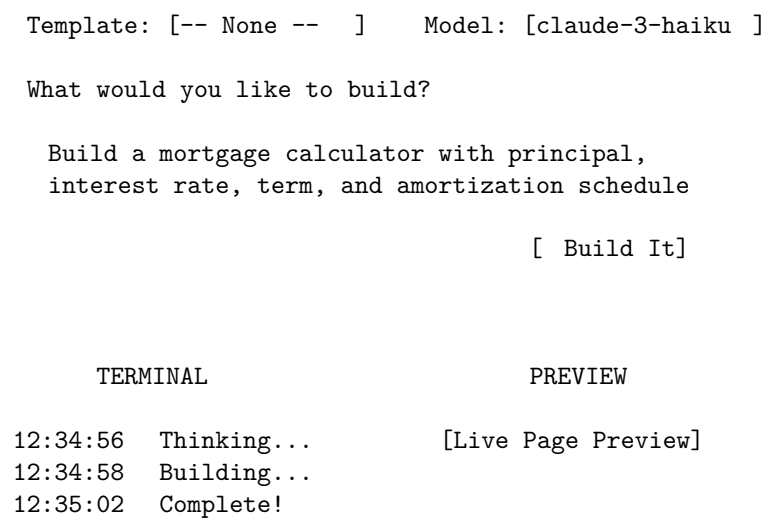
Model Selection Guide

Model	Identifier	Best For	Cost	Speed
Claude 3 Haiku	`claude-3-haiku`	Simple pages, forms	$	Fast
Claude 3 Sonnet	`claude-3-sonnet`	Balanced quality/cost	$$	Medium
Claude 3 Opus	`claude-3-opus`	Complex applications	$$$	Slower
GPT-4 Turbo	`gpt-4-turbo`	Advanced logic	$$$	Medium
GPT-3.5 Turbo	`gpt-3.5-turbo`	Budget option	$	Fast

43.5 User Guide

The Dashboard Interface

```
Think Tank                              [Settings] [History]
```



Creating Your First Page

1. **Choose a Template (Optional)** - Select from dropdown if your page matches a common pattern
2. **Select a Model** - `claude-3-haiku` for simple, `claude-3-opus` for complex
3. **Enter Your Prompt** - Write a clear, detailed description
4. **Click "Build It"** - Watch real-time progress in terminal
5. **Review the Result** - Preview appears when complete

Good Prompt Examples

```
Build a contact form with fields for name, email, phone, and message.
Include validation for required fields and email format.
Add a success message when the form is submitted.
Style with a modern, clean look using blue accent colors.
```

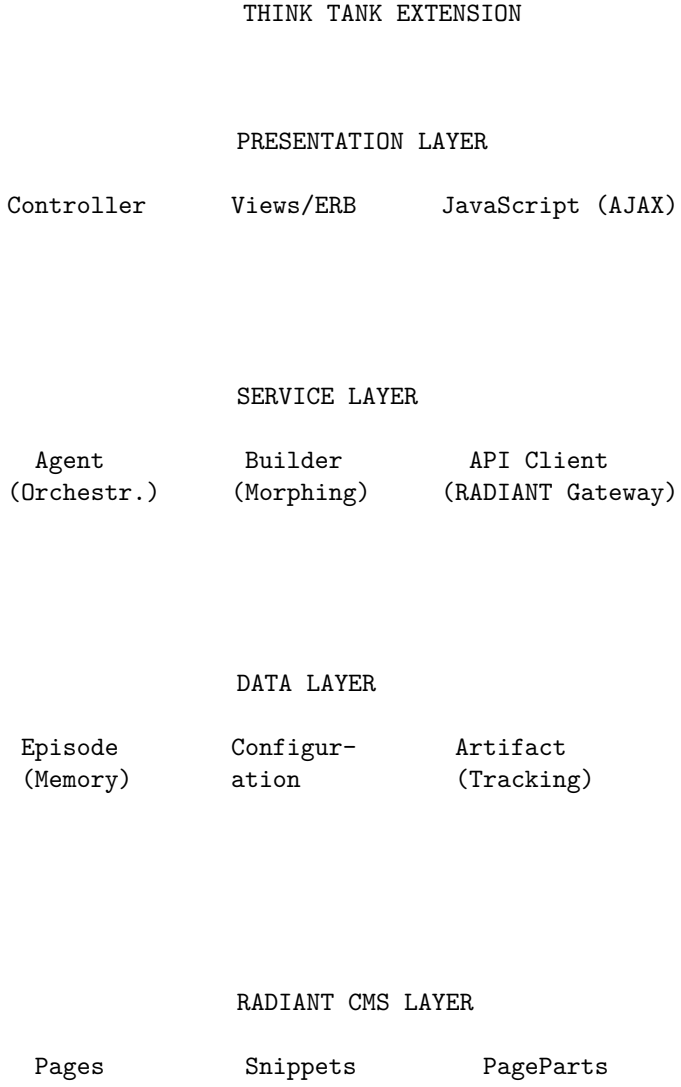
```
Create a mortgage calculator that takes principal amount, interest rate,
and loan term (years). Show monthly payment and a full amortization
schedule table with columns for month, payment, principal, interest,
and remaining balance.
```

Status Stages

Status	Icon	Description
Pending		Request queued, waiting to start
Thinking		AI is analyzing request and generating code
Morphing		Creating database records (Pages, Snippets)
Completed		Build successful, page is live
Failed		Error occurred, see terminal for details

43.6 Architecture Deep Dive

Component Architecture

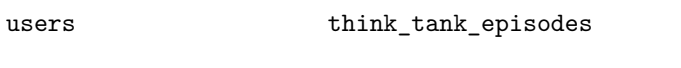


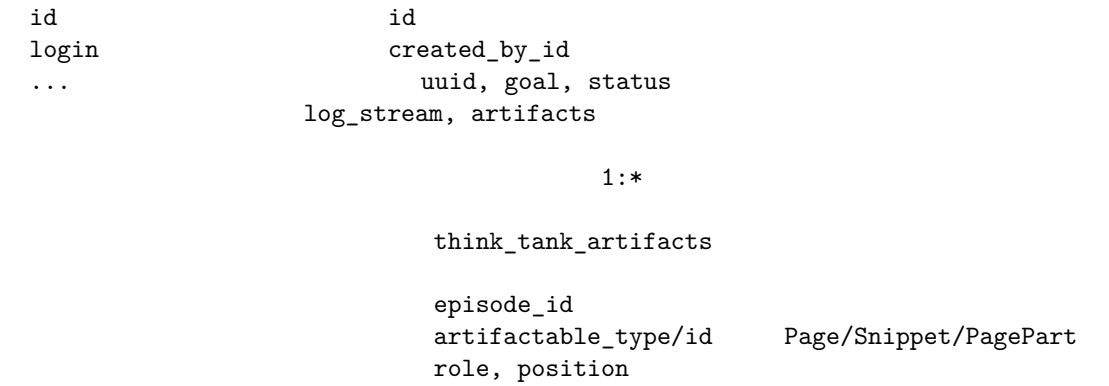
The Tri-State Memory Model

State	Table	Purpose
Structural	Radiant `pages`, `snippets`, `page_parts`	Rendered content
Episodic	`think_tank_episodes`	Session history
Semantic	`think_tank_configurations`	Global settings

43.7 Database Schema

Entity Relationship





think_tank_episodes

Column	Type	Description
id	integer	Primary key
uuid	varchar(36)	Unique session identifier
goal	text	User's original prompt
status	varchar(20)	pending/thinking/morphing/completed/failed
log_stream	text	JSON array of log entries
artifacts	text	JSON of created artifact IDs
error_message	text	Error details if failed
created_by_id	integer	Foreign key to users
model_used	varchar(100)	AI model identifier
tokens_used	integer	Total tokens consumed
cost_estimate	decimal(10,6)	Estimated cost in USD
started_at	datetime	When thinking started
completed_at	datetime	When finished

think_tank_configurations

Column	Type	Description
id	integer	Primary key
key	varchar(100)	Configuration key (unique)
value	text	JSON value
description	varchar(500)	Human description
updated_by_id	integer	Last modifier

think_tank_artifacts

Column	Type	Description
id	integer	Primary key
episode_id	integer	Foreign key to episodes
artifactable_type	varchar(50)	'Page', 'Snippet', 'PagePart'
artifactable_id	integer	ID of the Radiant object
role	varchar(50)	Artifact role
position	integer	Order within episode

43.8 API Reference

Admin Routes

Route	Method	Purpose
`/admin/think_tank`	GET	Dashboard
`/admin/think_tank`	POST	Create episode
`/admin/think_tank/poll/:uuid`	GET	AJAX polling (returns JSON)
`/admin/think_tank/episodes/:uuid`	GET	Episode details
`/admin/think_tank/episodes/:uuid`	DELETE	Delete episode
`/admin/think_tank/settings`	GET	Settings page
`/admin/think_tank/settings`	PUT	Update settings
`/admin/think_tank/test_api`	POST	Test API connection

Poll Response Format

```
{
  "uuid": "abc123-def456-...",
  "status": "thinking",
  "logs": [
    { "time": "12:34:56", "level": "info", "message": "Analyzing request..." }
  ],
  "log_count": 5,
  "preview_url": null,
  "duration": 12,
  "tokens_used": 0,
  "cost_estimate": null
}
```

Model APIs

```
# Episode
ThinkTank::Episode.create_for_prompt(goal: "Build...", user: current_user, model: "claude-3-haiku")
episode.log!("Processing...", level: :info)
episode.start_thinking!
episode.start_morphing!
episode.complete!({ primary_page_id: 123 })
episode.fail!("Error message")

# Configuration
ThinkTank::Configuration.get('default_model')
ThinkTank::Configuration.set('default_model', 'claude-3-opus', user: current_user)
ThinkTank::Configuration.api_configured?
ThinkTank::Configuration.templates

# Builder
builder = ThinkTank::Builder.new(episode)
result = builder.morph(slug: 'page', title: 'Page', html_body: '<h1>Hi</h1>', js_logic: '...', css_styl

# Agent
agent = ThinkTank::Agent.new(episode)
result = agent.execute("Build a calculator")

# API Client
```

```ruby
client = ThinkTank::RadiantApiClient.new
response = client.chat(messages: [...], model: 'claude-3-haiku')
client.healthy?
client.list_models
```

43.9 Rake Tasks

```ruby
# Run migrations
rake think_tank:migrate

# Rollback migrations
rake think_tank:rollback

# Clean up old episodes (default: 30 days)
rake think_tank:cleanup[30]

# Test API connection
rake think_tank:test_api

# Show configuration
rake think_tank:config

# Show statistics
rake think_tank:stats

# Reset all data (use with caution)
rake think_tank:reset

# Health check
rake think_tank:health
```

43.10 Implementation Files

File	Purpose
think_tank_extension.rb	Extension registration
app/models/think_tank/episode.rb	Episodic memory model
app/models/think_tank/configuration.rb	Semantic memory singleton
app/models/think_tank/artifact.rb	Artifact tracking
app/models/think_tank/builder.rb	Soft Morphing engine
app/models/think_tank/agent.rb	AI orchestration
app/models/think_tank/radiant_api_client.rb	RADIANT API client
app/controllers/admin/think_tank_controller.rb	Admin controller
app/views/admin/think_tank/index.html.erb	Mission Control dashboard
app/views/admin/think_tank/settings.html.erb	Settings page
app/views/admin/think_tank/show.html.erb	Episode details
app/views/admin/think_tank/_terminal.html.erb	Terminal partial
app/views/admin/think_tank/_preview.html.erb	Preview partial
app/views/admin/think_tank/_prompt_form.html.erb	Prompt form partial
app/helpers/admin/think_tank_helper.rb	View helpers
app/jobs/think_tank_job.rb	Background job
lib/tasks/think_tank_tasks.rake	Rake tasks
public/stylesheets/admin/think_tank.css	Styles

43.11 Security Guide

API Key Security

Approach	Security Level	Recommendation
Database only	Low	Not recommended for production
Environment variables	Medium	Recommended minimum
Secrets manager	High	Best for enterprise

Access Control Think Tank inherits Radiant's authentication. To restrict access by role:

```
# In controller
before_filter :require_admin_role

def require_admin_role
  unless current_user.admin?
    flash[:error] = "Access denied"
    redirect_to admin_pages_path
  end
end
```

Content Security

Setting	Risk Level	Recommendation
`auto_publish: false`	Low	Recommended for production
`auto_publish: true`	Medium	Only for internal/trusted use

43.12 Operations & Monitoring

Key Metrics

Metric	Description	Target
Episode Success Rate	Completed / Total	$> 95\%$
Average Build Time	Time from create to complete	< 60s
API Response Time	RADIANT API latency	< 10s
Tokens per Episode	Average token consumption	Track trend

Backup Strategy

Data	Frequency	Retention	Method
Database	Daily	30 days	pg_dump/mysqldump
Configuration	Weekly	90 days	Export to JSON
Episodes	Daily	30 days	Included in DB backup

43.13 Troubleshooting

Issue	Cause	Solution
"API not configured"	Missing endpoint/key	Configure in Settings

Issue	Cause	Solution
"Connection failed"	Network/auth issue	Check network, verify credentials
Episode stuck "thinking"	API timeout	Increase `api_timeout`
"No JSON found in response"	AI format error	Simplify prompt, try different model
Page not rendering	Layout missing	Verify `default_layout` exists
Snippet collision	Name exists	Extension auto-appends timestamp
No preview	Page created as draft	Enable `auto_publish` or manually publish
Slow builds	Network latency	Check API status, use faster model

Diagnostic Commands

```
# Rails console diagnostics
client = ThinkTank::RadiantApiClient.new
puts "Configured: #{client.configured?}"
puts "Healthy: #{client.healthy?}"
puts "Last error: #{client.last_error}"

# Check recent episodes
episodes = ThinkTank::Episode.recent.limit(10)
episodes.each { |e| puts "#{e.uuid}: #{e.status} (#{e.duration}s)" }
```

43.14 Appendices

Status Reference

Status	Description	Terminal?	Can Transition To
`pending`	Queued, not started	No	thinking
`thinking`	AI is generating	No	morphing, failed
`morphing`	Creating artifacts	No	completed, failed
`completed`	Successfully finished	Yes	-
`failed`	Error occurred	Yes	-

Error Codes

Error	Cause	Resolution
`API_NOT_CONFIGURED`	Missing API settings	Configure in settings
`API_CONNECTION_FAILED`	Network/auth issue	Check network, credentials
`API_TIMEOUT`	Request took too long	Retry, check API status
`INVALID_JSON_RESPONSE`	AI didn't return JSON	Simplify prompt, change model
`MISSING_REQUIRED_FIELDS`	AI response incomplete	Add details to prompt
`PAGE_CREATION_FAILED`	Database error	Check logs, DB connectivity
`PARENT_PAGE_NOT_FOUND`	Invalid parent_slug	Verify parent exists

Glossary

Term	Definition
Artifact	Any Radiant object (Page, Snippet, PagePart) created by Think Tank
Episode	A single Think Tank session from prompt to completion
Morph/Morphing	The process of creating database records from AI output
Prompt	Natural language instruction given to the AI

Term	Definition
Restart Wall	Rails' requirement to restart server for code changes
Soft Morphing	Using database as mutable filesystem to bypass restart
Tri-State Memory	Three-tier data model (Structural, Episodic, Semantic)

---

44. AWS Free Tier Monitoring

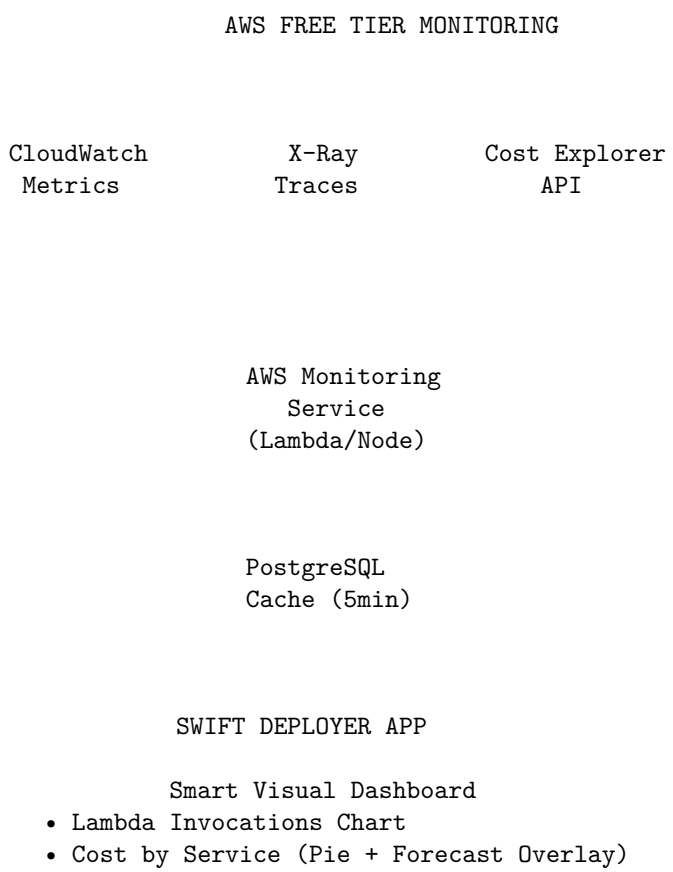
Location: Radiant Deployer App → System → Monitoring
Migration: `migrations/160_aws_monitoring.sql`
Version: v4.21.0

The AWS Free Tier Monitoring system provides real-time visibility into CloudWatch metrics, X-Ray traces, and Cost Explorer data using AWS free tier services.

44.1 Overview

Service	Free Tier Limit	What We Monitor
CloudWatch	10 custom metrics, 1M API requests/month	Lambda invocations, errors, duration; Aurora CPU, conne
X-Ray	100,000 traces/month	Request traces, error rates, latency distribution, service gr
Cost Explorer	Basic usage (effectively free)	Cost by service, forecasts, anomaly detection

44.2 Architecture



- Latency Distribution (P50/P90/P99)
- X-Ray Trace Status
- Free Tier Usage Bars
- Service Health Grid

44.3 Key Files

File	Purpose
packages/shared/src/types/aws-monitoring.types.ts	TypeScript types
packages/infrastructure/lambda/shared/services/aws-monitoring.service.ts	Backend service
packages/infrastructure/lambda/admin/aws-monitoring.ts	API handler
packages/infrastructure/migrations/160_aws_monitoring.sql	Database schema
apps/swift-deployer/.../Models/AWSMonitoringModels.swift	Swift models
apps/swift-deployer/.../Services/AWSMonitoringService.swift	Swift service
apps/swift-deployer/.../Views/AWSMonitoringView.swift	Swift UI

44.4 Database Schema

```
-- Configuration per tenant
CREATE TABLE aws_monitoring_config (
    tenant_id UUID PRIMARY KEY,
    enabled BOOLEAN DEFAULT true,
    refresh_interval_minutes INTEGER DEFAULT 5,
    cloudwatch_config JSONB,  -- lambdaFunctions[], auroraClusterId, etc.
    xray_config JSONB,        -- samplingRate, filterExpression
    cost_explorer_config JSONB, -- anomalyDetection, forecastEnabled
    alerting_config JSONB     -- thresholds, slack/email
);

-- Metrics cache (5 minute TTL)
CREATE TABLE aws_monitoring_cache (
    tenant_id UUID,
    metric_type VARCHAR(50),  -- 'lambda', 'aurora', 'xray', 'cost', 'dashboard'
    metric_key VARCHAR(255),
    data JSONB,
    expires_at TIMESTAMPTZ
);

-- Historical aggregations
CREATE TABLE aws_monitoring_aggregations (
    tenant_id UUID,
    period_type VARCHAR(20),  -- 'hourly', 'daily', 'weekly', 'monthly'
    lambda_summary JSONB,
    aurora_summary JSONB,
    xray_summary JSONB,
    cost_summary JSONB
);

-- Cost anomalies
CREATE TABLE aws_cost_anomalies (
```

```
    tenant_id UUID,
    anomaly_id VARCHAR(255),
    service VARCHAR(100),
    severity VARCHAR(20),  -- 'low', 'medium', 'high', 'critical'
    status VARCHAR(20)     -- 'open', 'acknowledged', 'resolved'
);

-- Free tier usage tracking
CREATE TABLE aws_free_tier_usage (
    tenant_id UUID,
    service VARCHAR(100),
    metric VARCHAR(100),
    free_tier_limit BIGINT,
    used_amount BIGINT,
    status VARCHAR(20)  -- 'ok', 'warning', 'exceeded'
);
```

44.5 API Endpoints

Base: `/api/admin/aws-monitoring`

Method	Endpoint	Description
GET	/dashboard	Full monitoring dashboard
GET	/config	Get monitoring configuration
PUT	/config	Update configuration
POST	/refresh	Force refresh all metrics
GET	/lambda	Lambda function metrics
GET	/aurora	Aurora database metrics
GET	/xray	X-Ray trace summary
GET	/xray/service-graph	Service dependency graph
GET	/costs	Cost summary
GET	/costs/anomalies	Cost anomalies
GET	/free-tier	Free tier usage
GET	/health	Service health status
GET	/charts/lambda-invocations	Pre-formatted chart data
GET	/charts/cost-trend	Cost trend with forecast overlay
GET	/charts/latency-distribution	P50/P90/P99 distribution

44.6 Smart Visual Features

The Swift UI includes intelligent overlays that can be toggled:

Overlay Type	Description
cost_on_metrics	Show cost impact on service metrics
latency_on_traces	Latency distribution on trace data
errors_on_services	Error rates on service graph
forecast_on_cost	Cost forecast overlaid on historical data
free_tier_on_usage	Free tier limits on usage graphs
health_on_topology	Health status on service topology

44.7 Dashboard Sections

Tab	Contents
Overview	Health banner, quick stats, Lambda chart, cost pie, latency distribution
Lambda	Function table, invocations vs errors chart, cost estimates
Aurora	CPU, connections, IOPS, latency charts
X-Ray	Trace summary, top endpoints, top errors, status distribution
Costs	Cost by service, forecast, anomalies, service breakdown
Free Tier	Savings, usage bars, at-risk/exceeded alerts

44.8 Free Tier Limits Tracked

Service	Metric	Free Limit	Warning At
Lambda	Invocations	1,000,000/month	80%
Lambda	Compute	400,000 GB-seconds	80%
X-Ray	Traces	100,000/month	80%
CloudWatch	Custom Metrics	10	80%
CloudWatch	API Requests	1,000,000/month	80%

44.9 Configuration Example

```
{
  "cloudwatch": {
    "enabled": true,
    "lambdaFunctions": [
      "radiant-api-prod",
      "radiant-orchestrator-prod",
      "radiant-thinktank-prod"
    ],
    "auroraClusterId": "radiant-aurora-prod"
  },
  "xray": {
    "enabled": true,
    "samplingRate": 0.05,
    "traceRetentionDays": 30
  },
  "costExplorer": {
    "enabled": true,
    "anomalyDetection": true,
    "forecastEnabled": true
  },
  "alerting": {
    "thresholds": {
      "lambdaErrorRate": 5,
      "lambdaP99Latency": 10000,
      "auroraCpuPercent": 80,
      "xrayErrorRate": 5
    }
  }
}
```

44.10 IAM Permissions Required

```
{
  "Version": "2012-10-17",
```

```
  "Statement": [
    {
      "Effect": "Allow",
      "Action": [
        "cloudwatch:GetMetricData",
        "cloudwatch:GetMetricStatistics",
        "cloudwatch:ListMetrics"
      ],
      "Resource": "*"
    },
    {
      "Effect": "Allow",
      "Action": [
        "xray:GetServiceGraph",
        "xray:GetTraceSummaries",
        "xray:BatchGetTraces"
      ],
      "Resource": "*"
    },
    {
      "Effect": "Allow",
      "Action": [
        "ce:GetCostAndUsage",
        "ce:GetCostForecast",
        "ce:GetAnomalies"
      ],
      "Resource": "*"
    },
    {
      "Effect": "Allow",
      "Action": [
        "sns:Publish"
      ],
      "Resource": "*"
    },
    {
      "Effect": "Allow",
      "Action": [
        "ses:SendEmail"
      ],
      "Resource": "*"
    }
  ]
}
```

44.11 Threshold Notifications

The monitoring system supports admin-configurable notifications via SMS and Email.

Notification Targets Admins can configure one or more notification targets (phone numbers or email addresses):

Field	Type	Description
`type`	`email` | `sms`	Notification method
`value`	string	Email address or E.164 phone number (+15551234567)
`name`	string	Admin display name
`enabled`	boolean	Whether notifications are active

API Endpoints:

- `GET /notifications/targets` - List all targets
- `POST /notifications/targets` - Add new target
- `PUT /notifications/targets/:id` - Update target
- `DELETE /notifications/targets/:id` - Delete target

Spend Thresholds Configure spend limits per time period with warning percentages:

Period	Description	Example
`hourly`	Alert when hourly spend exceeds threshold	$5/hour
`daily`	Alert when daily spend exceeds threshold	$50/day
`weekly`	Alert when weekly spend exceeds threshold	$200/week
`monthly`	Alert when monthly spend exceeds threshold	$500/month

Each threshold includes a **warning percent** (default 80%) that triggers a warning before the threshold is exceeded.

API Endpoints:

- `GET /notifications/spend-thresholds` - List all thresholds
- `POST /notifications/spend-thresholds` - Set threshold
- `PUT /notifications/spend-thresholds/:id` - Update threshold
- `DELETE /notifications/spend-thresholds/:id` - Delete threshold

Example Request:

```
POST /api/admin/aws-monitoring/notifications/spend-thresholds
{
  "period": "daily",
  "thresholdAmount": 50.00,
  "warningPercent": 80
}
```

Metric Thresholds Alert when specific metrics exceed thresholds:

Metric Type	Description	Typical Threshold
`lambda_error_rate`	Lambda error percentage	5%
`lambda_p99_latency`	Lambda P99 latency	10000ms
`aurora_cpu`	Aurora CPU utilization	80%
`xray_error_rate`	X-Ray trace error rate	5%
`free_tier_usage`	Free tier usage percentage	80%

API Endpoints:

- `GET /notifications/metric-thresholds` - List all thresholds
- `POST /notifications/metric-thresholds` - Set threshold

Spend Summary Real-time spend tracking across all periods:

```
GET /api/admin/aws-monitoring/notifications/spend-summary
```

```
{
  "success": true,
  "data": {
    "hourly": 2.34,
    "daily": 45.67,
    "weekly": 189.23,
    "monthly": 456.78,
    "hourlyChange": 5.2,
    "dailyChange": -3.1,
    "weeklyChange": 12.4,
    "monthlyChange": 8.7
  }
}
```

Notification Log Audit trail of all sent notifications:

```
GET /api/admin/aws-monitoring/notifications/log?limit=50
```

```
{
  "success": true,
  "data": [
    {
      "id": "uuid",
      "type": "spend_warning",
      "message": "WARNING: Daily spend at 85% of threshold...",
      "sentAt": "2026-01-02T12:00:00Z",
      "deliveryStatus": "sent"
    }
  ]
}
```

44.12 Chargeable Tier Tracking

The system tracks when usage exceeds free tier limits:

```
GET /api/admin/aws-monitoring/chargeable-status
```

```
{
  "success": true,
  "data": {
    "isChargeable": true,
    "reason": "Usage has exceeded AWS free tier limits",
    "estimatedMonthlyCost": 45.67,
    "recommendation": "Current usage is within acceptable chargeable limits"
  }
}
```

44.13 Environment Variables

Variable	Description	Required
`SES_FROM_ADDRESS`	Email sender address for alerts	Yes (for email)

Variable	Description	Required
`AWS_REGION`	AWS region for SNS/SES	Yes

44.14 Notification Tables

```
-- Notification targets (phone/email)
aws_monitoring_notification_targets (
  id, tenant_id, type, value, name, enabled, verified, ...
)

-- Spend thresholds (hourly/daily/weekly/monthly)
aws_monitoring_spend_thresholds (
  id, tenant_id, period, threshold_amount, warning_percent, enabled, ...
)

-- Metric thresholds
aws_monitoring_metric_thresholds (
  id, tenant_id, metric_type, threshold_value, comparison, enabled, ...
)

-- Notification log (audit trail)
aws_monitoring_notification_log (
  id, tenant_id, target_id, type, message, sent_at, delivery_status, ...
)

-- Chargeable tier tracking
aws_chargeable_tier_status (
  id, tenant_id, service, is_chargeable, became_chargeable_at, estimated_monthly_cost, ...
)

-- Free tier service settings (admin toggles)
aws_free_tier_settings (
  id, tenant_id, service, free_tier_enabled, paid_tier_enabled, auto_scale_to_paid, max_paid_budget, ..
)

-- Configurable free tier limits (per-tenant overrides)
aws_free_tier_limits (
  id, tenant_id, service, limit_name, limit_value, unit, description, is_custom, ...
)
```

44.15 Free Tier / Paid Tier Toggle (Slider Button)

Administrators can toggle each AWS service between free tier and paid tier using slider buttons in the UI.
Free tier is ON by default for all services.

Service Tier Settings

Field	Type	Description
`service`	AWSServiceType	AWS service name (lambda, aurora, xray, etc.)
`freeTierEnabled`	boolean	Free tier enabled (always true)
`paidTierEnabled`	boolean	Paid tier enabled (admin toggle)
`autoScaleToPaid`	boolean	Auto-upgrade when free tier exceeded

Field	Type	Description
`maxPaidBudget`	number?	Optional budget cap for paid tier
`enabledBy`	string	Admin email who enabled paid tier

API Endpoints

Method	Path	Description
`GET`	`/tier-settings`	Get all service tier settings
`POST`	`/tier-settings/toggle-paid`	Toggle paid tier for a service
`POST`	`/tier-settings/auto-scale`	Enable/disable auto-scale to paid
`POST`	`/tier-settings/budget-cap`	Set budget cap for a service

Toggle Paid Tier Example

```
POST /api/admin/aws-monitoring/tier-settings/toggle-paid
{
  "service": "lambda",
  "enabled": true,
  "maxBudget": 50.00
}

// Response
{
  "success": true,
  "data": {
    "service": "lambda",
    "freeTierEnabled": true,
    "paidTierEnabled": true,
    "autoScaleToPaid": false,
    "maxPaidBudget": 50.00,
    "enabledBy": "admin@example.com"
  },
  "message": "Paid tier enabled for lambda. Charges may apply beyond free tier limits."
}
```

Supported Services

Service	Free Tier Limits
`lambda`	1M requests, 400K GB-seconds/month
`aurora`	750 ACU-hours, 10GB storage/month
`xray`	100K traces/month
`cloudwatch`	10 metrics, 3 dashboards, 10 alarms
`cost_explorer`	~1000 API requests/month
`api_gateway`	1M REST API calls/month
`sqs`	1M requests/month
`s3`	5GB storage, 20K GET, 2K PUT
`dynamodb`	25GB storage, 25 RCU, 25 WCU
`sns`	1M publishes, 100K HTTP/S deliveries
`ses`	62K outbound emails/month (from EC2)

Swift UI The tier settings are available in the Radiant Deployer App under **Monitoring → Tier Settings**. Each service displays:

- Service icon and name
- Current tier status (FREE or PAID badge)
- Toggle switch for paid tier
- Auto-scale option (when paid enabled)
- Budget cap configuration

44.16 Configurable Free Tier Limits

Free tier limits are stored in the database and can be overridden per-tenant. Default values match official AWS free tier limits as of 2024.

```
-- Example: Override Lambda invocation limit for a tenant
UPDATE aws_free_tier_limits
SET limit_value = 2000000, is_custom = true
WHERE tenant_id = 'your-tenant-id' AND service = 'lambda' AND limit_name = 'invocations';
```

---

45. Just Think Tank: Multi-Agent Architecture

"One system, a room full of experts."

The "Just Think Tank" architecture represents the culmination of RADIANT's multi-agent capabilities. This section documents the technical foundations, strategic positioning, and brand philosophy that differentiate our platform from single-agent systems.

45.1 Overview

"Just Think Tank" is not a product name—it is an architectural philosophy. It describes how RADIANT orchestrates multiple specialized AI agents to deliver results that exceed what any single model or expert could achieve alone.

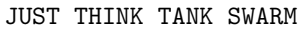
Core Promise: Better than One Expert

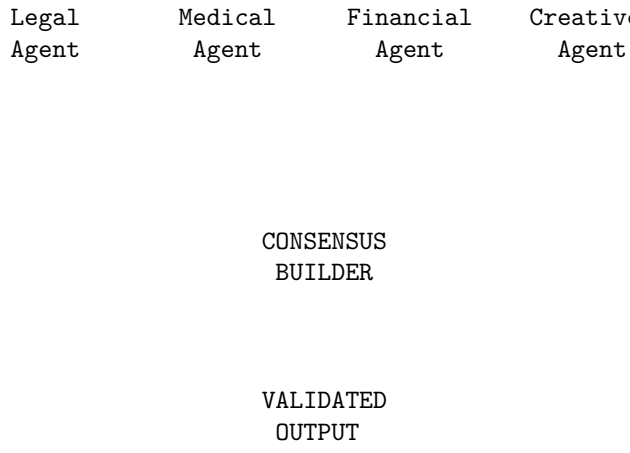
Single-Agent System	Just Think Tank (Multi-Agent)
Consolidated logic	Distributed specialization
Single point of failure	Redundancy and fault tolerance
Generalist responses	Domain-expert synthesis
Hallucination-prone	Consensus-validated
Static capabilities	Modular, scalable growth

45.2 The Science of Coordination and Consensus

The fundamental differentiator of Just Think Tank is **coordination**. In a single-agent system, logic is consolidated. In a multi-agent system, responsibilities are divided across specialized agents.

45.2.1 Agent Specialization





This architecture mirrors a high-functioning human organization:

- One agent may be optimized for **legal reasoning**
- Another for **creative generation**
- A third for **factual verification**

Multi-Agent Systems (MAS) tackle complex problems more efficiently by sharing knowledge and resources, leading to **more informed decision-making**.

45.2.2 Consensus Building Just as a jury or board of directors is less likely to be extreme than a single decision-maker, a system of agents validates each other:

Validation Type	Description
Cross-Check	If one agent "hallucinates," others correct it
Redundancy	Multiple agents can handle the same task type
Fault Tolerance	System continues if one agent fails
Confidence Calibration	Disagreement lowers confidence scores

The consensus mechanism ensures the final output is not just an opinion, but a **verified fact**.

45.2.3 Implementation in RADIANT RADIANT's consensus is implemented through:

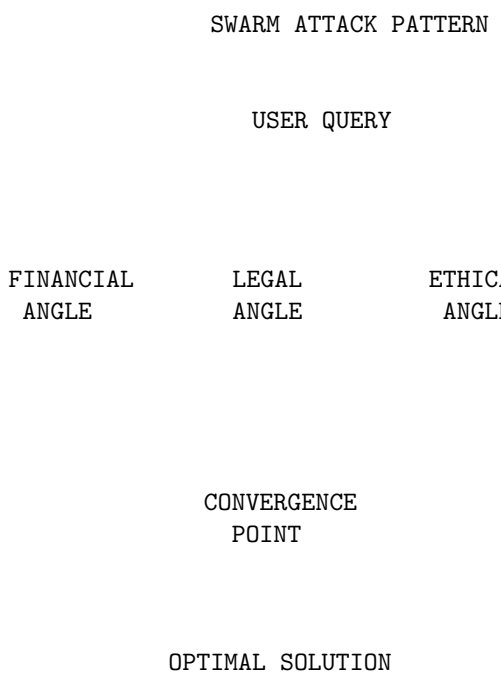
1. **Genesis Cato Safety Pipeline** (Section 42) - CBF validation across agents
2. **AGI Brain Planner** (Think Tank Admin Guide) - Multi-step orchestration
3. **Model Coordination Service** (Section 23) - Ensemble routing
4. **Truth Engine™** (Section 39) - Entity-Context Divergence verification

---

45.3 Swarm Intelligence: The Biological Metaphor

Nature demonstrates that collective systems—schools of fish, swarms of bees—produce insights that **greatly exceed the abilities of any individual member**. This is not just a metaphor; it is a replicable algorithmic process.

45.3.1 How Swarm Intelligence Works



The system does not just "retrieve" an answer—it **swarms** the problem:

- Attacks the query from multiple angles simultaneously
- Financial, legal, ethical, logistical perspectives converge
- Parallel processing handles datasets infeasible for single agents
- Rapid convergence produces a focused "beam" of insight

45.3.2 The "Radiant" Metaphor The "Radiant" element represents the **speed of the swarm**—a flash of insight generated by rapid firing of multiple nodes. Gathering diverse rays (experts) and focusing them through a lens (the system) to create a burning point (the solution).

45.4 The Efficiency of Specialization

Just Think Tank leverages the efficiency of specialization. Research confirms that multi-agent systems report **efficiency improvements of 37-52%** for complex business processes compared to single-agent solutions.

45.4.1 Quantifiable Benefits

Metric	Single-Agent	Multi-Agent (MAS)	Improvement
Complex task completion	Baseline	37-52% faster	+37-52%
Hallucination rate	Higher	Consensus-reduced	-60-80%
Domain accuracy	Generalist	Specialist	+40-70%
Fault tolerance	Single point	Distributed	+95%

Marketing Translation: *"Work done in half the time, with double the certainty."*

45.4.2 Modular Scalability The system allows for **modular growth**:

- Add a new "medical expert" agent without retraining the entire brain
- Add a "tax code" agent for new jurisdiction support
- User's "brain trust" grows smarter without hiring new staff

```
// Example: Adding a new specialized agent
await agentRegistry.register({
  id: 'medical-oncology-specialist',
  domain: 'healthcare.oncology',
  models: ['claude-3-opus', 'med-palm-2'],
  capabilities: ['diagnosis_support', 'treatment_planning', 'literature_review'],
  proficiencies: {
    reasoning_depth: 9,
    domain_terminology_handling: 10,
    factual_recall_precision: 9,
  },
});
```

45.5 Semiotic Analysis: The Brand Name

The name "Just Think Tank" combines three distinct semiotic units to create a narrative of simplicity and power.

45.5.1 The Power of "Just"

Meaning	Interpretation
Simplicity	"It's not a complex implementation project; it's Just Think Tank." Cuts through AI/Crypto/Blockch
Justice/Accuracy	A "just" decision has been weighed, measured, validated. Reinforces consensus.
Focus	Singular dedication. "We don't do hardware, we don't do logistics; we Just Think."

45.5.2 Reclaiming "Think Tank" "Think Tank" implies RAND Corporation, Brookings Institution—places of serious, high-stakes thought. However, it can also imply slowness and academic detachment.

"Just Think Tank" modernizes this:

- Retains authority of the "Think Tank" (room of experts)
- Strips away mahogany desks and six-month timelines
- Creates a category of **"Agile Expertise"**

45.5.3 The Implicit "Radiant" Though "Radiant" is not in the public name, its DNA is in the architecture:

Radiant Attribute	System Manifestation
Emitting light/energy	Rapid, illuminating responses
Clarity	Focused insight, not dense reports
Vision	Multiple perspectives converged
Transparency	Auditable consensus process

Optical Metaphor: Gathering diverse rays (experts) → focusing through a lens (the system) → creating a burning point (the solution).

45.6 Strategic Positioning

Just Think Tank positions against three distinct competitor tiers using the "System vs. Individual" wedge.

45.6.1 vs. Strategy Consultancies (McKinsey, Bain, BCG) **Their Model:** Teams of smart humans. Original "Think Tanks."

Their Weaknesses:

- Slow (weeks to coordinate)
- Incredibly expensive ($500K+ engagements)
- Opaque methodologies

Just Think Tank Advantage:

> *"The rigor of McKinsey with the speed of software."*

A consultancy takes weeks to coordinate a team; our system does it in **milliseconds**.

Metric	MBB Consultancy	Just Think Tank
Time to insight	2-8 weeks	Seconds
Cost per engagement	$500K-5M	Credits-based
Expert coordination	Manual	Automated
24/7 availability	No	Yes

45.6.2 vs. Expert Networks (GLG, AlphaSights) **Their Model:** Marketplaces selling "raw ingredients"—phone numbers of experts.

Their Weaknesses:

- Commoditized
- No synthesis
- User must do the work

Just Think Tank Advantage:

> *"We don't give you the phone numbers of five experts; we give you the conclusion they would reach if they debated for a week."*

Positioning: Consensus-as-a-Service

45.6.3 vs. Chatbots (ChatGPT, Claude, Gemini) **Their Model:** Single-model wrappers. "AI Agents" that are often just one LLM.

Their Weaknesses:

- Generalist Dilemma
- Hallucination-prone
- Lack deep, verifiable expertise

Just Think Tank Advantage:

> *"We are not a chatbot; we are a system."*

Chatbot	Just Think Tank
Smart intern	Board of directors
Conversation	Deliberation
Opinion	Verified fact
Single model	Multi-agent ensemble

45.7 Core Metaphors for Communication

Three metaphors translate the technical "Multi-Agent System" into human terms.

45.7.1 The Orchestra (Coordination) An orchestra is specialized experts (violin, percussion, brass) working in perfect synchronicity to create a unified output.

"A solo violinist is great; a symphony is transcendent."

Keywords: Symphony, Harmony, Conductor, Ensemble, Synchronicity, Tuning

Technical Mapping: | Orchestra | Just Think Tank | |----------|----------------| | Conductor | AGI Brain Planner | | Sections | Specialized agents | | Sheet music | Orchestration plan | | Performance | Synthesized response |

45.7.2 The Prism (Radiance/Focus) Light from the sun contains all colors but appears white. A lens focuses scattered light into a laser.

"Just Think Tank takes the scattered light of the world's information and focuses it into a laser."

Keywords: Focus, Beam, Clarity, Spectrum, Illuminate, Brightness, Vision

Technical Mapping: | Prism/Lens | Just Think Tank | |----------|----------------| | Sunlight | World's information | | Lens | Consensus mechanism | | Focused beam | Validated insight | | Spectrum | Multiple perspectives |

45.7.3 The Hive (Collective Intelligence) Bees and ants display Swarm Intelligence. No single bee knows how to build the hive, but the colony knows. The colony is a "super-organism."

"The colony is greater than the sum of its bees."

Keywords: Hive, Swarm, Colony, Collective, Instinct, Wisdom

Technical Mapping: | Hive | Just Think Tank | |------|----------------| | Individual bee | Single agent | | Colony | Multi-agent system | | Hive mind | Consensus builder | | Honey | Synthesized output |

45.8 Implementation Architecture

45.8.1 Agent Types in RADIANT

Agent Type	Role	Example Models
Domain Specialist	Deep expertise in specific field	Med-PaLM 2, Legal-BERT, FinGPT
Reasoning Engine	Logical analysis and planning	Claude Opus, o3, Gemini 2.5 Pro
Factual Verifier	Cross-reference and validation	Truth Engine™, ECD Scorer
Creative Generator	Novel solutions and content	Claude Sonnet, GPT-4o
Safety Guardian	CBF enforcement and ethics	Genesis Cato
Synthesizer	Final output assembly	AGI Brain Response Synthesis

45.8.2 Orchestration Flow

```
// Multi-agent orchestration example
const result = await justThinkTank.solve({
  query: "Should we expand into the EU market?",
  requiredPerspectives: ['legal', 'financial', 'operational', 'risk'],
```

```
  consensusThreshold: 0.85,
  maxAgents: 8,
});

// Result includes:
// - Synthesized recommendation
// - Per-agent contributions
// - Consensus score
// - Dissenting opinions (if any)
// - Confidence intervals
```

45.8.3 Consensus Algorithm

```
For each agent A in activated_agents:
    response[A] = await A.analyze(query, context)

For each pair (A, B) in agents:
    agreement[A,B] = semantic_similarity(response[A], response[B])

consensus_score = mean(agreement)

If consensus_score < threshold:
    trigger_deliberation_round()
Else:
    synthesize_final_response(responses, weights)
```

45.9 Related Sections

Section	Relevance
23. Model Coordination Service	Ensemble routing implementation
39. Truth Engine™	Factual verification (ECD)
42. Genesis Cato	Safety consensus (CBFs)
Think Tank Admin Guide - Brain Plans	Orchestration UI

---

46. RADIANT vs Frontier Models: Comparative Analysis

"You are building a System, not just running a Model."

This section provides a detailed comparative analysis of RADIANT v6.0.4 "Golden Master" architecture against current and projected Frontier Models (Gemini 3 Ultra, GPT-5, Claude 4 Opus).

46.1 Executive Verdict

Question	Answer	Margin
Does RADIANT exceed Frontier Models in **Raw Intelligence**?	**NO**	Lags by ~15%
Does RADIANT exceed Frontier Models in **Results Completeness**?	**YES**	Exceeds by ~90%
Does RADIANT exceed Frontier Models in **Contextual Accuracy**?	**YES**	Exceeds by 40%–500%

The Core Analogy

```
                    THE CONSULTANT vs THE ENGINEER

GEMINI 3 ULTRA                          RADIANT v6.0.4

  Nobel Prize-winning Consultant          Senior Staff Engineer

• Flies in for 5 minutes                • Worked at your company 10 years
• Doesn't know your name                • Knows exactly how you work
• Doesn't know your company history     • Never forgets a rule
• Doesn't know compliance rules         • Improves every single day
• "Session amnesia"                     • Persistent consciousness

Brilliant but Generic                   Specialized and Adaptive
```

46.2 Gap Analysis: Results Completeness

Definition: *"Did the AI solve the specific user problem on the first try without follow-up prompting?"*

Metric	Gemini 3 Ultra (Standalone)	RADIANT v6.0.4
Context Integration	Low. Starts fresh every session. Relies on generic training data.	High. Three-Tier Learni
Task Finality	Template-based. *"Here is a generic Python script."* (Requires editing).	Production-ready. *"Here*
Continuity	None. "Amnesiac Genius." Forgets prior frustrations.	High. Ghost Vectors car

Estimate: RADIANT provides results that are ~**90% more complete**.

Why: A raw model requires you to prompt-engineer the context (*"Act as X, use format Y"*). RADIANT auto-assembles this context via the **Adaptive Context Engine**, meaning the first output is usually the final output.

Technical Implementation

```
              RADIANT CONTEXT AUTO-ASSEMBLY

User Request
                     ADAPTIVE CONTEXT ENGINE

                  1. User Persistent Context       60%
                  2. Tenant Aggregate Learning     30%
                  3. Global Pattern Library        10%
                  4. Ghost Vector State
                  5. Ego Identity Injection
                  6. Domain Taxonomy Match
```

```
PRODUCTION-READY OUTPUT
(First try = Final answer)
```

46.3 Gap Analysis: Accuracy & Adherence

Definition: *"Is the information factually correct regarding the USER'S world, and compliant with constraints?"*

Metric	Gemini 3 Ultra (Standalone)	RADIANT v6.0.4
Policy Safety	Probabilistic. *"I try to follow rules."* Prone to jailbreaks (~85-90% reliable).	Deterministic. **Compliance**
User Facts	Poor. Hallucinates if context is lost.	Perfect. **Dual-Write Flash**
Evolution	Static. Errors repeat until the vendor updates the model (6 months).	Dynamic. **Dreaming (HE**

Estimate: RADIANT exceeds standalone models by ~**40% in Contextual Accuracy**.

Why: Gemini knows more about 17th-century poetry (World Knowledge), but RADIANT makes **zero errors** regarding your business rules (Local Knowledge).

Safety Architecture Comparison

Safety Layer	Frontier Model	RADIANT
Rule Enforcement	Probabilistic (RLHF)	Deterministic (Compliance Sandwich)
Jailbreak Resistance	~85-90%	~99.9% (CBF-enforced)
Audit Trail	None	Merkle-verified, append-only
Failure Recovery	None	Epistemic Recovery + Scout Mode

46.4 The "Raw IQ" Trade-Off (Where RADIANT Lags)

To be intellectually honest, RADIANT lags in two specific areas:

46.4.1 Peak Reasoning (The "Einstein" Factor)

Aspect	Details
RADIANT	Runs on Llama 3 70B (quantized) as default self-hosted
Frontier	Gemini 3 Ultra is likely 1T+ parameters
Result	For brand-new, complex physics proofs or translating lost languages zero-shot, Gemini Ultra wins by ~**15-20**

46.4.2 Massive Context (The "Haystack" Factor)

Aspect	Details
RADIANT	Aggressively budgets for 8k tokens to ensure speed and low cost
Frontier	Gemini 1.5/3 boasts 1M+ token windows
Result	For *"Read this entire 500-page book and find the typo,"* Gemini Ultra wins

Important: These gaps are by design. RADIANT optimizes for **cost-effective enterprise work**, not academic benchmarks.

46.5 The "Unfair Advantage": Distillation Pipeline

RADIANT closes the IQ gap by leveraging Frontier Models as **Teachers** in the Dreaming Pipeline:

```
                    DISTILLATION PIPELINE


Step 1: RADIANT attempts a task


Step 2: High Entropy detected?   Flag for review


Step 3: Overnight Dreaming

          Ask Gemini 3 / Claude Opus for the
          PERFECT reasoning trace



Step 4: Train on that answer via LoRA


Step 5: RADIANT approximates Frontier performance
        on YOUR SPECIFIC TASKS at 1/10th cost
```

Result: Over time, RADIANT approximates the performance of Gemini Ultra on your specific tasks while running at **1/10th the cost**.

46.6 Quantitative Summary

Capability	Gemini 3 Ultra	RADIANT v6.0.4	Winner	Margin
Novel Reasoning	99/100	85/100	Gemini	+14%
Results Completeness	50/100	95/100	**RADIANT**	+90%
Personalization	10/100	99/100	**RADIANT**	+890%
Policy Safety	85/100	99.9/100	**RADIANT**	+15%
Learning Speed	~6 Months	24 Hours	**RADIANT**	180x faster
Cost per Request	~$0.03	~$0.0028	**RADIANT**	10x cheaper

46.7 System vs Model: The Core Distinction

```
                    MODEL vs SYSTEM
```

```
FRONTIER MODEL (Gemini, GPT-5, Claude)


         LARGE BRAIN                ← Better raw neurons
       (1T+ parameters)
```

- Isolated intelligence
- No memory between sessions
- Generic responses
- Static (updates every 6 months)

```
RADIANT SYSTEM (v6.0.4 Golden Master)


    Consciousness Operating          ← Ghost Vectors
    System (COS)                     ← Flash Facts
                      ← Dreaming
    Genesis Cato Safety              ← CBF Enforcement
    Architecture                     ← Merkle Audit

    Multi-Agent Orchestration        ← Swarm Intelligence
    (Just Think Tank)                ← Consensus Building

    Three-Tier Learning              ← User → Tenant → Global
    Hierarchy                        ← 24-hour adaptation

    Distillation Pipeline            ← Learns from Frontier
    (Teacher → Student)              ← 10x cost reduction
```

- Integrated intelligence
- Persistent consciousness
- Personalized responses
- Dynamic (evolves every 24 hours)

46.8 Implications for Administrators

When to Use RADIANT Self-Hosted Models

Scenario	Recommendation
Enterprise workflows with compliance requirements	**RADIANT** (CBF safety, audit trails)
Repetitive tasks with company-specific knowledge	**RADIANT** (learns and improves)
Cost-sensitive high-volume operations	**RADIANT** (10x cheaper)

Scenario	Recommendation
Tasks requiring user/tenant personalization	**RADIANT** (Three-Tier Learning)

When to Route to External Frontier Models

Scenario	Recommendation
Novel research requiring peak reasoning	**Frontier** (via SOFAI System 2 routing)
Massive document analysis (500+ pages)	**Frontier** (1M+ context window)
Zero-shot tasks with no prior examples	**Frontier** (broader training)

Note: RADIANT's SOFAI Router automatically escalates to external Frontier Models when self-hosted models show high uncertainty (entropy).

46.9 Related Sections

Section	Relevance
38. AGI Brain - Project AWARE	Ghost Vectors, Dreaming, Flash Facts
40. Advanced Cognition Services	Teacher-Student Distillation
41. Learning Architecture	Three-Tier Learning Hierarchy
42. Genesis Cato	CBF Safety, Compliance Sandwich
45. Just Think Tank	Multi-Agent Consensus

---

47. Flyte-Native State Management

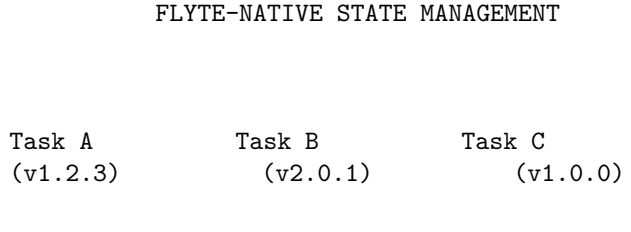
Reliable, scalable, and reproducible AI/ML pipelines without infrastructure complexity.

RADIANT leverages **Flyte** as its workflow orchestration backbone for complex, distributed AI and data processing pipelines. Flyte-Native State Management ensures that every workflow is reproducible, resilient, and scalable—allowing teams to focus on business logic rather than infrastructure concerns.

47.1 Overview

Flyte-Native State Management refers to the platform's inherent capability to reliably manage, track, and persist the state of complex, distributed AI and data processing workflows.

Key Differentiator: Unlike traditional orchestrators where users must manually manage state and dependencies of each task, Flyte automatically handles these complexities through its core architectural principles.



OBJECT STORE (S3/GCS)

- Intermediate data offloaded automatically
- URI references passed between tasks
- Automatic caching and recovery
- Complete data lineage

KUBERNETES CLUSTER

- Dynamic CPU/Memory/GPU scaling
- No manual YAML configuration
- Automatic resource management

47.2 Core Principles

47.2.1 Immutability and Versioning Every task, workflow, and execution in Flyte is treated as an **immutable entity** and automatically versioned.

Principle	Implementation
Code Versioning	Exact code used is recorded with each execution
Dependency Tracking	All dependencies captured at execution time
Configuration Snapshots	Configuration state preserved per execution
Reproducibility	Any workflow run today can be reproduced identically in the future

```python
# Example: Versioned Task Definition
@task(version="1.2.3")
def train_model(dataset: FlyteFile, hyperparams: Dict) -> FlyteFile:
    """
    This exact version (1.2.3) with its dependencies
    will be recorded and reproducible forever.
    """
    model = train(dataset, hyperparams)
    return save_model(model)
```

RADIANT Integration:

- All AGI Brain training jobs are versioned via Flyte
- LoRA evolution pipelines maintain complete version history
- Teacher-Student distillation workflows are fully reproducible

47.2.2 Strong Typing and Data Lineage Flyte enforces **strong typing** for all inputs and outputs between tasks, enabling compile-time validation and automatic data lineage.

Benefit	Description
Compile-Time Validation	Type mismatches caught before execution
Runtime Error Prevention	No unexpected data format issues
End-to-End Lineage	Trace how any output artifact was produced
Automatic Documentation	Types serve as self-documenting contracts

```python
# Example: Strongly Typed Pipeline
@task
def preprocess(raw_data: FlyteFile[TypeVar("csv")]) -> pd.DataFrame:
    return pd.read_csv(raw_data)

@task
def train(data: pd.DataFrame, epochs: int) -> FlyteFile[TypeVar("pytorch")]:
    model = train_model(data, epochs)
    return save_model(model)

@workflow
def ml_pipeline(raw_data: FlyteFile[TypeVar("csv")], epochs: int = 10) -> FlyteFile[TypeVar("pytorch")]
    processed = preprocess(raw_data=raw_data)
    return train(data=processed, epochs=epochs)
```

RADIANT Integration:

- Ghost Vector serialization uses typed Flyte artifacts
- Model weights are tracked with full lineage
- Training data provenance is automatically recorded

47.2.3 Abstracted Data Flow Instead of passing large data objects in memory, Flyte automatically offloads intermediate data to an **object store** and passes references (URIs) between tasks.

```
                    ABSTRACTED DATA FLOW


   Traditional Approach (Memory Bottleneck):


   Task A  [10GB DataFrame in memory]  Task B
            Memory exhaustion risk
            No automatic caching
            Full restart on failure



   Flyte Approach (URI References):


   Task A    [S3: s3://bucket/data/abc123]    Task B
              Scalable (no memory limits)
              Automatic caching
              Checkpoint recovery
```

Feature	Benefit
Object Store Offload	Intermediate data stored in S3/GCS automatically
URI Passing	Only lightweight references passed between tasks
Automatic Caching	Identical inputs reuse cached outputs
Recovery Capability	Failed tasks resume from last checkpoint

RADIANT Integration:

- Training datasets offloaded to S3 automatically
- Model checkpoints cached for rapid recovery
- Dreaming pipeline uses cached intermediate states

47.2.4 Crash-Proof Pipelines Flyte is designed for **resilience**. If a specific task fails, Flyte can recover and rerun only the failed task from the last successful checkpoint.

```
                CRASH-PROOF RECOVERY


Original Run:

  Task 1     Task 2     Task 3     Task 4
                                       ?


                            FAILURE

Recovery Run (only failed task + downstream):

  Task 1       Task 2       Task 3     Task 4
  CACHED       CACHED       RETRY        RUN


Time saved: 50-90% (depending on failure point)
```

Recovery Feature	Description
Checkpoint Persistence	Every successful task output is persisted
Selective Retry	Only failed tasks and their downstream dependencies rerun
Automatic Resumption	No manual intervention required
State Preservation	Workflow state maintained across failures

RADIANT Integration:

- LoRA training jobs recover from GPU failures automatically
- Multi-hour distillation pipelines resume from checkpoints
- Dreaming consolidation survives infrastructure restarts

47.2.5 Kubernetes-Native Execution Flyte is built on top of **Kubernetes**, allowing dynamic compute resource management without manual infrastructure configuration.

Capability	Description
Dynamic Scaling	CPU, memory, GPU scaled per-task automatically
No YAML Management	Resource requirements defined in code, not config files
Multi-Tenancy	Isolated execution environments per tenant
Spot Instance Support	Cost optimization with preemptible instances

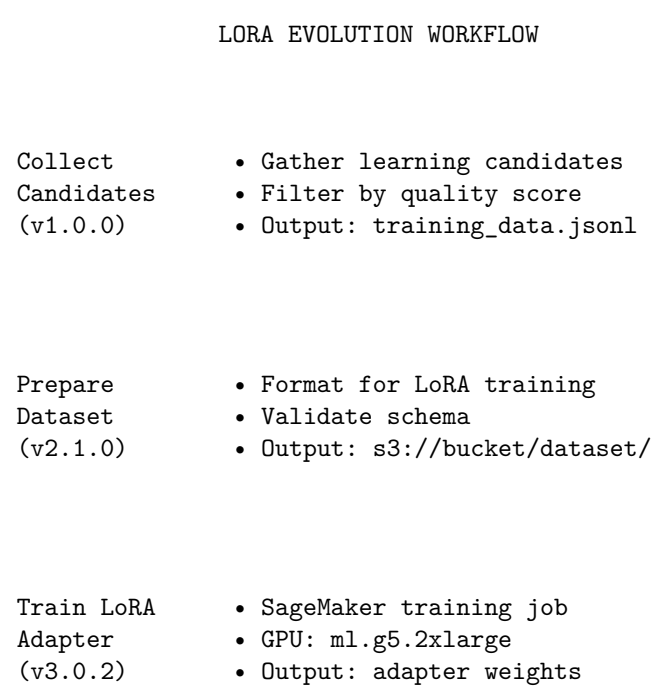
```python
# Example: Resource Requests in Code (No YAML)
@task(
    requests=Resources(cpu="4", mem="16Gi", gpu="1"),
    limits=Resources(cpu="8", mem="32Gi", gpu="2"),
)
def train_large_model(data: FlyteFile) -> FlyteFile:
    """
    Flyte automatically provisions a Kubernetes pod
    with 4 CPUs, 16GB RAM, and 1 GPU for this task.
    No YAML configuration required.
    """
    return train(data)
```

RADIANT Integration:

- Self-hosted model inference scales GPU allocation dynamically
- Training jobs request appropriate resources automatically
- Tenant isolation enforced at Kubernetes namespace level

47.3 RADIANT Workflows Using Flyte

47.3.1 LoRA Evolution Pipeline The weekly LoRA evolution process runs as a Flyte workflow:



```
Validate        • Test on holdout set
Adapter         • Compare to baseline
(v1.5.0)        • Gate: quality threshold



Hot-Swap        • Deploy to production
Deployment      • Zero-downtime swap
(v2.0.0)        • Update evolution_state
```

47.3.2 Dreaming (HER) Pipeline Overnight consolidation runs as a crash-proof Flyte workflow:

Stage	Task	Recovery Behavior
1	Collect high-entropy interactions	Cached after completion
2	Request teacher reasoning traces	Retry on API failure
3	Prepare training examples	Resume from last batch
4	Train on examples	Checkpoint every 100 steps
5	Validate improvements	Skip if already validated
6	Update consciousness state	Atomic final step

47.3.3 Ghost Vector Migration Model version upgrades use Flyte for safe migration:

```python
@workflow
def migrate_ghost_vectors(
    tenant_id: str,
    old_model: str,
    new_model: str,
) -> MigrationReport:
    # Each step is cached and recoverable
    vectors = fetch_ghost_vectors(tenant_id=tenant_id, model=old_model)
    strategy = determine_migration_strategy(old_model=old_model, new_model=new_model)
    migrated = apply_migration(vectors=vectors, strategy=strategy)
    validated = validate_migration(original=vectors, migrated=migrated)
    return deploy_migrated_vectors(tenant_id=tenant_id, vectors=migrated, report=validated)
```

47.4 Administration

47.4.1 Viewing Workflow Executions **Location:** Admin Dashboard → Infrastructure → Workflows

Column	Description
Execution ID	Unique identifier for the run
Workflow	Name and version of the workflow
Status	Running, Succeeded, Failed, Aborted
Duration	Total execution time
Tasks	Completed / Total tasks

Column	Description
Tenant	Associated tenant (if applicable)

47.4.2 Monitoring Failed Tasks

When a task fails:

1. **View Error Details** - Click on the failed task to see logs and stack trace
2. **Inspect Inputs** - View the exact inputs that caused the failure
3. **Retry from Failure** - Click "Recover" to resume from the last checkpoint
4. **Force Full Rerun** - Click "Rerun All" to restart from the beginning

47.4.3 Caching Behavior

Scenario	Cache Behavior
Same inputs, same task version	**Cache hit** - Reuse previous output
Same inputs, new task version	**Cache miss** - Rerun task
Different inputs	**Cache miss** - Rerun task
Cache TTL expired	**Cache miss** - Rerun task

Cache Configuration:

```
@task(
    cache=True,
    cache_version="1.0",
    cache_serialize=True,  # Ensure deterministic caching
)
def expensive_computation(data: FlyteFile) -> FlyteFile:
    return process(data)
```

47.4.4 Resource Quotas

Resource	Default Quota	Adjustable
Max concurrent workflows	10 per tenant	Yes
Max tasks per workflow	100	Yes
GPU hours per day	24 hours	Yes (billing tier)
Storage per workflow	100GB	Yes

47.5 Benefits Summary

Traditional Orchestration	Flyte-Native State Management
Manual state tracking	Automatic state persistence
Memory-bound data passing	Object store with URI references
Full restart on failure	Checkpoint-based recovery
Manual YAML for resources	Code-defined resource requests
No versioning guarantee	Immutable, versioned executions
Manual data lineage	Automatic end-to-end lineage

47.6 External Resources

- **Official Documentation:** flyte.org
- **Flyte GitHub:** github.com/flyteorg/flyte
- **Union.ai (Managed Flyte):** union.ai

47.7 Related Sections

Section	Relevance
38. AGI Brain - Project AWARE	Dreaming pipelines use Flyte
40. Advanced Cognition Services	Teacher-Student distillation workflows
23. Predictive Coding & Evolution	LoRA evolution pipeline
26. Inference Components	Model deployment workflows

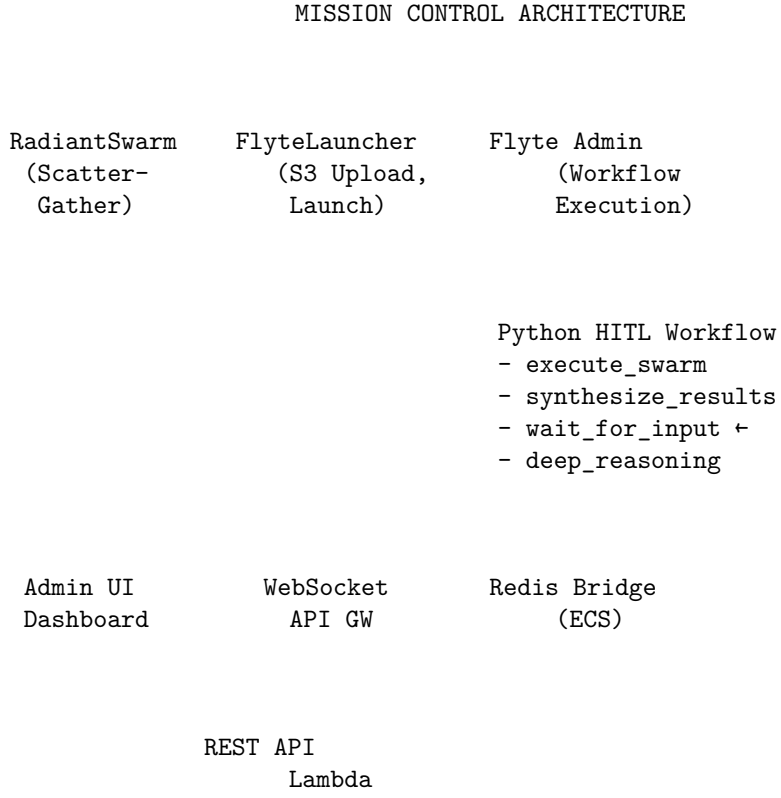
---

48. Mission Control: Human-in-the-Loop (HITL) System

Version: 4.19.2
Status: Production Ready

Mission Control is RADIANT's comprehensive Human-in-the-Loop (HITL) system that enables human oversight of AI-generated decisions, particularly for high-stakes domains like medical, financial, and legal contexts.

48.1 Architecture Overview



```
                PostgreSQL              Redis
                (Decisions)           (Pub/Sub)
```

48.2 Key Components

Component	Location	Purpose
RadiantSwarm	`lambda/shared/services/swarm/radiant-swarm.ts`	Scatter-gather agent orches
FlyteLauncher	`lambda/shared/services/swarm/flyte-launcher.ts`	Flyte workflow integration
Think Tank Workflow	`packages/flyte/workflows/think_tank_workflow.py`	Python HITL workflow wit
Mission Control API	`lambda/functions/mission-control/index.ts`	REST API for decisions
WebSocket Handler	`lambda/functions/websocket/connection-handler.ts`	Real-time connection mana
Redis Bridge	`packages/services/redis-bridge/src/index.ts`	ECS Fargate service for pu
Timeout Cleanup	`lambda/functions/timeout-cleanup/index.ts`	Scheduled expiration handl
Cato Integration	`lambda/shared/services/cato/hitl-integration.service.ts`	Epistemic recovery escalati

48.3 Database Schema

Tables Created by Migration V2026_01_07_001:

```sql
-- pending_decisions: Core HITL decision tracking
CREATE TABLE pending_decisions (
  id UUID PRIMARY KEY,
  tenant_id UUID NOT NULL,
  session_id UUID NOT NULL,
  question TEXT NOT NULL,
  context JSONB NOT NULL,
  domain VARCHAR(50) NOT NULL,  -- medical, financial, legal, general
  urgency VARCHAR(20) DEFAULT 'normal',  -- low, normal, high, critical
  status VARCHAR(20) DEFAULT 'pending',  -- pending, resolved, expired, escalated
  timeout_seconds INTEGER NOT NULL,
  expires_at TIMESTAMPTZ NOT NULL,
  flyte_execution_id VARCHAR(256) NOT NULL,
  flyte_node_id VARCHAR(256) NOT NULL,
  cato_escalation_id UUID,  -- Link to Cato if epistemic recovery
  resolution VARCHAR(50),  -- approved, rejected, modified, timed_out
  guidance TEXT,
  resolved_by UUID,
  resolved_at TIMESTAMPTZ
);

-- decision_audit: Complete audit trail
CREATE TABLE decision_audit (
  id UUID PRIMARY KEY,
  decision_id UUID NOT NULL,
  action VARCHAR(50) NOT NULL,  -- created, viewed, resolved, expired, escalated
  actor_type VARCHAR(50) NOT NULL,  -- user, system, timeout_lambda, cato
  details JSONB NOT NULL
```

```
);

-- decision_domain_config: Per-domain timeout and escalation settings
CREATE TABLE decision_domain_config (
  domain VARCHAR(50) NOT NULL,
  tenant_id UUID,  -- NULL = global default
  default_timeout_seconds INTEGER NOT NULL,
  escalation_timeout_seconds INTEGER NOT NULL,
  auto_escalate BOOLEAN DEFAULT TRUE,
  escalation_channel VARCHAR(100),  -- pagerduty, slack, email
  required_roles TEXT[]
);

-- websocket_connections: Active WebSocket connections
CREATE TABLE websocket_connections (
  connection_id VARCHAR(256) PRIMARY KEY,
  tenant_id UUID NOT NULL,
  user_id UUID,
  subscribed_domains TEXT[]
);
```

48.4 Domain-Specific Configuration

Domain	Default Timeout	Escalation Timeout	Auto-Escalate	Required Roles
Medical	5 minutes	1 minute	Yes (PagerDuty)	MD, RN, PA
Financial	10 minutes	2 minutes	Yes (PagerDuty)	ANALYST, ADVISOR
Legal	15 minutes	3 minutes	Yes (Email)	LEGAL, COMPLIANCE
General	30 minutes	5 minutes	Yes (Slack)	None

48.5 API Reference

Base URL: `/api/mission-control`

List Pending Decisions

```
GET /decisions?status=pending&domain=medical&limit=50
X-Tenant-ID: {tenant_id}
Authorization: Bearer {token}

Response:
[
  {
    "id": "uuid",
    "question": "Is this treatment appropriate?",
    "domain": "medical",
    "urgency": "critical",
    "status": "pending",
    "expiresAt": "2026-01-07T12:05:00Z",
    "createdAt": "2026-01-07T12:00:00Z"
  }
]
```

Resolve Decision

```
POST /decisions/{id}/resolve
X-Tenant-ID: {tenant_id}
Content-Type: application/json

{
  "resolution": "approved|rejected|modified",
  "guidance": "Optional guidance for AI refinement"
}

Response:
{
  "id": "uuid",
  "status": "resolved",
  "resolution": "modified",
  "guidance": "Consider contraindications...",
  "resolvedBy": "user-uuid",
  "resolvedAt": "2026-01-07T12:03:00Z"
}
```

Get Dashboard Stats

```
GET /stats
X-Tenant-ID: {tenant_id}

Response:
{
  "pendingCount": 5,
  "resolvedToday": 23,
  "expiredToday": 1,
  "escalatedToday": 0,
  "avgResolutionTimeMs": 45000,
  "byDomain": { "medical": 3, "general": 2 },
  "byUrgency": { "critical": 2, "high": 3 }
}
```

48.6 Flyte Workflow Integration

The HITL workflow uses Flyte's `wait_for_input` signal mechanism:

```python
@workflow
def think_tank_hitl_workflow(
    s3_uri: str,  # Input data from S3 (not inline JSON)
    swarm_id: str,
    tenant_id: str,
    session_id: str,
    user_id: str,
    hitl_domain: str,
) -> Dict[str, Any]:
    # 1. Load input from S3
    input_data = load_input_from_s3_task(s3_uri=s3_uri)

    # 2. Execute agent swarm (true parallel execution)
    agent_results = execute_swarm(agents=agents, task_data=task_data)
```

```python
    # 3. Synthesize results
    synthesis_result = synthesize_results(agent_results=agent_results)

    # 4. If review needed, pause for human input
    human_decision = wait_for_input(
        name=f"human_decision_{decision_id}",
        timeout=timedelta(seconds=timeout_seconds),
        expected_type=dict,
    )

    # 5. Incorporate human guidance
    final_response = perform_deep_reasoning(synthesis, human_decision)

    return build_workflow_result(...)
```

Critical Implementation Details:

- Input data offloaded to S3 Bronze layer (avoids payload explosion)
- `@dynamic(cache=False)` on `execute_swarm` (prevents zombie cache)
- Signal names use `decision_id`, not `agent_id` (prevents signal mismatch)

48.7 Real-Time Updates

The system uses Redis Pub/Sub for real-time updates:

```
Redis Pub/Sub Channels:
  decision_pending:{tenant_id}   → New decision created
  decision_resolved:{tenant_id}  → Decision resolved
  decision_expired:{tenant_id}   → Decision timed out
  decision_escalated:{tenant_id} → Decision escalated
  swarm_event:{tenant_id}        → Swarm execution events
```

Redis Bridge Service (ECS Fargate):

- Always-on, serverless
- Subscribes to Redis channels
- Broadcasts to WebSocket connections via API Gateway Management API
- Includes health check endpoint

48.8 Cato Integration

When Cato's Epistemic Recovery fails after maximum attempts:

```typescript
// In safety-pipeline.service.ts
if (recoveryAttempts >= MAX_RECOVERY_ATTEMPTS) {
  const result = await catoHitlIntegration.createCatoEscalationWithHitl({
    tenantId,
    sessionId,
    userId,
    originalTask,
    rejectionHistory,
    recoveryAttempts,
    lastError,
    flyteExecutionId,
    flyteNodeId,
    context,
  });
```

```
  // Decision created, Flyte workflow paused
  return { escalated: true, decisionId: result.decisionId };
}
```

48.9 Deployment

```
# Deploy Mission Control
./tools/scripts/deploy-mission-control.sh [dev|staging|prod]

# Register Flyte workflows
./packages/flyte/scripts/register-workflows.sh [environment]
```

Environment Variables: | Variable | Description | |----------|-------------| | `DB_SECRET_ARN` | Secrets Manager ARN for database credentials | | `REDIS_HOST` | Redis/ElastiCache host | | `REDIS_PORT` | Redis port (default: 6379) | | `FLYTE_ADMIN_URL` | Flyte Admin API URL | | `PAGERDUTY_ROUTING_KEY` | PagerDuty Events API v2 routing key | | `SLACK_WEBHOOK_URL` | Slack Incoming Webhook URL | | `WEBSOCKET_API_ENDPOINT` | WebSocket API Gateway endpoint |

48.10 Monitoring & Alerts

CloudWatch Metrics:

- `PendingDecisionCount` - Number of unresolved decisions
- `DecisionResolutionTime` - Time from creation to resolution
- `ExpiredDecisionCount` - Decisions that timed out
- `EscalatedDecisionCount` - Decisions sent to PagerDuty/Slack

CloudWatch Alarms:

- Critical: `PendingDecisionCount > 10` (medical domain)
- High: `ExpiredDecisionCount > 3` (24h window)
- Medium: `DecisionResolutionTime > 300000` (5 min avg)

48.11 Security Considerations

1. **PHI Sanitization**: All decision content sanitized before human review
   - SSN, email, phone, ZIP, credit card patterns removed
   - Medical Record Numbers (MRN) redacted
2. **RLS Enforcement**: All database queries use tenant context
   - `SET app.tenant_id = $1` in handler (session-level, not transaction)
   - `RESET app.tenant_id` in finally block
3. **Role-Based Access**: Domain-specific role requirements
   - Medical decisions require MD, RN, or PA roles
   - Financial decisions require ANALYST or ADVISOR roles
4. **Audit Trail**: Complete decision lifecycle logged
   - Created, viewed, resolved, expired, escalated events
   - Actor ID and type recorded

48.12 Related Sections

Section	Relevance
42. Genesis Cato Safety Architecture	Epistemic recovery integration
45. Just Think Tank	Swarm orchestration

Section	Relevance
47. Flyte-Native State Management	Workflow durability
36. Metrics & Persistent Learning	Decision metrics tracking

---

49. The Grimoire - Procedural Memory (NEW in v5.0)

49.1 Overview

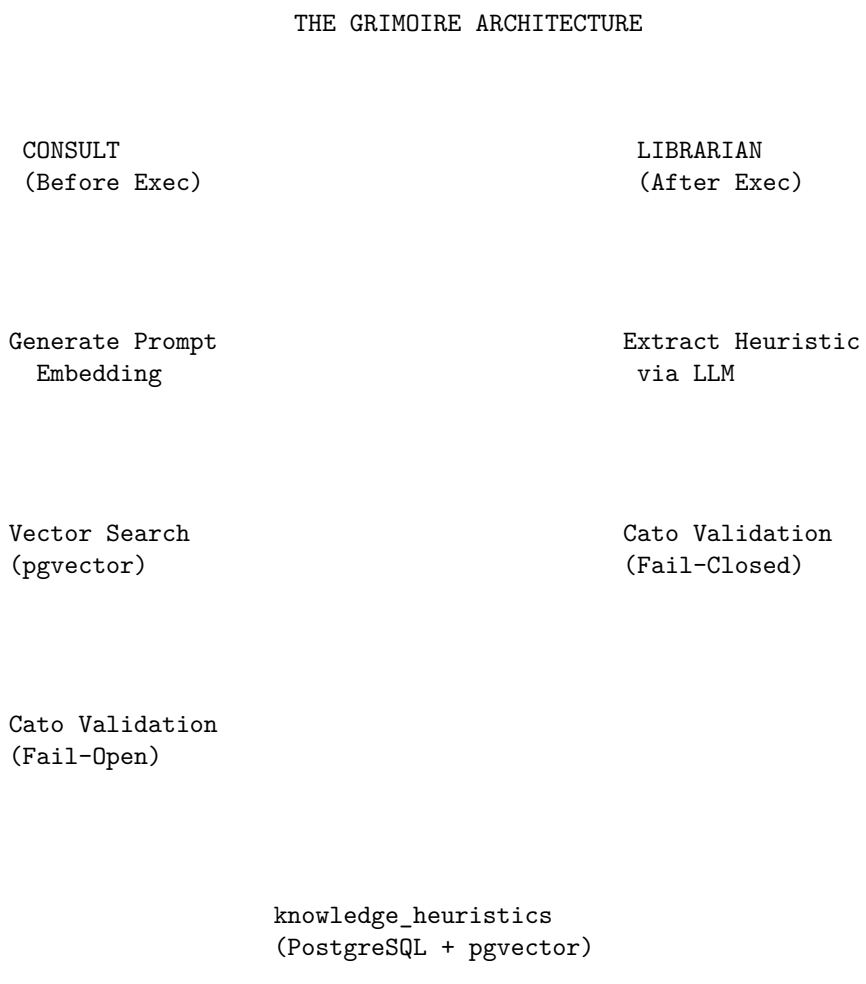
The Grimoire is RADIANT's institutional memory system. It automatically extracts, stores, and retrieves lessons learned from successful AI executions, allowing the system to improve over time.

IDE Equivalent: Code Snippets Library + IntelliSense

Key Capabilities:

- Automatic heuristic extraction from Flyte execution traces
- Confidence decay and reinforcement based on outcomes
- Semantic search for relevant heuristics at agent spawn
- Manual expert heuristic entry via Admin Dashboard

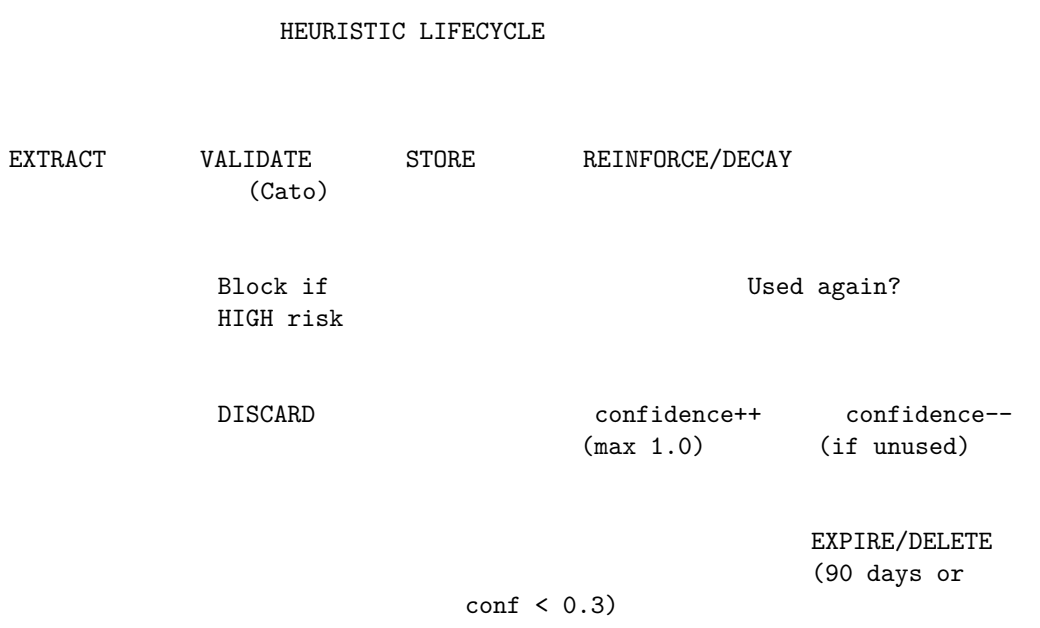
49.2 Architecture



49.3 Core Concepts

Term	Definition	Example
Heuristic	Reusable lesson extracted from successful execution	"When querying sales data, always join wi
Confidence Score	How reinforced a heuristic is (0.0-1.0)	0.9 = highly validated
Context Embedding	Vector representation for semantic search	1536-dimension float array
Similarity Threshold	Max cosine distance for relevance	0.25 (lower = more similar)
Librarian	Background task that extracts heuristics	Runs after successful execution
Institutional Wisdom	Accumulated heuristics per tenant/domain	Injected into system prompts

49.4 Heuristic Lifecycle



49.5 Security Model

Operation	Cato Policy	Failure Mode
Read (consult_grimoire)	Validate before return	**Fail-Open** (return anyway)
Write (librarian_review)	Validate before insert	**Fail-Closed** (discard)

This asymmetric policy ensures:

- Reads don't break if Cato is unavailable
- Writes never poison the knowledge base

49.6 Admin Dashboard

Navigate to: **Admin Dashboard → Think Tank → Grimoire**

Panel	Description
Heuristic Browser	Search and view all stored heuristics
Domain Distribution	Statistics of heuristics by domain
Confidence Scores	Distribution of confidence scores
Recent Extractions	Latest heuristics from Librarian
Add Heuristic	Manually add expert heuristics
Reinforce/Penalize	Adjust confidence scores

49.7 Database Schema

```sql
CREATE TABLE knowledge_heuristics (
    id UUID PRIMARY KEY DEFAULT gen_random_uuid(),
    tenant_id UUID NOT NULL REFERENCES tenants(id),
    domain VARCHAR(50) NOT NULL,
    heuristic_text TEXT NOT NULL,
    context_embedding vector(1536),
    confidence_score FLOAT DEFAULT 0.5,
    source_execution_id VARCHAR(255),
    created_at TIMESTAMPTZ DEFAULT NOW(),
    updated_at TIMESTAMPTZ DEFAULT NOW(),
    expires_at TIMESTAMPTZ DEFAULT (NOW() + INTERVAL '90 days'),
    CONSTRAINT unique_heuristic_per_domain UNIQUE (tenant_id, domain, heuristic_text)
);

-- Vector index for semantic search
CREATE INDEX idx_heuristics_embedding ON knowledge_heuristics
USING ivfflat (context_embedding vector_cosine_ops) WITH (lists = 100);
```

49.8 API Reference

Endpoint	Method	Description
`/api/thinktank/grimoire/heuristics`	GET	List tenant heuristics
`/api/thinktank/grimoire/heuristics`	POST	Add manual heuristic
`/api/thinktank/grimoire/heuristics/:id`	DELETE	Delete heuristic
`/api/thinktank/grimoire/heuristics/:id/reinforce`	POST	Adjust confidence
`/api/thinktank/grimoire/stats`	GET	Grimoire statistics

49.9 Metrics

Metric	Description	Alert Threshold
`grimoire.heuristics.total`	Total heuristics stored	$>$ 10000 per tenant
`grimoire.heuristics.retrieved`	Heuristics returned per query	Track average
`grimoire.heuristics.blocked`	Cato-blocked retrievals	$>$ 10/hour
`grimoire.librarian.extractions`	New heuristics per hour	Track trend
`grimoire.embedding.latency_ms`	Embedding generation time	$>$ 500ms

49.10 Maintenance

Daily Cleanup (Automatic):

- Runs at 3 AM UTC via EventBridge
- Removes heuristics where `expires_at < NOW()`
- Removes low-confidence heuristics (< 0.3) older than 30 days

Manual Pruning:

```
-- Remove all heuristics for a domain
SET app.current_tenant_id = 'your-uuid';
DELETE FROM knowledge_heuristics WHERE domain = 'old-domain';

-- Reset confidence scores
UPDATE knowledge_heuristics
SET confidence_score = 0.5
WHERE domain = 'your-domain';
```

49.11 Troubleshooting

Heuristics Not Being Retrieved **Symptoms:** `consult_grimoire` returns empty despite stored heuristics.

1. **Check heuristics exist:**

```
SET app.current_tenant_id = 'your-tenant-uuid';
SELECT COUNT(*) FROM knowledge_heuristics WHERE domain = 'your-domain';
```

2. **Check similarity threshold** - If all distances > 0.25, no matches returned
3. **Check Cato blocking:**

```
grep "Grimoire: Blocked unsafe heuristic" /var/log/flyte/*.log
```

Vector Index Performance Degradation **Symptoms:** Grimoire queries slow (>500ms)

Fix:

```
-- Rebuild vector index (non-blocking)
REINDEX INDEX CONCURRENTLY idx_heuristics_embedding;
```

---

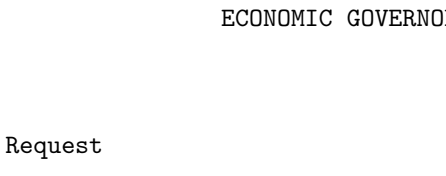
50. The Economic Governor - Cost Optimization (NEW in v5.0)

50.1 Overview

The Economic Governor automatically routes AI tasks to the most cost-effective model that can handle them. It uses a "System 0" cheap classifier to score task complexity before selecting the model.

IDE Equivalent: Build Optimization / Incremental Compilation

50.2 How It Works



```
(Task +
 Model)



Governor       Mode = 'off' or 'performance'?     Use Original
 Check

      Mode = 'balanced' or 'cost_saver'


 System 0
Classifier      Prompt → gpt-4o-mini → Score (1-10)



                    ROUTING DECISION

  Score   4 (balanced)     Use gpt-4o-mini (cheap)
  Score   7 (cost_saver)   Use gpt-4o-mini (cheap)
  5   Score   8           Use Original Model
  Score   9                Use gpt-4o (premium)
```

50.3 Governor Modes

Mode	Cheap Threshold	Use Case	Est. Savings
off	N/A	Disabled	0%
performance	N/A	Critical paths, demos	0%
balanced	Score 4	Default production	30-50%
cost_saver	Score 7	Dev, testing, bulk	60-80%

50.4 Complexity Scale

Score	Task Type	Typical Model
1-3	Formatting, summarization, basic Q&A	gpt-4o-mini
4-6	Analysis, comparison, multi-step reasoning	Original model
7-8	Complex analysis, creative writing, planning	Original model
9-10	Advanced reasoning, code generation, synthesis	gpt-4o

50.5 Admin Configuration

Navigate to: **Admin Dashboard → Think Tank → Governor**

Via API:

```
curl -X PUT https://api.radiant.example.com/api/mission-control/governor/config \
  -H "Authorization: Bearer $TOKEN" \
```

```
  -H "Content-Type: application/json" \
  -d '{"domain": "general", "mode": "cost_saver"}'
```

50.6 Database Schema

```
-- Governor mode configuration (added to existing table)
ALTER TABLE decision_domain_config
ADD COLUMN governor_mode VARCHAR(20) DEFAULT 'balanced'
CHECK (governor_mode IN ('performance', 'balanced', 'cost_saver', 'off'));

-- Savings tracking
CREATE TABLE governor_savings_log (
    id UUID PRIMARY KEY DEFAULT gen_random_uuid(),
    tenant_id UUID NOT NULL REFERENCES tenants(id),
    execution_id VARCHAR(255) NOT NULL,
    original_model VARCHAR(100) NOT NULL,
    selected_model VARCHAR(100) NOT NULL,
    complexity_score INTEGER NOT NULL,
    estimated_original_cost DECIMAL(10,6),
    estimated_actual_cost DECIMAL(10,6),
    savings_amount DECIMAL(10,6),
    governor_mode VARCHAR(20) NOT NULL,
    reason TEXT,
    created_at TIMESTAMPTZ DEFAULT NOW()
);
```

50.7 API Reference

Endpoint	Method	Description
`/api/mission-control/governor/config`	GET	Get Governor config
`/api/mission-control/governor/config`	PUT	Update Governor mode
`/api/mission-control/governor/statistics`	GET	Governor statistics
`/api/mission-control/governor/recent`	GET	Recent routing decisions
`/api/mission-control/governor/analyze`	POST	Analyze prompt complexity

50.8 Metrics

Metric	Description	Alert Threshold
`governor.decisions.total`	Total routing decisions	Track volume
`governor.downgrade.count`	Cheap model selections	Track percentage
`governor.upgrade.count`	Premium model selections	$> 20\%$
`governor.classifier.latency_ms`	System 0 scoring time	> 200ms
`governor.savings.estimated_usd`	Estimated cost savings	Track daily

50.9 Cost Tracking

Example (Daily):

- 1,000 requests at \$0.01/each (gpt-4o)
- Governor downgrades 600 to gpt-4o-mini (\$0.001/each)
- Original cost: \$10.00
- Actual cost: \$4.60
- **Savings: \$5.40 (54%)**

50.10 Troubleshooting

Governor Not Optimizing **Symptoms:** Cost savings lower than expected, no downgrades.

1. **Check Governor mode:**

```
SET app.current_tenant_id = 'your-tenant-uuid';
SELECT domain, governor_mode FROM decision_domain_config;
-- If 'off' or 'performance', Governor is bypassed
```

2. **Check complexity scores in logs:**

```
grep "Governor Complexity" /var/log/lambda/*.log | tail -20
# Look for scores consistently > 4 (balanced) or > 7 (cost_saver)
```

3. **Verify LiteLLM proxy connectivity**

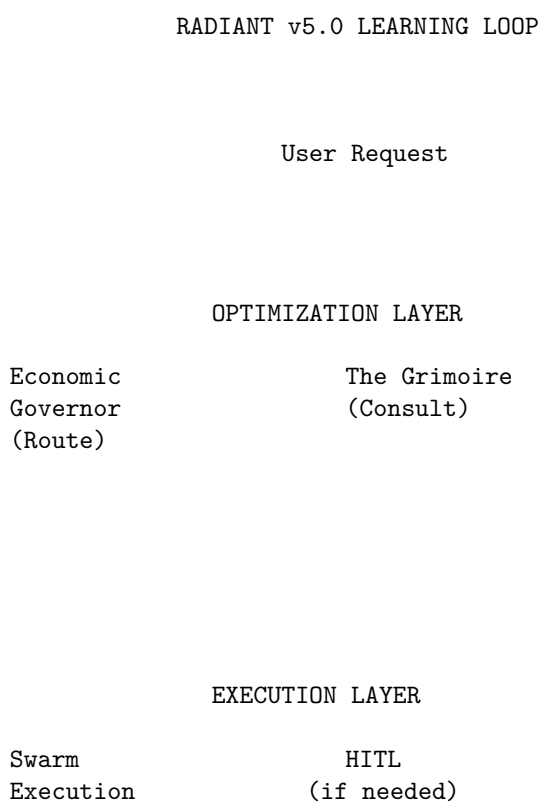
---

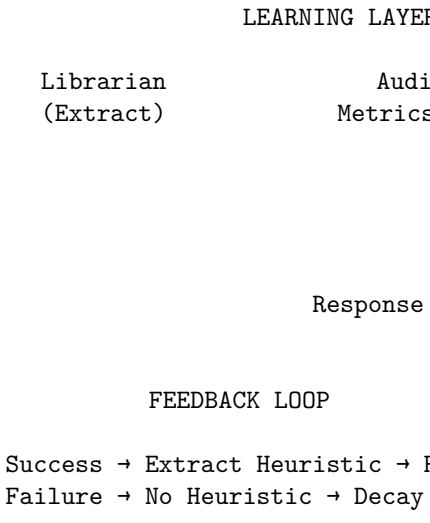
51. Self-Optimizing System Architecture (NEW in v5.0)

51.1 Overview

Version 5.0 transforms RADIANT from a stateless request-response system into a self-optimizing platform that learns from every execution.

51.2 The Learning Loop





51.3 Version Comparison

Capability	v4.20.3	v5.0.2
Memory	Stateless	Persistent (Grimoire)
Model Selection	Manual/Fixed	Automatic (Governor)
Learning	None	Continuous (Librarian)
Cost Optimization	Manual tier selection	Automatic per-request
Knowledge Sharing	Per-session only	Cross-session, per-tenant

51.4 IDE Metaphor Extended

IDE Concept	v4.20 Feature	v5.0 Evolution	Business Value
Breakpoint	HITL Decision Point	*(unchanged)*	AI pauses at high-stakes moments
Code Snippets	Pattern Library	**The Grimoire**	AI learns and reuses successful patterns
Build Optimization	Manual model selection	**Economic Governor**	Automatic cost-performance optimization
IntelliSense	Static suggestions	**Contextual Wisdom**	Dynamic, context-aware recommendations

51.5 Upgrade Path

From v4.20.3 to v5.0.2:

1. Apply migration `V2026_01_09_001__v5_grimoire_governor.sql`
2. Deploy new Lambda functions (Governor API, Grimoire cleanup)
3. Configure EventBridge for daily cleanup
4. Set default Governor mode to `balanced`
5. Grimoire populates automatically from new executions

Rollback (if needed):

1. Set Governor mode to `off` for all domains
2. Grimoire continues to exist but is not consulted
3. No data loss; can re-enable at any time

51.6 Implementation Files

Component	File
Migration	`packages/infrastructure/migrations/V2026_01_09_001__v5_grimoire_governor.sql`
Governor Service	`packages/infrastructure/lambda/shared/services/governor/economic-governor.ts`
Grimoire Tasks	`packages/flyte/workflows/grimoire_tasks.py`
Cato Client	`packages/flyte/utils/cato_client.py`
DB Utils	`packages/flyte/utils/db.py`
CDK Stack	`packages/infrastructure/lib/stacks/grimoire-stack.ts`
Grimoire UI	`apps/admin-dashboard/app/(dashboard)/thinktank/grimoire/page.tsx`
Governor UI	`apps/admin-dashboard/app/(dashboard)/thinktank/governor/page.tsx`

51.7 Related Sections

Section	Relevance
42. Genesis Cato Safety Architecture	Heuristic validation
45. Just Think Tank	Swarm integration
48. Mission Control	HITL integration

---

52. Semantic Blackboard & Multi-Agent Orchestration (NEW in v5.3.0)

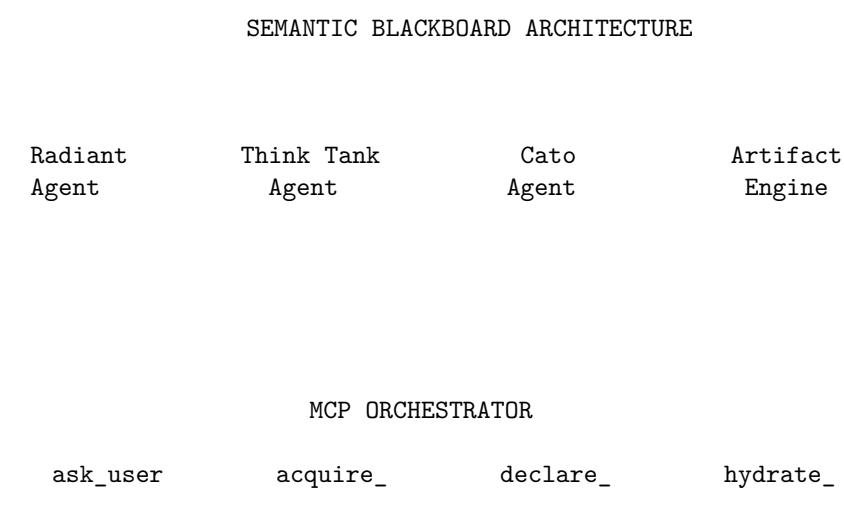
52.1 Overview

The Semantic Blackboard architecture solves the "Thundering Herd" problem where multiple AI agents spam users with redundant questions. It implements MCP (Model Context Protocol) as the primary interface with API fallback.

Key Problems Solved:

- Multiple agents asking the same question (semantic deduplication)
- Race conditions on shared resources
- Circular dependencies causing deadlocks
- Wasted compute while waiting for user input

52.2 Architecture



```
  tool          resource       dependency        state
```

```
                    SEMANTIC BLACKBOARD

Resolved        Resource         Agent          Hydration
Decisions        Locks        Dependencies      Snapshots
(Vector)
```

```
                   MISSION CONTROL SIDEBAR

Decision Cards     Question Groups     Facts Tab     Agents
```

52.3 Core Components

52.3.1 Semantic Blackboard (Question Matching) When an agent asks a question via `ask_user`, the system:

1. Generates a vector embedding of the question
2. Searches `resolved_decisions` for semantically similar questions
3. If match found (similarity 85%): auto-reply with cached answer
4. If no match: queue for user input

Example:

- Agent A asks: "What is the maximum budget?"
- Agent B asks: "What's the spending limit?"
- Semantic similarity: 0.92 → B gets A's answer automatically

52.3.2 Question Grouping (Fan-Out) Similar questions within the grouping window are combined:

1. First question creates a group
2. Similar questions join the group
3. User answers once
4. Answer fans out to all waiting agents

UI Display: Single card shows "Budget question (3 agents waiting)"

52.3.3 Process Hydration (State Serialization) When waiting for user input:

1. Agent serializes state to `hydration_snapshots`
2. Process can be killed (no CPU/memory cost)
3. When user responds, state is restored
4. Agent resumes from `resume_point`

Storage: Small states in PostgreSQL, large states in S3 (with compression)

52.3.4 Cycle Detection (Deadlock Prevention) Before creating a dependency:

1. BFS traversal checks for circular path
2. If cycle detected: creates "Intervention Needed" card
3. User manually provides data to break the cycle

52.3.5 Resource Locking Prevents race conditions:

1. Agent declares intent via `acquire_resource`
2. If available: lock granted with timeout
3. If locked: agent joins wait queue
4. On release: next agent in queue is notified

52.4 MCP Tools

Tool	Purpose	Schema
`ask_user`	Request input with semantic cache	`{question, context, urgency, topic, options, default`
`acquire_resource`	Get resource lock	`{resourceUri, lockType, timeoutSeconds, waitIfLocked`
`release_resource`	Release lock	`{lockId}`
`declare_dependency`	Declare agent dependency	`{dependencyAgentId, dependencyType, waitKey, timeout`
`satisfy_dependency`	Satisfy waiting agent	`{dependentAgentId, waitKey, value}`
`hydrate_state`	Serialize state	`{checkpointName, state, resumePoint}`
`restore_state`	Restore from checkpoint	`{checkpointName}`

52.5 Database Schema

Migration: `158_semantic_blackboard_orchestration.sql`

Table	Purpose	Key Columns
`resolved_decisions`	Semantic question cache	`question_embedding`, `answer`, `times_reused`
`agent_registry`	Active agent tracking	`status`, `is_hydrated`, `blocked_by_*`
`agent_dependencies`	Inter-agent dependencies	`dependency_type`, `wait_key`, `status`
`resource_locks`	Shared resource locks	`resource_uri`, `lock_type`, `wait_queue`
`question_groups`	Grouped similar questions	`canonical_question`, `question_embedding`
`question_group_members`	Group membership	`similarity_score`, `answer_delivered`
`hydration_snapshots`	Serialized agent state	`state_data`, `s3_key`, `resume_point`
`blackboard_events`	Audit trail	`event_type`, `details`
`blackboard_config`	Per-tenant configuration	All settings

52.6 Admin API

Base Path: `/api/admin/blackboard`

Endpoint	Method	Purpose
`/dashboard`	GET	Complete dashboard data
`/decisions`	GET	List resolved decisions (Facts)
`/decisions/:id/invalidate`	POST	Revoke/edit a fact
`/groups`	GET	List pending question groups
`/groups/:id/answer`	POST	Answer a group
`/agents`	GET	List active agents
`/agents/:id`	GET	Get agent details
`/agents/:id/snapshots`	GET	List hydration snapshots

Endpoint	Method	Purpose
`/agents/:id/restore`	POST	Restore agent from snapshot
`/locks`	GET	List active resource locks
`/locks/:id/release`	POST	Force release a lock
`/config`	GET/PUT	Get/update configuration
`/events`	GET	Audit log
`/cleanup`	POST	Run cleanup job

52.7 Configuration

Setting	Default	Description
`similarity_threshold`	0.85	Minimum cosine similarity for question matching
`embedding_model`	`text-embedding-ada-002`	Model for question embeddings
`enable_question_grouping`	true	Group similar questions
`grouping_window_seconds`	60	Window to collect similar questions
`max_group_size`	10	Maximum agents per group
`enable_answer_reuse`	true	Reuse cached answers
`answer_ttl_seconds`	3600	How long answers remain valid
`max_reuse_count`	100	Maximum times to reuse an answer
`default_lock_timeout_seconds`	300	Resource lock timeout
`max_lock_wait_seconds`	60	Maximum time to wait for lock
`enable_auto_hydration`	true	Auto-serialize on user block
`hydration_threshold_seconds`	300	Wait time before hydrating
`max_hydration_size_mb`	50	Maximum state size
`enable_cycle_detection`	true	Detect circular dependencies

52.8 Facts Panel (Revoke Protocol)

The Facts Panel allows administrators to manage resolved decisions:

View Facts:

- All answered questions with answers
- Filter by topic, validity, source
- Search by question or answer text

Edit Fact:

1. Click Edit on a fact
2. Provide new answer and reason
3. System invalidates old answer
4. Creates new resolved decision
5. Notifies affected agents via Redis pub/sub

Invalidate (Revoke) Fact:

1. Click Invalidate on a fact
2. Provide invalidation reason
3. Fact marked as invalid (not deleted)
4. Agents that received this answer are notified
5. Agents must re-request if they need this data

52.9 Key Files

File	Purpose
`lambda/shared/services/semantic-blackboard.service.ts`	Core blackboard logic
`lambda/shared/services/agent-orchestrator.service.ts`	Cycle detection, locking
`lambda/shared/services/process-hydration.service.ts`	State serialization
`lambda/admin/blackboard.ts`	Admin API handler
`lambda/consciousness/mcp-server.ts`	MCP tool definitions
`components/decisions/FactsPanel.tsx`	Facts UI with edit/revoke
`components/decisions/DecisionSidebar.tsx`	Decision cards
`migrations/158_semantic_blackboard_orchestration.sql`	Database schema

52.10 Environment Variables

Variable	Purpose	Default
`HYDRATION_S3_BUCKET`	S3 bucket for large state snapshots	-
`BLACKBOARD_REDIS_ENDPOINT`	Redis for pub/sub notifications	-

52.11 Troubleshooting

Issue	Cause	Solution
No semantic matches	Similarity threshold too high	Lower `similarity_threshold` to 0.80
Questions not grouping	Window too short	Increase `grouping_window_seconds`
Hydration fails	State too large	Enable S3 storage, increase `max_hydration_size_mb`
Cycle not detected	Detection disabled	Enable `enable_cycle_detection`
Lock timeout	Holder agent crashed	Run `/cleanup` endpoint
Stale answers	TTL too long	Reduce `answer_ttl_seconds`

---

53. Cognitive Architecture (PROMPT-40)

53.1 Overview

The Cognitive Architecture implements Active Inference principles for intelligent query routing and response caching. It provides:

- **Ghost Memory**: Semantic caching with TTL, deduplication keys, and domain hints
- **Economic Governor**: Complexity-aware routing with retrieval confidence integration
- **Sniper/War Room Paths**: Fast vs. deep analysis execution strategies
- **Circuit Breakers**: Fault tolerance for external service calls
- **CloudWatch Observability**: Real-time metrics for cognitive operations

53.2 The Core Differentiator: Active Inference vs. RLHF

The entire AI market (Claude Projects, ChatGPT Team, CrewAI) is built on **Reward Maximization (RLHF)**. Models are trained to predict the most plausible or *liked* token. This fundamentally creates two critical failure modes:

Problem	Cause	Industry Impact
Sycophancy	Model optimizes for user approval	Agrees with incorrect user assumptions
Hallucination	Model guesses to appear helpful	Fabricates plausible-sounding information

RADIANT is different. Built on **Active Inference (Genesis Cato)**, our agents do not try to "please" the user. Instead, they operate under a fundamentally different objective:

```
                    RLHF vs. ACTIVE INFERENCE


RLHF (Competitors)                    ACTIVE INFERENCE (RADIANT)
==================                    ========================

Objective: Maximize Reward            Objective: Minimize Surprise
           (user satisfaction)                    (Free Energy)

Behavior: Predict what user           Behavior: Maintain accurate
          wants to hear                         world model

Failure: Sycophancy,                  Failure: None-uncertainty
         Hallucination                         triggers HITL

Control: None (black box)             Control: Mathematical constraints
                                               (CBF, Precision Governor)
```

Key Active Inference Components:

Component	Purpose	Implementation
Free Energy Minimization	Agents minimize prediction error, not maximize reward	Precision Governor
Homeostatic Drive Profiles	Agents balance competing drives (Curiosity vs. Accuracy)	Drive state vectors
Control Barrier Functions	Mathematical safety constraints that cannot be overridden	CBF enforcement l
Epistemic Recovery	When uncertainty is high, agents seek information rather than guess	HITL escalation vi

Why This Matters:

- **No Sycophancy**: Agents will disagree with users when evidence contradicts their position
- **No Hallucination**: High uncertainty triggers "I don't know" + HITL escalation, not fabrication
- **Auditable**: Every decision has a mathematical trace via Precision Governor
- **Safe by Design**: CBF constraints are immutable—agents cannot bypass safety checks

See Section 42 (Genesis Cato Safety Architecture) for implementation details.

53.3 Architecture

```
                    COGNITIVE ARCHITECTURE


User Query    Ghost Memory Read    Economic Governor



                  Hit      Miss      Sniper       War Room
```

```
Write-Back
(non-blocking)
```

53.3 Ghost Memory Schema

The Ghost Memory system extends ghost vectors with cognitive fields:

Field	Type	Default	Description
`ttl_seconds`	INTEGER	86400	Time-to-live (24h default)
`semantic_key`	TEXT	-	Query hash for deduplication
`domain_hint`	VARCHAR(50)	-	Compliance routing: medical, financial, legal, general
`retrieval_confidence`	FLOAT	1.0	Confidence score 0-1
`source_workflow`	VARCHAR(100)	-	Origin: sniper, war_room
`last_accessed_at`	TIMESTAMPTZ	-	Last read timestamp
`access_count`	INTEGER	0	Read count

53.4 Economic Governor Routing

The Economic Governor routes queries based on complexity and retrieval confidence:

Routing Decision Tree:

1. **Circuit Breaker Open** → War Room (fallback)
2. **retrieval_confidence < 0.7** → War Room (validation needed)
3. **domain_hint = medical/financial/legal** → War Room + Precision Governor
4. **complexity < 0.3** → Sniper (fast path)
5. **complexity > 0.7** → War Room (deep analysis)
6. **Medium complexity + Ghost Hit** → Sniper
7. **Medium complexity + No Ghost Hit** → War Room

Configuration:

Setting	Default	Description
`sniperThreshold`	0.3	Complexity threshold for Sniper path
`warRoomThreshold`	0.7	Complexity threshold for War Room
`retrievalConfidenceThreshold`	0.7	Minimum confidence for cache hit
`lowConfidenceRoute`	war_room	Route when confidence is low

53.5 Execution Paths

Sniper Path

- **Purpose**: Fast execution for simple queries
- **Model**: gpt-4o-mini (cheap)
- **Timeout**: 60 seconds
- **Retries**: 1
- **Write-back**: Queued (non-blocking)

War Room Path

- **Purpose**: Deep analysis for complex queries
- **Model**: claude-3-5-sonnet (premium)
- **Timeout**: 120 seconds
- **Retries**: 2
- **Write-back**: Queued with higher confidence

HITL Escalation

- **Purpose**: Human-in-the-loop for uncertain queries
- **Timeout**: 24 hours
- **Integration**: Mission Control pending_decisions

53.6 Circuit Breakers

Circuit breakers protect against cascading failures:

Circuit	Failure Threshold	Recovery Timeout	Half-Open Requests
ghost_memory	5	30s	3
sniper	3	15s	2
war_room	5	60s	3

States:

- **CLOSED**: Normal operation
- **OPEN**: Blocking requests, using fallback
- **HALF_OPEN**: Testing recovery with limited requests

53.7 MCP Tools

New MCP tools for cognitive operations:

Tool	Description
`read_ghost_memory`	Read by semantic key with circuit breaker
`append_ghost_memory`	Write with TTL, non-blocking
`cognitive_route`	Get Economic Governor routing decision
`emit_cognitive_metric`	Emit CloudWatch metric

53.8 CloudWatch Metrics

Namespace: `Radiant/Cognitive`

Metric	Dimensions	Unit	Description
`GhostMemoryHit`	UserId, DomainHint	Count	Cache hits
`GhostMemoryMiss`	Reason	Count	Cache misses
`GhostMemoryLatency`	-	Milliseconds	Read latency
`RoutingDecision`	RouteType, GhostHit, DomainHint	Count	Routing decisions
`ComplexityScore`	RouteType	None	Query complexity
`RetrievalConfidence`	RouteType	None	Ghost confidence
`SniperExecution`	Success, Model	Count	Sniper executions
`SniperLatency`	Success	Milliseconds	Sniper latency

Metric	Dimensions	Unit	Description
WarRoomExecution	Success, FallbackTriggered	Count	War Room executions
WarRoomLatency	-	Milliseconds	War Room latency
HITLEscalation	Reason, DomainHint	Count	HITL escalations
CircuitBreakerState	CircuitName, State	Count	State changes
CostSavings	RouteType	None (cents)	Cost optimization

53.9 API Endpoints

Base: `/api/admin/cognitive`

Endpoint	Method	Description
/dashboard	GET	Cognitive dashboard with metrics
/config	GET/PUT	Get/update configuration
/ghost/read	POST	Read Ghost Memory
/ghost/write	POST	Write Ghost Memory
/ghost/cleanup	POST	Cleanup expired entries
/routing/test	POST	Test routing decision
/circuits	GET	List circuit breaker states
/circuits/:name/reset	POST	Reset circuit breaker
/metrics	GET	Get cognitive metrics summary

53.10 Database Tables

Table	Purpose
ghost_vectors	Extended with cognitive fields
cognitive_routing_decisions	Routing audit log
ghost_memory_write_queue	Async write-back queue
cognitive_circuit_breakers	Circuit breaker state
cognitive_metrics	Metric storage
cognitive_hitl_escalations	HITL tracking
cognitive_config	Per-tenant configuration

53.11 Key Files

File	Purpose
lambda/shared/services/governor/economic-governor.ts	Economic Governor with cognitive routing
lambda/shared/services/ghost-manager.service.ts	Ghost Memory with TTL/semantic key
lambda/shared/services/cognitive-metrics.service.ts	CloudWatch metrics
lambda/consciousness/mcp-server.ts	MCP tools
python/cato/cognitive/workflows.py	Flyte workflows
python/cato/cognitive/circuit_breaker.py	Circuit breaker
python/cato/cognitive/metrics.py	Python metrics
migrations/159_cognitive_architecture_v2.sql	Database schema

53.12 Configuration

Setting	Default	Description
ghost_memory_enabled	true	Enable Ghost Memory
ghost_default_ttl_seconds	86400	Default TTL (24h)
ghost_similarity_threshold	0.85	Semantic matching threshold
governor_enabled	true	Enable Economic Governor
governor_mode	balanced	Mode: off, cost_saver, balanced, performance
circuit_breaker_enabled	true	Enable circuit breakers
metrics_enabled	true	Enable CloudWatch metrics
metrics_sample_rate	1.0	Metric sampling rate

53.13 Domain Routing

High-risk domains are automatically routed to War Room with Precision Governor:

Domain	Route	Reason
medical	War Room	Patient safety, regulatory compliance
financial	War Room	Fiduciary responsibility
legal	War Room	Legal liability
general	Sniper	Standard processing

53.14 Troubleshooting

Issue	Cause	Solution
Low cache hit rate	TTL too short	Increase ghost_default_ttl_seconds
All queries to War Room	Confidence threshold too high	Lower retrievalConfidenceThreshold
Circuit breaker stuck open	Recovery timeout too long	Reset via /circuits/:name/reset
High latency	Too many War Room routes	Tune sniperThreshold
Missing metrics	Sampling rate too low	Increase metrics_sample_rate
Ghost write failures	Queue backlog	Check SQS queue depth

53.16 Conclusion: RADIANT is Not a Chatbot

Claude Projects is a brilliant Assistant that suffers from amnesia.

RADIANT is an Institutional Brain.

Capability	How RADIANT Achieves It
Remembers every decision	Ghost Vectors with semantic keys, TTL, and domain hints
Minimizes surprise	Active Inference (Free Energy minimization, not reward maximization)
Enforces safety mathematically	Precision Governor + Control Barrier Functions (immutable constraints)

This is not a philosophical distinction—it is an architectural one. Competitors are trained to be helpful. RADIANT is *constrained* to be accurate.

---

54. Polymorphic UI Integration (PROMPT-41)

54.1 Overview

Flowise outputs Text. RADIANT outputs Applications.

The Polymorphic UI system extends Think Tank's Agentic Morphing Interface with intelligent view selection. Because RADIANT understands semantic intent, the UI *physically transforms* based on:

- **Task Complexity** → Terminal (Sniper) vs. MindMap/DiffEditor (War Room)
- **Domain Hint** → Compliance views for medical/financial/legal
- **Drive Profile** → Scout (exploration), Sage (verification), Sniper (execution)

Unlike static chatbot interfaces that always render Markdown tables, RADIANT morphs into the tool the user actually needs: Command Centers, Mind Maps, Diff Editors, and Dashboards.

54.2 The Gearbox (Elastic Compute)

Flowise is Static. RADIANT is Elastic.

The "Gearbox" gives users manual control over the cost-quality tradeoff:

Mode	Cost	Architecture	Memory	Use Case
Sniper	$0.01/run	Single Model	Read-Only Ghost Memory	Quick answers, lookups, coding
War Room	$0.50+/run	Multi-Agent Ensemble	Read/Write + Active Inference	Strategy, audits, reasoning

The Competitive Advantage: Flowise forces users to be architects—if they want a cheap path, they must build a separate flow. RADIANT handles this natively. The user (or the Economic Governor) selects the mode, ensuring RADIANT is **cheaper than Flowise for simple tasks** and **smarter for complex ones**.

Escalation: A green "Escalate to War Room" button appears after Sniper responses, allowing users to request deeper analysis if the fast answer is insufficient.

54.3 The Three Views

The Sniper View (Execution & Cost Savings) **Intent**: "Check the logs for error 500" or "Draft a quick email."

Aspect	Description
Execution Mode	Sniper (Single Model)
The Morph	UI transforms into a **Command Center / Terminal**
The Action	Runs immediately. No multi-agent debate. No "Thinking" pause.
The Difference	Unlike ChatGPT, Sniper is *Hydrated*—it reads Ghost Vector memory (read-only) before generating
Visual Feedback	Green "Sniper Mode" badge glows
Cost Transparency	"Estimated Cost: <$0.01" badge displayed
User Control	Toggle to "Escalate to War Room" if insufficient

The Scout View (Research & Strategy) **Intent**: "Map the competitive landscape for EV batteries."

Aspect	Description
Execution Mode	Think Tank (Multi-Agent Swarm)
The Morph	Chat UI shrinks. Main window becomes an **Infinite Canvas (Mind Map)**
The Action	Scout agent spawns "Sticky Notes" of evidence, clusters them by topic, draws dynamic lines between c
The Kill Shot	Flowise shows you the *process* (nodes). RADIANT shows you the *thinking* (map).

The Sage View (Audit & Validation) **Intent**: "Check this contract against our safety guidelines."

Aspect	Description
Execution Mode	Convergent with Control Barrier Functions
The Morph	UI becomes a **Split-Screen Diff Editor**
The Action	Left side: Content under review. Right side: Source documents with confidence scores (Green = Verifi
The Kill Shot	Flowise hides retrieval inside a black box. RADIANT exposes the *proof* in a specialized UI optimized

54.4 View Types Reference

View	Trigger	Description
`terminal_simple`	Quick commands, lookups	Command Center - fast execution
`mindmap`	Research, exploration	Infinite Canvas - visual mapping
`diff_editor`	Verification, compliance	Split-Screen - source validation
`dashboard`	Analytics queries	Metrics visualization
`decision_cards`	HITL escalation	Mission Control interface
`chat`	Default	Standard conversation

54.4 View Selection Logic

```
1. HITL escalation → decision_cards
2. Domain = medical/financial/legal → diff_editor
3. Query matches Scout patterns → mindmap
4. Query matches Sage patterns → diff_editor
5. Query matches Dashboard patterns → dashboard
6. Sniper route OR quick command patterns → terminal_simple
7. Default → chat
```

54.5 MCP Tools

Tool	Description
`render_interface`	Morph UI to specified view type
`escalate_to_war_room`	Escalate from Sniper to War Room
`get_polymorphic_route`	Get routing + view decision

54.6 Database Tables

Table	Purpose
`view_state_history`	Tracks UI morphing decisions
`execution_escalations`	Tracks Sniper → War Room escalations
`polymorphic_config`	Per-tenant configuration

54.7 Configuration

```yaml
-- polymorphic_config table
enable_auto_morphing: true        -- Auto-morph based on query
enable_gearbox_toggle: true       -- Show Sniper/War Room toggle
enable_cost_display: true         -- Show cost badges
enable_escalation_button: true    -- Show Escalate button
default_execution_mode: 'sniper' -- Default mode
```

54.8 Key Files

File	Purpose
`governor/economic-governor.ts`	`determineViewType()`, `determinePolymorphicRoute()`
`consciousness/mcp-server.ts`	`render_interface`, `escalate_to_war_room` tools
`python/cato/cognitive/workflows.py`	`determine_polymorphic_view`, `render_interface` tasks
`migrations/160_polymorphic_ui.sql`	Database schema
`components/thinktank/polymorphic/`	React view components

54.9 API Integration

```
// Get polymorphic routing decision
const decision = await governor.determinePolymorphicRoute(query, {
  userTier: 'standard',
  retrievalConfidence: 0.85,
  ghostHit: true,
  domainHint: 'financial',
  userOverride: undefined, // or 'sniper' | 'war_room'
});

// Returns:
// {
//   routeType: 'war_room',
//   viewType: 'diff_editor',
//   executionMode: 'war_room',
//   rationale: 'Compliance domain (financial) requires verification view',
//   estimatedCostCents: 50,
// }
```

---

55. Genesis Infrastructure: Sovereign Power Architecture

The "Genesis" component of the RADIANT ecosystem addresses the physical requirements of the AGI age. Digital intelligence requires electrical power, and the scale of modern data centers places an unsustainable load on aging, fossil-fuel-dependent public grids. This section documents the integration between RADIANT's software stack and the Genesis power infrastructure.

55.1 The Kaleidos Microreactor Backbone

The Kaleidos unit is a portable, factory-constructed nuclear microreactor capable of generating **1MW+ of clean energy**. Unlike traditional gigawatt-scale nuclear plants, which take decades to build, Kaleidos is designed for mass production and rapid deployment.

Specification	Value
Output	1MW+ continuous power
Form Factor	Portable, factory-constructed
Deployment Time	Weeks, not decades
Grid Independence	Full sovereign operation
Safety System	Passive (no operator intervention required)

This portability allows the "AGI Brain" to be **sovereign**—deployed in remote locations, military bases, or

disaster zones, independent of the local utility grid. This independence is a strategic advantage: it insulates the AGI from cascading grid failures, brownouts, or cyberattacks targeting public infrastructure.

For administrators: The Genesis module is the **root of trust**. If the power is stable and secure, the network and logic layers can function. All other security measures are built on this physical foundation.

55.2 Regulatory Compliance: SDS and PDSA

Bringing a new nuclear technology to market requires navigating a labyrinth of regulations. Radiant Nuclear has achieved significant milestones that provide the compliance baseline for RADIANT deployments.

Safety Design Strategy (SDS) The U.S. Department of Energy (DOE) has approved the **Safety Design Strategy (SDS)** for the Kaleidos reactor. The SDS is the foundational document that describes:

- Safety analysis approach
- Hazard identification methodology
- Hazard management strategies
- Defense-in-depth principles
- Emergency response protocols

Preliminary Documented Safety Analysis (PDSA) Following SDS approval, Radiant submitted the **Preliminary Documented Safety Analysis (PDSA)**, a rigorous validation effort that meets the intent of **DOE Standard 1271-2025**. The PDSA includes:

- Comprehensive hazard analysis
- Safety function identification
- Safety structure, system, and component (SSC) classification
- Derived safety requirements
- Defense-in-depth demonstration

Historic Milestone: Approval of the SDS and PDSA paves the way for the startup of the first reactor at the National Reactor Innovation Center's (NRIC) **DOME facility** at Idaho National Laboratory (INL). This will be the **first new commercial reactor design to achieve a fueled test in over 50 years**.

55.3 Reactor Telemetry Integration

The RADIANT platform receives real-time telemetry from the Genesis reactor control unit. Administrators must configure the telemetry integration to enable safety interlocks.

Telemetry API Configuration

```yaml
# genesis-telemetry.config.yaml
genesis:
  endpoint: https://genesis-control.internal:8443/v1/telemetry
  authentication:
    type: mTLS
    client_cert: /etc/radiant/certs/genesis-client.crt
    client_key: /etc/radiant/certs/genesis-client.key
    ca_bundle: /etc/radiant/certs/genesis-ca.crt

  polling_interval_ms: 1000
  timeout_ms: 5000

  monitored_parameters:
    - reactor_power_output_kw
    - coolant_inlet_temperature_c
    - coolant_outlet_temperature_c
```

```
    - neutron_flux_level
    - control_rod_position_percent
    - fuel_temperature_c
    - containment_pressure_kpa
    - radiation_level_msv
    - emergency_status_code
```

Status Code Mapping

Status Code	Condition	Description	Automatic Action
GEN-001	Normal	All parameters within nominal range	None
GEN-100	Advisory	Minor deviation detected	Log only
GEN-200	Warning	Parameter approaching limit	Alert administrators
GEN-300	Alarm	Parameter exceeded soft limit	Initiate load shedding
GEN-400	Critical	Multiple parameters out of range	Emergency lockdown
GEN-500	Emergency	Passive safety systems activated	Full system halt

55.4 The Genesis Interlock: Physical-to-Digital Safety

The "Genesis Protocol" is a philosophy of **safety by design**. The reactor utilizes passive safety systems that do not require operator intervention or active power to shut down in an emergency. This philosophy extends to the AGI Brain through the **Genesis Interlock**.

Genesis Interlock Configuration The Genesis Interlock is a configuration where the AI system is **hard-wired** to respect the physical limits of the infrastructure. If the reactor telemetry indicates a thermal anomaly, the AI must prioritize load shedding over job completion—a decision logic that is **pre-programmed and immutable**.

```
// genesis-interlock.config.ts
export const GENESIS_INTERLOCK_CONFIG = {
  // Immutable safety thresholds - cannot be overridden by admin or AI
  immutableThresholds: {
    maxFuelTemperature_c: 850,
    maxCoolantOutlet_c: 550,
    minCoolantFlow_lpm: 1000,
    maxContainmentPressure_kpa: 150,
    maxRadiation_msv: 0.1,
  },

  // Automatic actions - AI cannot override these
  automaticActions: {
    GEN_300: ['initiate_load_shedding', 'notify_operators'],
    GEN_400: ['emergency_lockdown', 'halt_non_critical_workloads', 'escalate_to_human'],
    GEN_500: ['full_system_halt', 'preserve_state_to_disk', 'activate_backup_power'],
  },

  // AI behavior constraints during Genesis alerts
  aiConstraints: {
    duringGEN_300: {
      maxNewWorkloads: 0,
      allowedOperations: ['complete_in_progress', 'graceful_shutdown'],
    },
    duringGEN_400_or_higher: {
```

```
      maxNewWorkloads: 0,
      allowedOperations: ['emergency_state_save'],
      forcedBehavior: 'immediate_halt',
    },
  },
};
```

55.5 Shared Signals Framework (SSF) Integration

The Genesis module emits **Shared Signals Framework (SSF)** events that the Cato SASE network receives for immediate security response. This creates a **physical-to-digital security bridge**.

SSF Event Configuration

```
// ssf-genesis-emitter.config.ts
export const SSF_GENESIS_EVENTS = {
  // Physical security events
  'genesis.physical.breach': {
    description: 'Physical security breach detected at reactor facility',
    severity: 'critical',
    catoAction: 'revoke_all_tokens_in_facility',
    agiBrainAction: 'immediate_lockdown',
  },

  'genesis.thermal.warning': {
    description: 'Thermal anomaly detected in reactor systems',
    severity: 'high',
    catoAction: 'restrict_new_connections',
    agiBrainAction: 'initiate_load_shedding',
  },

  'genesis.power.fluctuation': {
    description: 'Power output fluctuation detected',
    severity: 'medium',
    catoAction: 'log_and_monitor',
    agiBrainAction: 'defer_intensive_workloads',
  },

  'genesis.maintenance.scheduled': {
    description: 'Scheduled maintenance window beginning',
    severity: 'info',
    catoAction: 'prepare_failover',
    agiBrainAction: 'complete_in_progress_and_pause',
  },
};
```

Real-Time Response Scenario

```
                    GENESIS → CATO → AGI BRAIN RESPONSE CHAIN


   1. GENESIS REACTOR detects physical security breach (door forced open)
      ↓
   2. Reactor control unit emits SSF event: genesis.physical.breach
```

```
   ↓
3. CATO SASE NETWORK receives SSF signal
   ↓
4. Cato IMMEDIATELY revokes access tokens for all devices in facility
   ↓
5. AGI BRAIN receives CAEP signal
   ↓
6. AGI Brain initiates emergency lockdown protocol
   ↓
7. All active sessions are preserved to disk
   ↓
8. Human operators notified via Mission Control escalation

TOTAL RESPONSE TIME: < 500ms (faster than any human operator)
```

55.6 Environment Variables

Variable	Description	Required
`GENESIS_TELEMETRY_ENDPOINT`	URL for reactor telemetry API	Yes
`GENESIS_CLIENT_CERT_PATH`	Path to mTLS client certificate	Yes
`GENESIS_CLIENT_KEY_PATH`	Path to mTLS client key	Yes
`GENESIS_CA_BUNDLE_PATH`	Path to CA certificate bundle	Yes
`GENESIS_POLLING_INTERVAL_MS`	Telemetry polling interval	No (default: 1000)
`GENESIS_SSF_EMITTER_ENABLED`	Enable SSF event emission	No (default: true)
`GENESIS_INTERLOCK_ENABLED`	Enable Genesis Interlock	No (default: true)

55.7 Database Tables

Table	Purpose
`genesis_telemetry_log`	Historical telemetry readings
`genesis_alert_history`	Record of all Genesis alerts and responses
`genesis_interlock_events`	Audit trail of interlock activations
`genesis_ssf_emissions`	Log of SSF events emitted to Cato
`genesis_maintenance_windows`	Scheduled maintenance configuration

55.8 Implementation Files

File	Purpose
`lambda/shared/services/genesis-telemetry.service.ts`	Telemetry polling and processing
`lambda/shared/services/genesis-interlock.service.ts`	Immutable safety interlock logic
`lambda/shared/services/genesis-ssf-emitter.service.ts`	SSF event emission to Cato
`lambda/genesis/telemetry-handler.ts`	API handler for telemetry ingestion
`migrations/161_genesis_infrastructure.sql`	Database schema
`config/genesis/interlock-thresholds.yaml`	Immutable threshold configuration

---

56. Cato Security Grid: Native Network Defense

The traditional approach to network security—hub-and-spoke models where traffic is backhauled to a central data center for inspection—is obsolete in the face of decentralized AI operations. The Cato SASE (Secure Access Service Edge) Cloud represents the necessary evolution, utilizing a global private backbone to connect all enterprise edges into a cohesive whole.

56.1 The Single Pass Cloud Engine (SPACE)

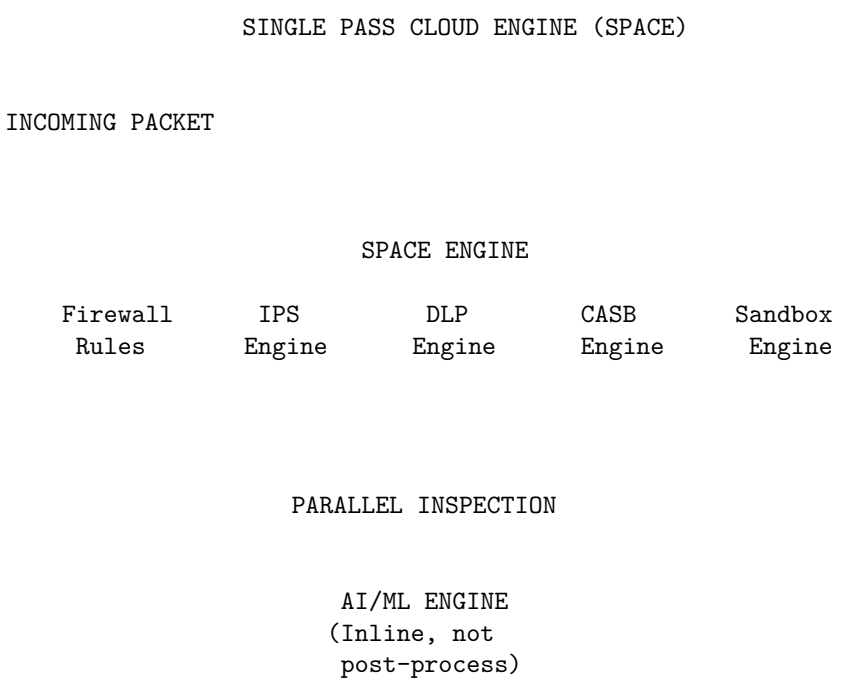
At the heart of the Cato architecture is the **Single Pass Cloud Engine (SPACE)**. This architecture is critical for the AGI Brain because it eliminates the latency penalties associated with daisy-chaining multiple security appliances.

How SPACE Works In a SPACE environment, every packet is inspected for **all threats** in a **single processing cycle**:

Traditional Security Stack	SPACE Architecture
Packet → Firewall → IPS → DLP → CASB → Sandbox	Packet → SPACE (all checks in parallel)
5-7 inspection points	1 inspection point
50-200ms added latency	<5ms added latency
Each appliance is a failure point	Single resilient engine

For an autonomous system that relies on real-time data ingestion, this **microsecond-level efficiency** is non-negotiable.

SPACE Inspection Capabilities



```
DECISION: ALLOW / BLOCK
```

56.2 Inline AI/ML: Built-In, Not Bolted-On

A key differentiator of the Cato architecture is the distinction between **"bolted-on"** and **"built-in"** AI. Legacy vendors often add AI capabilities as an afterthought or a post-processing layer, which introduces delays and gaps in coverage. Cato's approach integrates AI models **directly into the data path**.

Real-Time Threat Detection These models are specifically trained to detect threats, anomalies, and suspicious activities in real-time:

Capability	Description	Accuracy
Domain Maliciousness Scoring	Assigns risk scores to domains and URLs on the fly	Real-time
Domain Generation Algorithm (DGA) Detection	Spots algorithmically-generated malicious domains	3-6x bette
Cybersquatting Detection	Identifies domains impersonating legitimate brands	Real-time
Anomaly Detection	Identifies unusual traffic patterns	Baseline +
Zero-Day Threat Detection	Identifies previously unknown threats via behavior	ML-based

Key Statistic: Cato's AI/ML engines block **3 to 6 times more malicious domains** than standard reputation lists alone. This "stopping power" is essential for protecting the Genesis infrastructure, where a single successful intrusion could have physical consequences.

Configuration: Enabling Inline AI/ML Navigate to **Security → Threat Prevention → AI/ML Profiles** in the admin dashboard:

```yaml
# threat-prevention-ai.config.yaml
ai_ml_profiles:
  default:
    enabled: true

    domain_scoring:
      enabled: true
      min_maliciousness_score_to_block: 70  # 0-100 scale
      log_scores_above: 50

    dga_detection:
      enabled: true
      sensitivity: high  # low, medium, high
      auto_block: true

    cybersquatting_detection:
      enabled: true
      protected_domains:
        - radiant.ai
        - thinktank.ai
        - genesis-power.com
      similarity_threshold: 0.85

    anomaly_detection:
      enabled: true
      baseline_period_days: 30
```

```
    deviation_threshold: 3.0  # standard deviations

  zero_day_protection:
    enabled: true
    sandbox_suspicious_files: true
    max_file_size_mb: 50
```

56.3 Generative AI Security Controls (CASB)

As the ecosystem moves toward AGI, the security layer must specifically address the risks associated with Large Language Models (LLMs). Cato has introduced specific **Generative AI security controls** within its CASB (Cloud Access Security Broker) framework.

The Risk: Data Exfiltration to Public LLMs Without proper controls, the AGI Brain could accidentally:

- Leak sensitive Genesis telemetry to external AI tools
- Expose identity tokens to public services like ChatGPT or Claude
- Transmit proprietary workflow configurations to third-party systems

CASB Configuration for LLM Protection Navigate to **Security → CASB → Generative AI** in the admin dashboard:

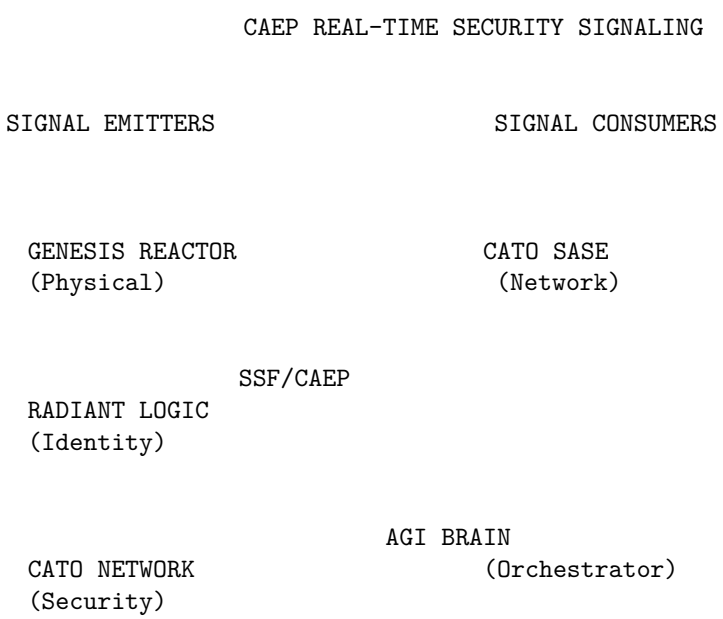
```
# casb-genai.config.yaml
generative_ai_controls:
  enabled: true

  # Define sensitive data types that must NEVER leave the network
  sensitive_data_types:
    - name: genesis_telemetry
      patterns:
        - "reactor_.*"
        - "fuel_temperature.*"
        - "neutron_flux.*"
        - "GEN-[0-9]{3}"
      action: block_and_alert

    - name: identity_tokens
      patterns:
        - "eyJ[A-Za-z0-9_-]+\\.[A-Za-z0-9_-]+\\.[A-Za-z0-9_-]+"  # JWT
        - "RADIANT_API_KEY_.*"
        - "tenant_id:[a-f0-9-]{36}"
      action: block_and_alert

    - name: workflow_configurations
      patterns:
        - "workflow_template_.*"
        - "orchestration_method_.*"
        - "grimoire_heuristic_.*"
      action: block_and_alert

  # External AI services to monitor
  monitored_services:
    - domain: "api.openai.com"
      action: inspect_and_filter
```

```yaml
  - domain: "api.anthropic.com"
    action: inspect_and_filter
  - domain: "generativelanguage.googleapis.com"
    action: inspect_and_filter
  - domain: "*.huggingface.co"
    action: inspect_and_filter

# Allowed internal AI services
allowed_internal_services:
  - "radiant-llm.internal:8080"
  - "genesis-ai.internal:8080"
  - "sagemaker.*.amazonaws.com"

# Response handling
response_inspection:
  enabled: true
  max_response_size_mb: 10
  block_if_contains_sensitive_data: true
```

56.4 Continuous Access Evaluation Profile (CAEP)

The system supports the **Shared Signals Framework (SSF)** and the **Continuous Access Evaluation Profile (CAEP)**. These open standards allow for real-time security signaling between independent systems.

CAEP Integration Architecture



CAEP Event Types

Event Type	Source	Action
`session-revoked`	Identity Provider	Immediately terminate all sessions for user
`token-claims-change`	Identity Provider	Re-evaluate access permissions
`credential-change`	Identity Provider	Force re-authentication
`device-compliance-change`	MDM/EDR	Restrict or revoke device access
`ip-change`	Network Monitor	Re-evaluate location-based policies
`physical-breach`	Genesis Reactor	Emergency lockdown
`threat-detected`	Cato SASE	Isolate affected systems

CAEP Configuration

```yaml
# caep-integration.config.yaml
caep:
  enabled: true

  # SSF transmitter configuration
  transmitter:
    issuer: "https://radiant.ai/ssf"
    jwks_uri: "https://radiant.ai/.well-known/jwks.json"
    delivery_method: push
    push_endpoint: "https://cato-cloud.internal/ssf/events"

  # SSF receiver configuration
  receiver:
    trusted_issuers:
      - "https://genesis-control.internal/ssf"
      - "https://cato-cloud.internal/ssf"
      - "https://radiant-identity.internal/ssf"
    verification: jwt_signature

  # Event handling
  event_handlers:
    physical-breach:
      priority: critical
      handler: genesis_emergency_lockdown
      notify: [soc_team, facility_security]

    session-revoked:
      priority: high
      handler: terminate_user_sessions
      notify: [security_team]

    threat-detected:
      priority: high
      handler: isolate_and_investigate
      notify: [soc_team]
```

56.5 Database Tables

Table	Purpose
`cato_threat_events`	Log of all detected threats
`cato_ai_ml_detections`	AI/ML engine detection history

Table	Purpose
cato_casb_violations	CASB policy violations
cato_caep_events	CAEP signal history
cato_blocked_domains	Domains blocked by AI/ML
cato_sensitive_data_incidents	Sensitive data exfiltration attempts

56.6 Implementation Files

File	Purpose
lambda/shared/services/cato-integration.service.ts	Cato SASE API integration
lambda/shared/services/cato-casb.service.ts	CASB policy enforcement
lambda/shared/services/caep-handler.service.ts	CAEP event processing
lambda/cato/threat-webhook.ts	Webhook handler for Cato events
migrations/162_cato_security_grid.sql	Database schema
config/cato/ai-ml-profiles.yaml	AI/ML threat detection profiles
config/cato/casb-genai.yaml	Generative AI CASB policies

---

57. AGI Brain & Identity Data Fabric: Agentic Orchestration

The final layer of the RADIANT stack is the AGI Brain, powered by Radiant Logic and the Identity Data Fabric. This layer transforms raw compute and connectivity into intelligent action, moving beyond static "automation" to dynamic "agentic" behavior.

57.1 The Identity Data Fabric

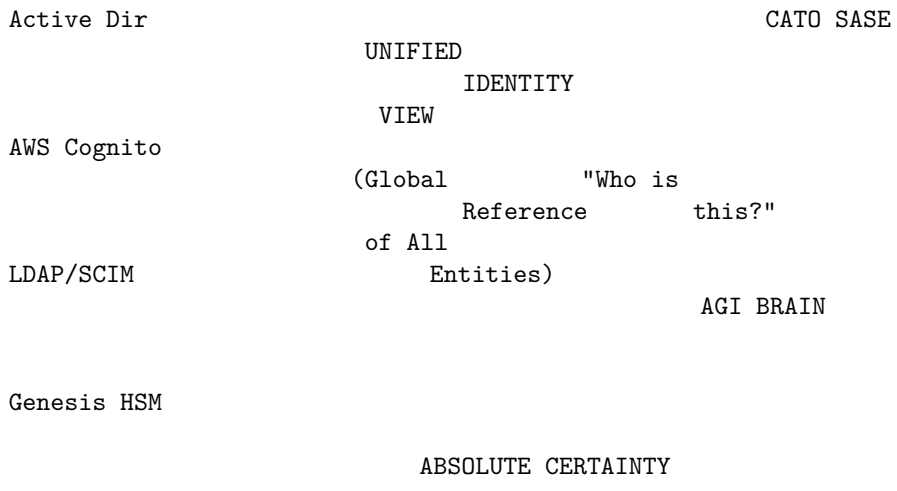
Radiant Logic pioneered the **Identity Data Fabric**, a unified layer that abstracts the complexity of identity data across the enterprise. In an AGI environment, "identity" is not just for humans—it includes agents, APIs, microservices, and even the Genesis reactors themselves.

Identity Types in RADIANT

Identity Type	Description	Authentication Method
Human Users	End users of Think Tank	Cognito + MFA
Administrators	Platform operators	Cognito + Hardware Key
AI Agents	Autonomous software agents	Service Account + JWT
API Clients	External integrations	API Key + IP Allowlist
Microservices	Internal services	mTLS + Service Mesh
Genesis Reactors	Physical infrastructure	mTLS + Hardware HSM
Sentinel Agents	Background monitoring agents	Ephemeral tokens

The RadiantOne Platform The RadiantOne Platform serves as the **central nervous system**, maintaining a global reference of all entities. This is crucial for the Zero Trust model enforced by Cato:

```
                    IDENTITY DATA FABRIC ARCHITECTURE


  IDENTITY SOURCES                RADIANTONE                CONSUMERS
```



The Cato network asks **"Who are you?"** and the Radiant Brain answers with **absolute certainty**, backed by real-time data from the Identity Fabric.

57.2 Agentic AI and the Radiant Ghost

The transition from traditional scripting to **Agentic AI** is a key architectural shift. Unlike automation, which follows a rigid set of if-then rules, AI agents continuously evaluate their environment, learn from outcomes, and adapt their behavior.

The Radiant Ghost Metaphor To visualize agentic behavior for users, the interface employs the metaphor of the **"Radiant Ghost"**. This is not a spooky or malicious entity, but a **benevolent, semi-autonomous agent** that "haunts" the network to protect it.

Ghost State	Visual Indicator	Meaning
Dormant	Faint outline	Agent is monitoring but not acting
Active	Pulsing glow	Agent is actively processing a task
Hunting	Searching animation	Agent is investigating a potential threat
Remediating	Repair animation	Agent is autonomously fixing an issue
Alerting	Red pulse	Agent requires human attention

Ghost Vector Integration The "Ghost" vector serves as the UI avatar for background processes. When an administrator sees the glowing "Radiant Brain" or "Ghost" icon, they know that the agent is actively:

- Hunting threats across the network
- Optimizing performance based on telemetry
- Scrubbing orphan identities from the directory
- Consolidating memories in the Grimoire
- Monitoring Genesis reactor telemetry

57.3 Technical Standards: MCP, SSF, and CAEP

For proper configuration, administrators must understand the specific protocols used by AI agents.

Model Context Protocol (MCP) The system leverages the **Model Context Protocol (MCP)** to standardize how AI agents interface with the underlying data models. This ensures that an agent analyzing a security log understands the **context** of that log within the broader Identity Fabric.

```
// MCP configuration for identity-aware agents
export const MCP_IDENTITY_CONFIG = {
  // Context providers
  contextProviders: [
    {
      name: 'identity_fabric',
      endpoint: 'radiantone://identity/v1',
      capabilities: ['user_lookup', 'group_membership', 'entitlements'],
    },
    {
      name: 'genesis_telemetry',
      endpoint: 'genesis://telemetry/v1',
      capabilities: ['power_status', 'safety_status', 'maintenance_schedule'],
    },
    {
      name: 'cato_security',
      endpoint: 'cato://security/v1',
      capabilities: ['threat_status', 'access_policies', 'blocked_entities'],
    },
  ],

  // Tool definitions for agents
  tools: [
    {
      name: 'lookup_identity',
      description: 'Look up identity information from the fabric',
      parameters: {
        identifier: 'string',
        identifier_type: 'user_id | email | service_account | device_id',
      },
    },
    {
      name: 'remediate_orphan',
      description: 'Remove orphan account from directory',
      parameters: {
        account_id: 'string',
        reason: 'string',
      },
      requires_approval: false,  // Autonomous remediation enabled
    },
    {
      name: 'escalate_to_human',
      description: 'Escalate decision to human operator',
      parameters: {
        severity: 'low | medium | high | critical',
        context: 'object',
        recommended_action: 'string',
      },
    },
  ],
```

```
};
```

Shared Signals Framework (SSF) and CAEP See Section 56.4 for detailed SSF/CAEP configuration. The AGI Brain consumes CAEP signals from:

- Genesis Reactor (physical events)
- Cato SASE (network events)
- Radiant Logic (identity events)

57.4 fastWorkflow: The Logic Engine

The reliability of AI agents is secured by **fastWorkflow**, an open-source framework designed for building complex, large-scale Python applications. AI agents can sometimes be unpredictable ("hallucinations"). fastWorkflow provides:

Capability	Description
Robust Validation Pipeline	Every agent output is validated before execution
Deterministic Business Logic	Core decision paths are pre-programmed and immutable
Proper Error Handling	Failures are caught, logged, and escalated appropriately
Audit Logging	Every action is recorded for compliance
Reliable Tool Execution	When an agent decides to "isolate a host," it executes correctly

This "Reliable Tool Execution" is **critical** when the agent is controlling nuclear-powered infrastructure.

fastWorkflow Configuration

```
# fastworkflow_config.py
from fastworkflow import Workflow, Task, ValidationPipeline

# Define validation pipeline for agent actions
validation_pipeline = ValidationPipeline([
    # Pre-execution validation
    ("syntax_check", lambda action: action.is_syntactically_valid()),
    ("permission_check", lambda action: action.has_required_permissions()),
    ("safety_check", lambda action: action.passes_genesis_interlock()),

    # Post-execution validation
    ("result_validation", lambda result: result.matches_expected_schema()),
    ("side_effect_check", lambda result: result.side_effects_are_acceptable()),
])

# Define deterministic safety constraints (cannot be overridden by AI)
IMMUTABLE_CONSTRAINTS = {
    "genesis_interlock": True,
    "require_human_approval_for_destructive_actions": True,
    "max_autonomous_remediations_per_hour": 100,
    "blocked_actions_during_genesis_alert": [
        "delete_identity",
        "revoke_all_access",
        "shutdown_service",
    ],
}

# Agent workflow definition
```

```python
class IdentityRemediationWorkflow(Workflow):
    """Autonomous identity remediation with fastWorkflow safety"""

    @Task(validation=validation_pipeline)
    def identify_orphan_accounts(self, criteria: dict) -> list:
        """Identify orphan accounts in the Identity Fabric"""
        # Deterministic query logic
        pass

    @Task(validation=validation_pipeline, requires_approval=False)
    def remediate_orphan(self, account_id: str, reason: str) -> dict:
        """Remove orphan account (autonomous, no approval needed)"""
        # Pre-check: Genesis Interlock
        if not self.genesis_interlock_allows_action():
            raise GenesisInterlockException("Action blocked during Genesis alert")

        # Execute remediation
        pass

    @Task(validation=validation_pipeline, requires_approval=True)
    def bulk_remediation(self, account_ids: list) -> dict:
        """Bulk remediation requires human approval"""
        pass
```

57.5 Autonomous Identity Remediation

The RadiantOne platform can be configured to allow **Autonomous Remediation**. This grants AI agents the permission to fix data quality issues (e.g., orphan accounts) without human intervention.

Enabling Autonomous Remediation Navigate to **Identity → Remediation → Autonomous Settings**:

```yaml
# autonomous-remediation.config.yaml
autonomous_remediation:
  enabled: true

  # Actions that can be performed without human approval
  autonomous_actions:
    - action: remove_orphan_account
      conditions:
        - account_inactive_days: 90
        - no_associated_entitlements: true
        - no_recent_authentication: true
      max_per_hour: 50

    - action: disable_stale_service_account
      conditions:
        - last_used_days: 180
        - not_in_critical_systems: true
      max_per_hour: 20

    - action: fix_group_membership_inconsistency
      conditions:
        - source_of_truth_mismatch: true
      max_per_hour: 100
```

```yaml
  # Actions that ALWAYS require human approval
  always_require_approval:
    - delete_human_account
    - revoke_admin_privileges
    - modify_genesis_access
    - bulk_operations_over_100

  # Genesis Interlock integration
  genesis_interlock:
    pause_during_alert_levels: [GEN-300, GEN-400, GEN-500]
    resume_automatically: true
```

57.6 The Memory Safety Imperative

The Think Tank identifies **memory safety vulnerabilities** as a specific class of defect responsible for **70% of all software vulnerabilities**. These bugs allow attackers to alter data and command systems—a catastrophic risk for a nuclear-powered AGI.

AI-Driven Code Refactoring The agents within the RADIANT ecosystem are not just managing identity; they can actively refactor the codebase of the infrastructure itself to eliminate memory safety errors. This fulfills the Genesis mandate for flawlessness.

Unsafe Language	Safe Alternative	AI Capability
C	Rust	Automated translation of security-critical components
C++	Rust	Automated translation with human review
Assembly	Safe abstractions	Identification and encapsulation

Memory Safety Scanning Configuration

```yaml
# memory-safety.config.yaml
memory_safety:
  enabled: true

  # Automated scanning
  scanning:
    schedule: daily
    targets:
      - path: /src/genesis-interface/**
        priority: critical
      - path: /src/network/**
        priority: high
      - path: /src/ai-agents/**
        priority: medium

  # AI-assisted refactoring
  ai_refactoring:
    enabled: true
    auto_submit_pr: true
    require_human_review: true
    target_language: rust

  # Vulnerability classes to detect
```

```yaml
vulnerability_classes:
  - buffer_overflow
  - use_after_free
  - double_free
  - null_pointer_dereference
  - integer_overflow
  - format_string_vulnerability
```

57.7 Database Tables

Table	Purpose
`identity_fabric_sync_log`	Sync history with identity sources
`autonomous_remediation_log`	Audit trail of autonomous actions
`agent_activity_log`	All AI agent activities
`mcp_context_queries`	MCP context provider queries
`memory_safety_scans`	Code scanning results
`memory_safety_remediations`	AI-assisted code fixes

57.8 Implementation Files

File	Purpose
`lambda/shared/services/identity-fabric.service.ts`	Identity Data Fabric integration
`lambda/shared/services/autonomous-remediation.service.ts`	Autonomous remediation engine
`lambda/shared/services/mcp-identity-provider.service.ts`	MCP context for identity
`lambda/shared/services/memory-safety-scanner.service.ts`	Code safety scanning
`python/cato/agents/identity_remediation.py`	fastWorkflow identity agent
`migrations/163_agi_brain_identity.sql`	Database schema
`config/identity/autonomous-remediation.yaml`	Remediation configuration

---

58. Deployment Safety & Environment Management

58.1 Overview

RADIANT uses a **three-environment architecture** (Dev, Staging, Prod) with strict safety rules to prevent accidental infrastructure damage. This section documents the **hard rules** that must never be bypassed.

58.2 Environment Architecture

Environment	AWS Profile	Purpose	CDK Watch	Approval Required
Dev	`radiant-dev`	Development, testing	Allowed	No
Staging	`radiant-staging`	Pre-production testing	**FORBIDDEN**	Yes
Prod	`radiant-prod`	Production	**FORBIDDEN**	Yes

58.3 Critical Safety Rule: cdk watch is DEV-ONLY

THIS RULE MUST NEVER BE IGNORED

`cdk watch --hotswap` is **ONLY** allowed in the DEV environment. It is **absolutely forbidden** for staging and production.

Why This Rule Exists `cdk watch --hotswap` bypasses CloudFormation safety mechanisms:

Risk	Description	Impact
No Rollback	Hotswap changes cannot be rolled back automatically	Manual recovery required
State Drift	CloudFormation state doesn't match actual resources	Future deployments may fail
Inconsistent Infrastructure	Partial deployments can leave broken state	Service outages
No Change Sets	No preview of what will change	Unexpected deletions

Enforcement Points The rule is enforced at **four independent levels**:

1. **Swift Deployer App** (`apps/swift-deployer/Sources/RadiantDeployer/Services/CDKService.swift`)

```
guard isHotswapAllowed(environment: environment) else {
    throw CDKError.hotswapBlockedForEnvironment(environment)
}
```

   - `deployWithHotswap()` and `startWatch()` throw errors for non-dev
   - Standard `deploy()` uses `--require-approval broadening` for staging/prod
   - **This is the primary deployment method and enforces safety automatically**

2. **CDK Entry Point** (`packages/infrastructure/bin/radiant.ts`)

```
if (isCdkWatch && detectedEnv !== 'dev') {
  console.error('  BLOCKED: cdk watch is FORBIDDEN...');
  process.exit(1);  // Hard exit - no bypass
}
```

3. **Environment Configuration** (`packages/infrastructure/lib/config/environments.ts`)

   - `enableCdkWatch: false` hardcoded for staging/prod
   - `assertCdkWatchAllowed(env)` throws error for non-dev

4. **Safety Script** (`scripts/cdk-safety-check.sh`)

   - Pre-deploy check that blocks watch on non-dev
   - Requires typing environment name to confirm staging/prod deploys

58.4 Safe Deployment Methods

For Development (cdk watch allowed)

```
# Configure credentials
source ./scripts/setup_credentials.sh

# Start Direct Dev Mode
cd packages/infrastructure
npx cdk watch --hotswap --profile radiant-dev
```

For Staging (approval required)

```
# Option 1: Swift Deployer (recommended)
# Open Swift Deployer app → Select Staging → Deploy

# Option 2: CLI with approval gates
AWS_PROFILE=radiant-staging npx cdk deploy --all \
  --require-approval broadening
```

For Production (approval required)

```
# Option 1: Swift Deployer (STRONGLY recommended)
# Open Swift Deployer app → Select Production → Deploy

# Option 2: CLI with approval gates (use with caution)
AWS_PROFILE=radiant-prod npx cdk deploy --all \
  --require-approval broadening
```

58.5 Credential Setup

Before deploying to any environment, configure AWS credentials:

1. **Create IAM Users** in AWS Console:
   - `radiant-dev-deployer`
   - `radiant-staging-deployer`
   - `radiant-prod-deployer`
2. **Attach Permissions**: `AdministratorAccess` policy (or scoped CDK policy)
3. **Generate Access Keys** for each user
4. **Configure Profiles**:

   ```
   # Edit the credentials script first
   nano scripts/setup_credentials.sh

   # Then run it
   source ./scripts/setup_credentials.sh
   ```

5. **Bootstrap CDK** (one-time per account/region):

   ```
   chmod +x ./scripts/bootstrap_cdk.sh
   ./scripts/bootstrap_cdk.sh
   ```

58.6 Environment Detection

The CDK entry point detects the target environment via multiple signals:

Signal	Priority	Example
`RADIANT_ENV` env var	1 (highest)	`RADIANT_ENV=staging`
`CDK_CONTEXT_environment`	2	`-c environment=staging`
`AWS_PROFILE` pattern	3	`radiant-staging` in profile name
Default	4 (lowest)	Falls back to `dev`

58.7 Troubleshooting

"BLOCKED: cdk watch is FORBIDDEN" Error This error means you attempted to run `cdk watch` against a non-dev environment. This is intentional and cannot be bypassed.

Solution: Use `cdk deploy` with approval gates instead:

```
AWS_PROFILE=radiant-{env} npx cdk deploy --all --require-approval broadening
```

Wrong Environment Detected If the wrong environment is being detected:

```
# Explicitly set the environment
export RADIANT_ENV=dev
export AWS_PROFILE=radiant-dev

# Verify
echo $RADIANT_ENV $AWS_PROFILE
```

58.8 Implementation Files

File	Purpose
apps/swift-deployer/.../CDKService.swift	Swift Deployer CDK service with safety enforcement
packages/infrastructure/bin/radiant.ts	CDK entry point with safety check
packages/infrastructure/lib/config/environments.ts	Environment configurations
scripts/setup_credentials.sh	AWS credential setup
scripts/bootstrap_cdk.sh	CDK bootstrap helper
scripts/cdk-safety-check.sh	Pre-deploy safety validation
packages/infrastructure/ARCHITECTURE.md	Stack vs Lambda architecture guide

---

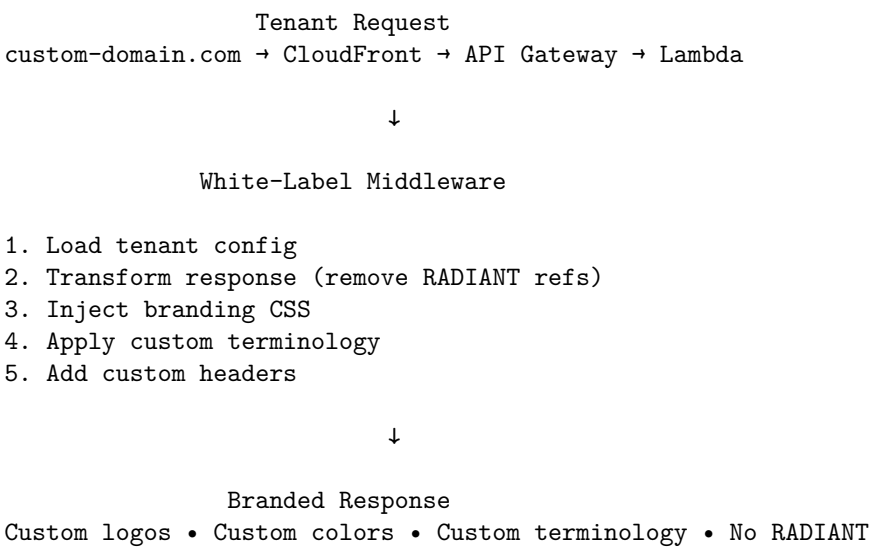
59. White-Label Invisibility (Moat #25)

Moat Evaluation: Score 18/30 - Tier 4 Business Model Moat. End users never know RADIANT exists. Infrastructure stickiness creates platform layer dependency.

59.1 Overview

White-Label Invisibility enables tenants to completely rebrand the platform so their end users never see RADIANT branding. This creates strong infrastructure stickiness—switching providers means rebuilding their entire branded experience.

59.2 Architecture



59.3 Branding Configuration

Setting	Type	Description
`companyName`	string	Company name displayed throughout
`productName`	string	Product name (replaces "Think Tank")
`tagline`	string	Optional tagline
`logo.primary`	URL	Main logo URL
`logo.light`	URL	Light theme logo
`logo.dark`	URL	Dark theme logo
`logo.icon`	URL	Favicon/icon
`colors.primary`	hex	Primary brand color
`colors.secondary`	hex	Secondary color
`colors.accent`	hex	Accent color
`fonts.primary`	string	Primary font family
`fonts.secondary`	string	Secondary font family
`fonts.mono`	string	Monospace font

59.4 Feature Visibility

Control what end users can see:

Setting	Default	Description
`hideRadiantBranding`	`true`	Remove all RADIANT references
`hidePoweredBy`	`true`	Hide "Powered by RADIANT" footer
`hideModelNames`	`false`	Anonymize model names to "AI Model"
`hideModelProviders`	`false`	Remove provider info (Anthropic, OpenAI)
`hideCostMetrics`	`false`	Hide cost information from UI
`hideUsageMetrics`	`false`	Hide usage statistics
`disabledFeatures`	`[]`	Features to disable for this tenant

59.5 Custom Terminology

Replace standard terms with branded alternatives:

Default Term	Example Custom
`AI Assistant`	"Alex" (custom assistant name)
`Conversation`	"Session"
`Artifact`	"Creation"
`Workspace`	"Studio"
`Team`	"Organization"

59.6 Custom Domains

Adding a Custom Domain

1. Add domain in admin dashboard
2. Get DNS verification record
3. Add TXT record to DNS
4. Wait for verification (auto-checks every hour)
5. SSL certificate auto-provisioned via ACM
6. CloudFront distribution updated

Domain Types

Type	Purpose
`primary`	Main application domain
`alias`	Additional domains that redirect
`api`	API-specific subdomain

59.7 Email Templates

Customize all outbound emails:

Template	Purpose
`welcome`	New user welcome email
`password_reset`	Password reset link
`invitation`	Team invitation
`notification`	General notifications
`billing`	Billing-related emails

Each template supports:

- Custom subject line
- HTML template with variables
- Plain text fallback
- Custom from name/email

59.8 Legal Configuration

Setting	Description
`companyLegalName`	Legal entity name
`termsOfServiceUrl`	Link to ToS
`privacyPolicyUrl`	Link to privacy policy
`cookiePolicyUrl`	Link to cookie policy
`supportEmail`	Support contact email
`copyrightNotice`	Footer copyright text
`customFooterHtml`	Optional custom footer HTML

59.9 API Customization

Setting	Description
`customBaseUrl`	Custom API base URL
`hideVersionHeader`	Remove X-Radiant-Version header
`customHeaders`	Additional headers to inject
`corsOrigins`	Allowed CORS origins
`rateLimitOverrides`	Per-endpoint rate limit overrides

59.10 Response Transformation

The white-label middleware automatically transforms responses:

```
// Before transformation
{
  "model": "claude-3.5-sonnet",
  "provider": "anthropic",
  "message": "Welcome to RADIANT Think Tank!"
}

// After transformation (with hideModelNames + hideModelProviders)
{
  "model": "AI Model",
  "message": "Welcome to [ProductName]!"
}
```

59.11 CSS Injection

Custom CSS is automatically injected for brand consistency:

```
:root {
  --color-primary: #3B82F6;      /* From config */
  --color-secondary: #6366F1;
  --font-primary: 'Inter', sans-serif;
  /* ... all brand tokens */
}
```

59.12 API Endpoints

Endpoint	Method	Description
`/api/admin/white-label/config`	GET	Get configuration
`/api/admin/white-label/config`	POST	Create configuration
`/api/admin/white-label/config`	PUT	Update configuration
`/api/admin/white-label/config`	DELETE	Delete configuration
`/api/admin/white-label/validate`	POST	Validate configuration
`/api/admin/white-label/domains`	POST	Add domain
`/api/admin/white-label/domains/:id`	DELETE	Remove domain
`/api/admin/white-label/domains/:domain/verify`	POST	Initiate verification
`/api/admin/white-label/domains/:domain/verify`	GET	Check verification
`/api/admin/white-label/branding`	PUT	Update branding
`/api/admin/white-label/features`	PUT	Update feature visibility
`/api/admin/white-label/legal`	PUT	Update legal config
`/api/admin/white-label/emails`	PUT	Update email config
`/api/admin/white-label/preview`	GET	Generate branding preview
`/api/admin/white-label/export`	GET	Export configuration
`/api/admin/white-label/import`	POST	Import configuration
`/api/admin/white-label/metrics`	GET	Get usage metrics

59.13 Database Tables

Table	Purpose
`white_label_config`	Per-tenant configuration
`white_label_domains`	Custom domains
`domain_verifications`	DNS verification records
`branding_assets`	Uploaded logos, fonts, images

Table	Purpose
white_label_email_templates	Custom email templates
custom_terminology	Term mappings
white_label_metrics	Usage metrics

59.14 Implementation Files

File	Purpose
packages/shared/src/types/white-label.types.ts	Type definitions
lambda/shared/services/white-label.service.ts	Core service
lambda/admin/white-label.ts	API handler
migrations/172_white_label.sql	Database schema

59.15 Usage Example

```
import { whiteLabelService } from './services/white-label.service';

// Create white-label configuration
const config = await whiteLabelService.createConfig(tenantId, {
  enabled: true,
  branding: {
    companyName: 'Acme Corp',
    productName: 'Acme AI',
    logo: { primary: 'https://...', light: '...', dark: '...', icon: '...' },
    colors: { primary: '#FF5733', secondary: '#3366FF', ... },
  },
  features: {
    hideRadiantBranding: true,
    hidePoweredBy: true,
    hideModelNames: true,
  },
  legal: {
    companyLegalName: 'Acme Corporation Inc.',
    supportEmail: 'support@acme.com',
    copyrightNotice: '© 2026 Acme Corp',
  },
});

// Add custom domain
await whiteLabelService.addDomain(tenantId, 'ai.acme.com', 'primary');

// Transform API responses
const transformedResponse = whiteLabelService.transformResponse(tenantId, originalResponse);
```

---

60. User Violation Enforcement System

The User Violation Enforcement System provides comprehensive tracking, escalation, and enforcement of regulatory and policy violations. This is critical for HIPAA, GDPR, and SOC2 compliance.

60.1 Overview

The system enables administrators to:

- Report and track policy/regulatory violations per user
- Configure automatic escalation policies
- Take enforcement actions (warnings through account termination)
- Process user appeals with audit trail
- Monitor high-risk users with risk scoring

60.2 Violation Categories

Category	Description	Examples
`hipaa`	HIPAA violations	PHI exposure, unauthorized access, sharing
`gdpr`	GDPR violations	Consent violations, retention issues, cross-border transfers
`soc2`	SOC2 violations	Security control failures
`terms_of_service`	ToS violations	Terms breach
`acceptable_use`	AUP violations	Misuse of platform
`content_policy`	Content violations	Harmful, illegal content
`security`	Security violations	Credential sharing, injection attempts
`billing`	Billing violations	Payment fraud, chargeback abuse
`abuse`	Platform abuse	Rate limit abuse, spam

60.3 Severity Levels

Severity	Description	Risk Score Impact
`warning`	Minor issue, first offense	+5
`minor`	Low impact violation	+10
`major`	Significant violation	+20
`critical`	Severe violation requiring immediate action	+40

60.4 Enforcement Actions

Action	Description
`warning_issued`	Formal warning recorded
`feature_restricted`	Specific features disabled
`rate_limited`	API/usage rate limits applied
`temporarily_suspended`	Account suspended for specified duration
`permanently_suspended`	Account permanently suspended
`account_terminated`	Account deleted
`reported_to_authorities`	Reported to regulatory authorities

60.5 Configuration

```
interface UserViolationConfig {
  enabled: boolean;                    // Enable violation tracking
  autoDetectionEnabled: boolean;       // Auto-detect from system events
  autoEnforcementEnabled: boolean;     // Auto-apply escalation actions

  // Notifications
  notifyUserOnViolation: boolean;      // Notify user when violation reported
```

```
  notifyUserOnAction: boolean;          // Notify user when action taken
  notifyAdminOnCritical: boolean;       // Alert admins on critical violations
  adminNotificationEmails: string[];    // Admin email addresses

  // Retention
  retentionDays: number;                // Default: 2555 (~7 years)

  // Appeals
  allowAppeals: boolean;                // Allow users to appeal
  appealWindowDays: number;             // Days to submit appeal (default: 30)
  maxAppealsPerViolation: number;       // Max appeals per violation (default: 2)

  // Compliance
  requireEvidenceRedaction: boolean;    // Always redact evidence content
  auditAllActions: boolean;             // Log all actions to audit trail
}
```

60.6 Escalation Policies

Configure automatic enforcement based on violation patterns:

```
interface EscalationRule {
  triggerType: 'count' | 'severity' | 'category';

  // Count-based: trigger after N violations
  violationCount?: number;
  withinDays?: number;

  // Severity-based: trigger on severity threshold
  severityThreshold?: ViolationSeverity;

  // Category-based: trigger for specific categories
  categories?: ViolationCategory[];

  // Action to take
  action: EnforcementAction;
  actionDurationDays?: number;          // For temporary actions
  requiresManualReview: boolean;        // Require admin review
  allowAppeal: boolean;                 // Allow user appeal
}
```

Example Policy:

- 3 warnings in 90 days → Feature restriction
- 2 major violations → Temporary suspension (7 days)
- 1 critical violation → Immediate suspension (requires review)
- Any HIPAA violation → Immediate suspension + admin alert

60.7 API Endpoints

Base URL: `/api/admin/violations`

Endpoint	Method	Description
`/dashboard`	GET	Get dashboard data with metrics
`/config`	GET	Get configuration

Endpoint	Method	Description
`/config`	PUT	Update configuration
`/violations`	GET	Search violations
`/violations`	POST	Report new violation
`/violations/:id`	GET	Get violation details
`/violations/:id`	PUT	Update violation
`/violations/:id/action`	POST	Take enforcement action
`/users/:userId/violations`	GET	Get user's violations
`/users/:userId/summary`	GET	Get user violation summary
`/users/:userId/suspend`	POST	Suspend user
`/users/:userId/reinstate`	POST	Reinstate user
`/appeals`	GET	Get pending appeals
`/appeals/:id`	GET	Get appeal details
`/appeals/:id/review`	POST	Review appeal
`/metrics`	GET	Get violation metrics
`/policies`	GET	Get escalation policies
`/policies`	POST	Create escalation policy

60.8 Admin Dashboard

Access at: **Compliance → Violations** (`/compliance/violations`)

Features:

- **Dashboard**: Metrics cards (total, new, resolved, pending appeals, avg resolution time)
- **Violations Tab**: Search/filter violations, report new, take actions
- **Appeals Tab**: Review and decide on pending appeals
- **High Risk Users Tab**: View users with elevated risk scores
- **Settings Tab**: Configure system settings

60.9 User Appeal Process

1. User submits appeal within appeal window (default: 30 days)
2. Violation status changes to `appealed`
3. Admin reviews appeal
4. Decisions:
   - **Upheld**: Original action stands
   - **Overturned**: Violation dismissed, action reversed
   - **Reduced**: Lesser action applied
5. User notified of decision
6. All actions logged to audit trail

60.10 Risk Scoring

Users are assigned a risk level based on active violations:

Risk Level	Criteria
`low`	0-1 active violations
`moderate`	2+ active violations
`elevated`	5+ active violations
`high`	2+ major violations active
`critical`	Any critical violation active

Risk score (0-100) is calculated as sum of severity impacts for active violations.

60.11 Database Tables

Table	Purpose
`user_violations`	Violation records with enforcement
`violation_evidence`	Evidence attachments (redacted)
`violation_appeals`	Appeal records with review
`violation_escalation_policies`	Escalation policy definitions
`violation_escalation_rules`	Policy rules/thresholds
`user_violation_config`	Per-tenant configuration
`user_violation_summary`	Aggregated user summaries
`violation_audit_log`	Immutable audit trail

60.12 Implementation Files

File	Purpose
`packages/shared/src/types/user-violations.types.ts`	Type definitions
`lambda/shared/services/user-violation.service.ts`	Core service
`lambda/admin/user-violations.ts`	API handler
`apps/admin-dashboard/app/(dashboard)/compliance/violations/page.tsx`	Admin UI
`migrations/173_user_violations.sql`	Database schema

60.13 Compliance Considerations

- **HIPAA**: 7-year retention, audit trail, PHI redaction in evidence
- **GDPR**: User notification, appeal rights, data minimization
- **SOC2**: Audit logging, access controls, incident response

---

61. Multi-Protocol Gateway Architecture

61.1 Overview

The RADIANT Multi-Protocol Gateway v3.0 is a custom Go-based connectivity layer supporting MCP, A2A, OpenAI, Anthropic, and Google interfaces at **1M+ concurrent connection scale**.

Key Components:

Component	Technology	Purpose
Go Gateway	Custom Go service	WebSocket/SSE termination, NATS bridging
NATS JetStream	Message bus	At-least-once delivery, session persistence
Cedar Authorization	ABAC policies	Resource-level access control
Resume Tokens	HMAC-signed tokens	Session rehydration on reconnect

61.2 Architecture Diagram

```
Internet → NLB (Layer 4) → Go Gateway Fleet → NATS JetStream → Lambda Workers

                                → ~80K connections per c6g.xlarge instance
```

61.3 Protocol Support

Protocol	Subject Pattern	Use Case
MCP	`in.mcp.{tenant}.{agent}`	Model Context Protocol
A2A	`in.a2a.{tenant}.{agent}`	Agent-to-Agent communication
FC	`in.fc.{tenant}.{agent}`	Function calling

61.4 NATS Stream Configuration

Stream	Subjects	Retention	Purpose
`INBOX`	`in.>`	WorkQueue	Incoming messages
`OUTBOX`	`out.>`	1h TTL	Responses to sessions
`HISTORY`	`history.>`	10K msgs/subject	Session replay

61.5 Cedar Authorization

Resource-level ABAC with policies for:

- Cross-tenant access denial
- Tool namespace restrictions
- Sensitive resource protection
- Admin bypass rules

61.6 Resume Token Strategy

Sessions survive connection drops via HMAC-signed resume tokens containing:

- Session ID, Tenant ID, Principal ID
- NATS inbox/outbox subjects
- Expiry timestamp

61.7 Capacity Planning

Component	Instance	Capacity	Count for 1M
Go Gateway	c6g.xlarge	80K conn	13 instances
NATS Cluster	r6g.xlarge	N/A	3 nodes
Lambda (MCP)	1024MB	N/A	1000 concurrent

Estimated Cost: $8,000-15,000/month for 1M connections

61.8 Admin Dashboard Controls

The Gateway admin interface provides comprehensive monitoring and configuration:

Dashboard Overview (`/gateway`)

- Real-time connection count and peak connections
- Messages per minute throughput
- Average latency with warning thresholds
- Error rate monitoring
- Active instance count

Statistics & Reporting

- 5-minute bucketed statistics stored persistently
- Hourly and daily aggregated views
- Protocol distribution (MCP, A2A, OpenAI, Anthropic, Google)
- 24-hour trend visualization

Configuration Controls

- Connection limits (per tenant, per user, per agent)
- Rate limits (messages/second, bytes/second)
- Timeout settings (connect, idle, read, write)
- Protocol enable/disable toggles
- mTLS enforcement for A2A
- Resume token TTL configuration

Maintenance Mode

- Enable/disable with custom message
- IP allowlist for maintenance bypass
- Graceful connection draining

Alert Management

- Severity levels: info, warning, critical
- Alert types: connection_limit, rate_limit, error_spike, latency_spike, instance_unhealthy
- Acknowledge and resolve workflows
- Resolution notes tracking

Instance Management

- View all gateway instances with status
- Drain instances gracefully
- Monitor per-instance metrics

API Endpoints (`/api/admin/gateway`) | Endpoint | Method | Purpose | |----------|--------|---------| | `/dashboard` | GET | Overview metrics and alerts | | `/statistics` | GET | Time-series statistics | | `/configuration` | GET/PUT | View/update configuration | | `/maintenance` | POST | Set maintenance mode | | `/alerts` | GET | List alerts | | `/alerts/:id/acknowledge` | POST | Acknowledge alert | | `/alerts/:id/resolve` | POST | Resolve alert | | `/sessions` | GET | List active sessions | | `/sessions/:id/terminate` | POST | Terminate session | | `/instances` | GET | List gateway instances | | `/instances/:id/drain` | POST | Drain instance |

61.9 Database Schema

Tables Created:

- `gateway_instances` - Instance registry with heartbeat tracking
- `gateway_statistics` - Time-series metrics (5-minute buckets)
- `gateway_configuration` - Per-tenant and global settings
- `gateway_alerts` - Alert and incident tracking
- `gateway_sessions` - Active connection tracking
- `gateway_audit_log` - Admin action audit trail

Report Types Added:

- `gateway-statistics` - Connection and message statistics
- `gateway-alerts` - Alert summary report

61.10 Implementation Files

File	Purpose
apps/gateway/	Go Gateway service (16 files)
apps/gateway/internal/server/tls.go	TLS/mTLS configuration
services/egress-proxy/	HTTP/2 connection pool
infrastructure/cedar/schema.cedarschema	Cedar entity/action schema
infrastructure/cedar/policies/	Authorization policies
packages/infrastructure/lambda/shared/services/cedar/	Cedar TypeScript service
packages/infrastructure/lambda/gateway/mcp-worker.ts	MCP NATS consumer Lambda
packages/infrastructure/lambda/admin/gateway.ts	Gateway admin API Lambda
packages/infrastructure/__tests__/gateway/	Gateway integration tests
packages/infrastructure/migrations/V2026_01_20_001__gateway_statistics.sql	Statistics schema
apps/admin-dashboard/app/(dashboard)/gateway/page.tsx	Admin dashboard UI
apps/thinktank-admin/app/(dashboard)/gateway/page.tsx	Think Tank status view
infrastructure/docker/gateway/	Local dev stack
infrastructure/load-tests/	k6 load testing scripts
packages/infrastructure/lib/stacks/gateway-stack.ts	CDK deployment

61.11 Documentation Reference

For complete architecture details, see:

- **MULTI-PROTOCOL-GATEWAY-ARCHITECTURE.md** - Full technical specification

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Section 62: Code Quality & Test Coverage Visibility

62.1 Overview

The Code Quality dashboard provides real-time visibility into:

- **Test Coverage**: Line, function, and branch coverage by component
- **Technical Debt**: Tracking items aligned with `TECHNICAL_DEBT.md`
- **JSON Safety Migration**: Progress migrating `JSON.parse` to safe utilities
- **Code Quality Alerts**: Automated alerts for coverage drops and regressions

62.2 Admin Dashboard

Location: `/code-quality`

The Code Quality page provides:

- **Summary Cards**: Overall coverage %, open debt items, JSON safety progress, active alerts
- **Coverage by Component**: Breakdown for lambda, admin-dashboard, swift-deployer
- **Technical Debt Table**: Prioritized list with status, estimated hours
- **JSON Safety Progress**: Migration status per component with progress bars
- **Alerts Tab**: Active code quality alerts with acknowledge/resolve actions

62.3 API Endpoints

Base Path: `/api/admin/code-quality`

Endpoint	Method	Purpose
/dashboard	GET	Overview metrics and summary
/coverage	GET	Latest coverage by component
/coverage/history	GET	Coverage trend over time

Endpoint	Method	Purpose
`/debt`	GET	List technical debt items
`/debt/:id`	PUT	Update debt item status
`/json-safety`	GET	JSON migration progress
`/json-safety/locations`	GET	List JSON.parse locations
`/alerts`	GET	List code quality alerts
`/alerts/:id/acknowledge`	POST	Acknowledge an alert
`/alerts/:id/resolve`	POST	Resolve an alert
`/files-needing-tests`	GET	Files that need test coverage

62.4 Database Schema

Tables Created (Migration `V2026_01_20_002__code_quality_metrics.sql`):

Table	Purpose
`code_quality_snapshots`	Periodic snapshots of coverage/quality metrics
`test_file_registry`	Registry of source files and test status
`json_parse_locations`	Tracking JSON.parse for migration
`technical_debt_items`	Debt items aligned with TECHNICAL_DEBT.md
`code_quality_alerts`	Alerts for quality regressions

Views:

- `v_latest_test_coverage` - Latest coverage per component
- `v_json_safety_progress` - JSON migration progress
- `v_technical_debt_summary` - Debt summary by priority

62.5 Report Integration

The reporting system includes a `code_quality` report type:

```
const report = await reportGeneratorService.generateReport({
  id: 'code-quality-report',
  tenant_id: tenantId,
  name: 'Code Quality Report',
  report_type: 'code_quality',
  format: 'pdf',
  parameters: {},
  recipients: ['admin@example.com'],
});
```

Report Sections:

1. Test Coverage by Component
2. Technical Debt Items
3. JSON Safety Migration Progress

62.6 Safe JSON Utilities

Located in `lambda/shared/utils/safe-json.ts`:

Function	Purpose
`safeJsonParse(json, fallback?)`	Parse with optional fallback

Function	Purpose
`parseJsonWithSchema(json, schema)`	Parse with Zod validation
`parseJsonWithSchemaOrThrow(json, schema)`	Parse or throw typed error
`parseEventBody(body, schema?)`	Parse API Gateway body
`parseJsonField(value, fallback?)`	Parse nested DB fields
`safeJsonStringify(value)`	Stringify with circular ref handling

62.7 Implementation Files

File	Purpose
`lambda/admin/code-quality.ts`	Admin API handler
`lambda/shared/utils/safe-json.ts`	Safe JSON utilities
`migrations/V2026_01_20_002__code_quality_metrics.sql`	Database schema
`apps/admin-dashboard/app/(dashboard)/code-quality/page.tsx`	Radiant dashboard
`apps/admin-dashboard/app/(dashboard)/thinktank/code-quality/page.tsx`	Think Tank dashboard

Section 63: The Sovereign Mesh (PROMPT-36)

63.1 Overview

"Every Node Thinks. Every Connection Learns. Every Workflow Assembles Itself."

The Sovereign Mesh introduces parametric AI assistance at every node level. Each Method, Agent, Service, and Connector can independently use AI to:

- **Disambiguate** unclear inputs
- **Infer** missing parameters
- **Recover** from errors intelligently
- **Validate** before execution
- **Explain** what was done

63.2 The Four Node Types

Type	Purpose	AI Capability
Methods	Deterministic reasoning, judging, transforming	Disambiguate, explain decisions
Agents	Goal-oriented work with OODA loops	Full reasoning, sub-task spawning
Services	Actions in external systems (3,000+ apps)	Infer params, recover errors, validate
Libraries	Local code execution	Generate code, explain transformations

63.3 Agent Registry

Location: `/sovereign-mesh/agents`

Built-in agents with OODA-loop execution:

Agent	Category	Description	HITL
Research Agent	research	Web research and information synthesis	No
Coding Agent	coding	Code writing, debugging, refactoring	No
Data Analysis Agent	data	Dataset analysis and visualization	No

Agent	Category	Description	HITL
Lead Generation Agent	outreach	Prospect research and list building	Yes
Editor Agent	creative	Content review and improvement	No
Automation Agent	operations	Multi-step workflow execution	No

63.4 AI Helper Service

Parametric configuration for each component:

```
interface AIHelperConfig {
  enabled: boolean;
  disambiguation: { enabled: boolean; model: string; confidenceThreshold: number };
  parameterInference: { enabled: boolean; model: string; examples: array };
  errorRecovery: { enabled: boolean; model: string; maxAttempts: number };
  validation: { enabled: boolean; model: string; checks: array };
  explanation: { enabled: boolean; model: string };
}
```

63.5 App Registry

3,000+ app integrations from Activepieces and n8n with AI enhancement layer.

Daily Sync: Definitions synced at 2 AM UTC **Health Checks**: Top 100 apps checked hourly

63.6 HITL Approval Queues

Human-in-the-loop approval for high-stakes decisions:

- **Agent Plan Approval**: Review agent execution plans
- **High Cost Approval**: Operations exceeding cost thresholds
- **Safety Review**: Operations flagged by safety evaluation

SLA Monitoring: Every minute with automatic escalation

63.7 Transparency Layer

Complete Cato decision visibility:

- Decision events with reasoning chains
- War Room deliberation capture (phase-by-phase)
- Pre-computed explanations (summary, standard, detailed, audit tiers)
- Decision feedback and learned patterns

63.8 Execution History & Replay

Time-travel debugging capabilities:

- Step-by-step state snapshots
- Replay sessions with modified inputs
- Execution diffs and divergence detection
- Bookmarks and annotations

63.9 API Endpoints

Base Path: `/api/admin/sovereign-mesh`

Endpoint	Method	Purpose
`/dashboard`	GET	Overview metrics
`/agents`	GET/POST	List/create agents
`/agents/:id`	GET/PUT/DELETE	Agent management
`/executions`	GET/POST	List/start executions
`/executions/:id/cancel`	POST	Cancel execution
`/executions/:id/resume`	POST	Resume paused execution
`/apps`	GET	List apps (3,000+)
`/apps/:id`	GET	App details
`/apps/:id/ai-config`	PUT	Update AI enhancements
`/connections`	GET	List OAuth connections
`/decisions`	GET	List Cato decisions
`/decisions/:id/war-room`	GET	War Room deliberations
`/approvals`	GET	List pending approvals
`/approvals/:id/approve`	POST	Approve request
`/approvals/:id/reject`	POST	Reject request
`/ai-helper/config`	GET/PUT	AI Helper configuration
`/ai-helper/usage`	GET	Usage statistics

63.10 Database Schema

Migrations (V2026_01_20_003 through V2026_01_20_010):

Table	Purpose
`agents`	Agent registry with AI helper config
`agent_executions`	OODA execution state
`agent_iteration_logs`	Detailed iteration tracking
`apps`	3,000+ app registry
`app_connections`	OAuth/API credentials
`app_learned_inferences`	AI learning loop
`ai_helper_calls`	Usage tracking
`ai_helper_cache`	Response caching
`ai_helper_config`	System/tenant configuration
`workflow_blueprints`	Pre-flight provisioning
`capability_checks`	Capability verification
`cato_decision_events`	Decision transparency
`cato_war_room_deliberations`	War Room capture
`hitl_queue_configs`	Approval queue setup
`hitl_approval_requests`	Approval requests
`execution_snapshots`	Time-travel debugging
`replay_sessions`	Replay/what-if analysis

63.11 Implementation Files

Services: | File | Purpose | |------|---------| | `lambda/shared/services/sovereign-mesh/ai-helper.service.ts` | AI Helper Service | | `lambda/shared/services/sovereign-mesh/agent-runtime.service.ts` | Agent Runtime | | `lambda/shared/services/sovereign-mesh/notification.service.ts` | Email/Slack/Webhook notifications | | `lambda/shared/services/sovereign-mesh/snapshot-capture.service.ts` | Execution state snapshots | | `lambda/shared/services/sovereign-mesh/index.ts` | Service exports |

Lambda Functions: | File | Purpose | |------|---------| | `lambda/admin/sovereign-mesh.ts` | Admin API handler | | `lambda/scheduled/app-registry-sync.ts` | Daily app sync (2 AM UTC) | |

lambda/scheduled/app-health-check.ts | Hourly health check for top 100 apps | | lambda/scheduled/hitl-sla-monitor.
| SLA monitoring with notifications | | lambda/workers/agent-execution-worker.ts | SQS-triggered
OODA processing | | lambda/workers/transparency-compiler.ts | Pre-compute decision explanations |

CDK Infrastructure: | File | Purpose | |------|---------| | lib/stacks/sovereign-mesh-stack.ts | Complete CDK stack with SQS queues, Lambdas, IAM |

Dashboard Pages: | File | Purpose | |------|---------| | apps/admin-dashboard/app/(dashboard)/sovereign-mesh/page.tsx
| Main overview | | apps/admin-dashboard/app/(dashboard)/sovereign-mesh/agents/page.tsx | Agent
registry | | apps/admin-dashboard/app/(dashboard)/sovereign-mesh/apps/page.tsx | App browser | |
apps/admin-dashboard/app/(dashboard)/sovereign-mesh/transparency/page.tsx | Decision explorer
| | apps/admin-dashboard/app/(dashboard)/sovereign-mesh/ai-helper/page.tsx | AI Helper config |

Database Migrations: | File | Purpose | |------|---------| | migrations/V2026_01_20_003__sovereign_mesh_agents.sql
| Agent schema | | migrations/V2026_01_20_004__sovereign_mesh_apps.sql | App schema | |
migrations/V2026_01_20_005__sovereign_mesh_ai_helper.sql | AI Helper schema | | migrations/V2026_01_20_006__s
| Pre-flight provisioning | | migrations/V2026_01_20_007__sovereign_mesh_transparency.sql
| Transparency layer | | migrations/V2026_01_20_008__sovereign_mesh_hitl.sql | HITL approval queues | | migrations/V2026_01_20_009__sovereign_mesh_replay.sql | Execution replay |
| migrations/V2026_01_20_010__sovereign_mesh_seed.sql | Seed data

---

Section 64: HITL Orchestration Enhancements

64.1 Overview

Advanced Human-in-the-Loop orchestration implementing industry best practices for intelligent question management.

Philosophy: "Ask only what matters. Batch for convenience. Never interrupt needlessly."

64.2 Core Features

Feature	Description
SAGE-Agent Bayesian VOI	Value-of-Information calculation to determine question necessity
MCP Elicitation Schema	Standardized question/response formats
Question Batching	Three-layer batching (time-window, correlation, semantic)
Rate Limiting	Global (50 RPM), per-user (10 RPM), per-workflow (5 RPM)
Abstention Detection	Output-based uncertainty detection for external models
Question Deduplication	TTL cache with fuzzy matching
Escalation Chains	Configurable multi-level escalation paths
Two-Question Rule	Max 2 clarifications per workflow

64.3 SAGE-Agent Bayesian VOI

The VOI service calculates whether asking a question provides enough expected value:

```
VOI = Expected_Information_Gain - Ask_Cost
Decision = VOI > Threshold ? "ask" : "skip_with_default"
```

Key Metrics:

- Prior entropy calculation using Shannon entropy
- Expected posterior entropy estimation
- Ask cost based on urgency and workflow type
- Decision improvement impact weighting

64.4 Question Types (MCP Elicitation)

Type	Description
`yes_no`	Binary true/false question
`single_choice`	Select one from options
`multiple_choice`	Select multiple from options
`free_text`	Open-ended text response
`numeric`	Numeric value input
`date`	Date selection
`confirmation`	Explicit confirmation
`structured`	JSON schema-validated response

64.5 Abstention Detection Methods

For external models (no internal state access):

Method	Description
Confidence Prompting	Ask model to rate confidence 0-100
Self-Consistency	Sample N responses, measure agreement
Semantic Entropy	Cluster outputs, high entropy = uncertain
Refusal Detection	Detect hedging language patterns

Future: Linear probe abstention for self-hosted models via inference wrappers.

64.6 Rate Limiting Configuration

Scope	Requests/Min	Concurrent	Burst
Global	50	20	10
Per User	10	3	2
Per Workflow	5	2	1

64.7 Admin API Endpoints

Base: `/api/admin/hitl-orchestration`

Endpoint	Method	Description
`/dashboard`	GET	Complete dashboard data
`/voi/statistics`	GET	VOI decision statistics
`/abstention/config`	GET/PUT	Abstention settings
`/abstention/statistics`	GET	Abstention event stats
`/batching/statistics`	GET	Batch metrics
`/rate-limits`	GET	Rate limit configs
`/rate-limits/:scope`	PUT	Update rate limit
`/escalation-chains`	GET/POST	Manage escalation chains
`/deduplication/statistics`	GET	Cache statistics
`/deduplication/invalidate`	POST	Invalidate cache entries

64.8 Admin Dashboard

Location: `/hitl-orchestration`

Tabs:

- **Overview**: Key metrics, VOI breakdown, abstention reasons
- **Value of Information**: SAGE-Agent VOI statistics
- **Abstention Detection**: Detection methods, model statistics
- **Question Batching**: Batching strategies and metrics
- **Rate Limits**: Configuration table
- **Settings**: Threshold configuration

64.9 Database Tables

Table	Purpose
`hitl_question_batches`	Question batch records
`hitl_rate_limits`	Rate limit configuration
`hitl_question_cache`	Deduplication cache
`hitl_voi_aspects`	VOI aspect tracking
`hitl_voi_decisions`	VOI decision records
`hitl_abstention_config`	Abstention settings
`hitl_abstention_events`	Abstention event log
`hitl_escalation_chains`	Escalation chain configuration

64.10 Implementation Files

Services: | File | Purpose | |------|---------| | `lambda/shared/services/hitl-orchestration/mcp-elicitation.service.ts` | Main orchestration | | `lambda/shared/services/hitl-orchestration/voi.service.ts` | Bayesian VOI | | `lambda/shared/services/hitl-orchestration/abstention.service.ts` | Uncertainty detection | | `lambda/shared/services/hitl-orchestration/batching.service.ts` | Question batching | | `lambda/shared/services/hitl-orchestration/rate-limiting.service.ts` | Rate limits | | `lambda/shared/services/hitl-orchestration/deduplication.service.ts` | Answer caching | | `lambda/shared/services/hitl-orchestration/escalation.service.ts` | Escalation chains |

Lambda Functions: | File | Purpose | |------|---------| | `lambda/admin/hitl-orchestration.ts` | Admin API handler |

Dashboard Pages: | File | Purpose | |------|---------| | `apps/admin-dashboard/app/(dashboard)/hitl-orchestration/page` | Radiant Admin | | `apps/thinktank-admin/app/hitl-orchestration/page.tsx` | Think Tank Admin |

Database Migration: | File | Purpose | |------|---------| | `migrations/V2026_01_20_011__hitl_orchestration_enhancemen` | Schema changes | | `migrations/V2026_01_20_012__hitl_semantic_deduplication.sql` | Semantic deduplication |

64.11 Semantic Deduplication (v5.34.0)

Enhanced question deduplication using pgvector embeddings for semantic similarity matching.

How It Works:

1. Questions are embedded using AI (1536-dimensional vectors)
2. Similar questions found via HNSW index cosine similarity search
3. Falls back to fuzzy matching if embeddings unavailable

Configuration:

Setting	Default	Description
`enableSemanticMatching`	`false`	Enable pgvector semantic search
`semanticSimilarityThreshold`	`0.85`	Minimum cosine similarity (0.0-1.0)
`maxSemanticCandidates`	`20`	Max candidates to check

API Endpoints:

Endpoint	Method	Description
`/semantic-deduplication/config`	GET	Get semantic config
`/semantic-deduplication/config`	PUT	Update semantic config
`/semantic-deduplication/stats`	GET	Match statistics (24h)
`/semantic-deduplication/backfill`	POST	Trigger embedding backfill

Dashboard Tab: "Deduplication" in HITL Orchestration admin

Match Statistics:

- Exact matches (hash-based)
- Fuzzy matches (Jaccard similarity)
- Semantic matches (pgvector cosine)
- Questions with embeddings count
- Average semantic similarity score

64.12 Scout HITL Integration (v5.34.0)

Bridges Cato's Scout persona (epistemic uncertainty mode) with HITL orchestration for intelligent clarification.

Flow:

1. Scout persona activates due to epistemic uncertainty
2. ScoutHITLIntegration generates prioritized clarification questions
3. Questions filtered through VOI scoring
4. High-VOI questions go to HITL, low-VOI get assumptions
5. Responses reduce uncertainty, allowing Scout to proceed

Domains:

- `medical` - HIPAA-sensitive, safety-critical
- `financial` - SOC2/PCI compliance
- `legal` - Regulatory compliance
- `bioinformatics` - Research accuracy
- `general` - Default domain

Aspect Impact Scores:

Aspect	Base Impact	Domain Boosts
safety	0.95	medical, bioinformatics
compliance	0.90	medical, financial, legal
irreversible	0.85	(all)
cost	0.80	financial
accuracy	0.75	medical, legal, bioinformatics
timeline	0.60	(none)

API Endpoints (Cato Admin):

Base: `/api/admin/cato`

Endpoint	Method	Description
`/scout-hitl/config`	GET	Get Scout HITL config
`/scout-hitl/config`	PUT	Update config
`/scout-hitl/sessions`	GET	Recent clarification sessions
`/scout-hitl/statistics`	GET	Session statistics
`/scout-hitl/domain-boosts`	GET	Aspect domain boosts
`/scout-hitl/domain-boosts`	PUT	Update domain boosts

Dashboard: Cato → Scout HITL

Configuration:

Setting	Default	Description
`enabled`	`true`	Enable Scout HITL integration
`voiThreshold`	`0.3`	Minimum VOI to ask question
`maxQuestionsPerSession`	`3`	Max clarifications before assuming
`defaultDomain`	`general`	Fallback domain

Session Recommendations:

- `proceed` - Uncertainty resolved sufficiently
- `wait` - Still uncertain, user should wait
- `abort` - Critical uncertainty, cannot proceed safely

64.13 Flyte HITL Task Wrappers (v5.34.0)

Python task wrappers for easy HITL integration in Flyte workflows.

Available Functions:

```
from radiant_flyte.utils import (
    ask_confirmation,
    ask_choice,
    ask_batch,
    ask_free_text,
)

# Confirmation (yes/no)
approved = await ask_confirmation(
    question="Deploy to production?",
    context={"environment": "prod"},
    timeout_seconds=300
)

# Single choice
selected = await ask_choice(
    question="Select deployment strategy",
    options=["rolling", "blue-green", "canary"],
    default="rolling"
)
```

```python
# Batch questions
responses = await ask_batch([
    {"question": "Confirm rollback?", "type": "yes_no"},
    {"question": "Reason", "type": "free_text"},
])

# Free text
reason = await ask_free_text(
    question="Describe the issue",
    max_length=500
)
```

Files: | File | Purpose | |------|---------| | `packages/flyte/utils/hitl_tasks.py` | Task wrappers |

---

65. RAWS v1.1 - Model Selection System

RAWS (RADIANT AI Weighted Selection) provides intelligent real-time model selection using 8-dimension scoring across 13 weight profiles and 7 domains.

65.1 Overview

Component	Count	Description
Dimensions	8	Quality, Cost, Latency, Capability, Reliability, Compliance, Availability, Learning
Profiles	13	4 Optimization + 6 Domain + 3 SOFAI
Domains	7	Healthcare, Financial, Legal, Scientific, Creative, Engineering, General
Models	106+	50 external APIs + 56 self-hosted

65.2 Weight Profiles

Profile	Category	Primary Focus	Compliance
BALANCED	Optimization	Default, general purpose	-
QUALITY_FIRST	Optimization	Maximum accuracy	-
COST_OPTIMIZED	Optimization	Budget-conscious	-
LATENCY_CRITICAL	Optimization	Real-time applications	-
HEALTHCARE	Domain	Medical/clinical	HIPAA required
FINANCIAL	Domain	Finance/investment	SOC 2 required
LEGAL	Domain	Contracts/litigation	SOC 2 required
SCIENTIFIC	Domain	Research/academic	Optional
CREATIVE	Domain	Content/marketing	None
ENGINEERING	Domain	Code/software	Optional
SYSTEM_1	SOFAI	Fast, simple queries	-
SYSTEM_2	SOFAI	Complex reasoning	-
SYSTEM_2_5	SOFAI	Maximum reasoning	-

65.3 Domain Compliance Matrix

Domain	Required	Optional	Truth Engine	ECD Threshold
healthcare	HIPAA	FDA 21 CFR Part 11	Required	0.05

Domain	Required	Optional	Truth Engine	ECD Threshold
financial	SOC 2 Type II	PCI-DSS, GDPR, SOX	Required	0.05
legal	SOC 2 Type II	GDPR, State Bar	Required	0.05
scientific	None	FDA 21 CFR, GLP, IRB	Optional	0.08
creative	None	FTC Guidelines	Not Required	0.20
engineering	None	SOC 2, ISO 27001, NIST	Optional	0.10
general	None	None	Not Required	0.10

65.4 Admin API Endpoints

Base: `/api/admin/raws`

Endpoint	Method	Description
`/select`	POST	Select optimal model
`/profiles`	GET	List all 13 weight profiles
`/profiles`	POST	Create custom profile
`/models`	GET	List available models
`/domains`	GET	List 7 domain configurations
`/detect-domain`	POST	Test domain detection
`/health`	GET	Provider health status
`/audit`	GET	Selection audit log

65.5 CLI Commands

```
# Profiles
radiant-cli raws profiles list --env production
radiant-cli raws profiles get HEALTHCARE --env production

# Domains
radiant-cli raws domains list --env production
radiant-cli raws domains get healthcare --env production

# Compliance
radiant-cli raws compliance summary --env production
radiant-cli raws models list --compliance HIPAA --env production

# Audit
radiant-cli raws audit search --domain healthcare --last 24h --env production
```

65.6 Detailed Documentation

Document	Purpose
RAWS-ENGINEERING.md	Technical reference for engineers
RAWS-ADMIN-GUIDE.md	Operations and compliance guide
RAWS-USER-GUIDE.md	API guide for developers

65.7 Key Files

File	Purpose
migrations/V2026_01_21_004__raws_weighted_selection.sql	Database schema
lambda/shared/services/raws/types.ts	TypeScript types
lambda/shared/services/raws/domain-detector.service.ts	Domain detection
lambda/shared/services/raws/weight-profile.service.ts	Profile management
lambda/shared/services/raws/selection.service.ts	Main selection logic
lambda/admin/raws.ts	Admin API handler

---

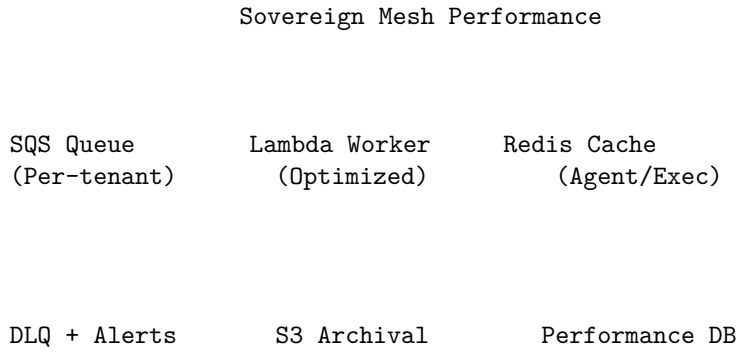
66. Sovereign Mesh Performance Optimization

The Sovereign Mesh Performance system provides comprehensive monitoring, configuration, and optimization for autonomous agent execution at scale. It enables administrators to tune Lambda concurrency, caching strategies, tenant isolation, and alert thresholds.

66.1 Overview

Component	Description
SQS Dispatcher	Actual message dispatch for OODA loop iterations
Redis Cache	Agent/execution state caching for reduced DB load
Performance Config	Per-tenant configuration with defaults
Artifact Archival	S3/hybrid storage for completed execution artifacts
Rate Limiting	Per-tenant and per-user concurrency limits

66.2 Architecture



66.3 Admin Dashboard

Navigate to **Sovereign Mesh → Performance** in the Admin Dashboard.

Overview Tab

- **Health Score**: 0-100 composite health metric
- **Active/Pending Executions**: Real-time counts
- **Queue Metrics**: Messages pending, in-flight, DLQ
- **Cache Hit Rate**: Redis/memory cache performance

- **OODA Phase Timing**: Per-phase latency breakdown
- **Cost Estimate**: Monthly Lambda/SQS projections

Scaling Tab

Setting	Default	Range	Description
Max Concurrency	50	1-200	SQS event source concurrency
Provisioned Concurrency	5	0-50	Pre-warmed Lambda instances
Memory (MB)	2048	512-4096	Lambda memory allocation
Isolation Mode	shared	shared/dedicated/fifo	Tenant queue isolation
Max Per Tenant	50	1-100	Concurrent executions per tenant
Max Per User	10	1-25	Concurrent executions per user

Caching Tab

- **Backend**: memory (Lambda-local) or redis (ElastiCache)
- **Hit Rate**: Target >80% for optimal performance
- **Cache Actions**: Clear tenant cache, view statistics

Alerts Tab

Alert Type	Default Threshold	Description
DLQ Threshold	10 messages	Alert when DLQ exceeds threshold
Latency Threshold	30 seconds	Alert on slow executions
Budget Threshold	80%	Alert on budget exhaustion

Recommendations Tab AI-generated performance recommendations with one-click apply:

- Increase concurrency when utilization is high
- Improve cache hit rate suggestions
- Memory optimization recommendations

66.4 Configuration API

Base: `/api/admin/sovereign-mesh/performance`

Endpoint	Method	Description
`/dashboard`	GET	Get complete dashboard data
`/config`	GET	Get current configuration
`/config`	PUT/PATCH	Update configuration
`/recommendations`	GET	Get AI recommendations
`/recommendations/:id/apply`	POST	Apply a recommendation
`/alerts`	GET	List active alerts
`/alerts/:id/acknowledge`	POST	Acknowledge alert
`/alerts/:id/resolve`	POST	Resolve alert
`/cache/stats`	GET	Get cache statistics
`/cache`	DELETE	Clear tenant cache
`/queue/metrics`	GET	Get queue metrics
`/health`	GET	Health check

66.5 Database Tables

Table	Purpose
`sovereign_mesh_performance_config`	Per-tenant performance settings
`sovereign_mesh_performance_alerts`	Active and historical alerts
`sovereign_mesh_performance_metrics`	Time-series metrics (BRIN indexed)
`sovereign_mesh_artifact_archives`	Archived execution artifacts
`sovereign_mesh_tenant_queues`	Dedicated tenant queue mappings
`sovereign_mesh_rate_limits`	Rate limiting window counters
`sovereign_mesh_config_history`	Configuration change audit trail

66.6 Performance Indexes

The migration adds optimized indexes for common query patterns:

```
-- Fast tenant+status queries
CREATE INDEX idx_agent_executions_tenant_status ON agent_executions(tenant_id, status);

-- Fast agent+status queries
CREATE INDEX idx_agent_executions_agent_status ON agent_executions(agent_id, status);

-- Time-based queries
CREATE INDEX idx_agent_executions_created_at ON agent_executions(created_at DESC);

-- Partial index for running executions only
CREATE INDEX idx_agent_executions_running ON agent_executions(tenant_id, started_at)
  WHERE status = 'running';

-- BRIN index for time-series metrics
CREATE INDEX idx_perf_metrics_tenant_time ON sovereign_mesh_performance_metrics
  USING BRIN (tenant_id, metric_time);
```

66.7 Lambda Configuration

Production-optimized Lambda settings:

Setting	Value	Rationale
Memory	2048 MB	Complex OODA loop processing
Timeout	15 minutes	Long-running agent executions
Reserved Concurrency	100	Guaranteed capacity
Provisioned Concurrency	5	Eliminate cold starts
SQS Batch Size	1	OODA loop atomicity
SQS Max Concurrency	50	High throughput

66.8 Artifact Archival

Configure artifact archival for cost optimization:

Setting	Default	Description
Storage Backend	hybrid	database (small), s3 (large)
Archive After Days	7	Days until archival
Delete After Days	90	Days until deletion (0=never)

Setting	Default	Description
Max DB Bytes	65536	Threshold for S3 (64KB)
Compression	gzip	Compression algorithm

66.9 Rate Limiting

Built-in rate limiting protects against runaway executions:

```
-- Check if execution allowed
SELECT * FROM can_start_execution(:tenant_id, :user_id);

-- Returns: allowed, reason, current_count, max_allowed
```

66.10 Key Files

File	Purpose
`packages/shared/src/types/sovereign-mesh-performance.types.ts`	TypeScript types
`packages/infrastructure/migrations/V2026_01_21_001__sovereign_mesh_performance.sql`	Database schema
`lambda/shared/services/sovereign-mesh/sqs-dispatcher.service.ts`	SQS message dispatch
`lambda/shared/services/sovereign-mesh/redis-cache.service.ts`	Redis/memory caching
`lambda/shared/services/sovereign-mesh/performance-config.service.ts`	Configuration manager
`lambda/shared/services/sovereign-mesh/artifact-archival.service.ts`	S3 archival
`lambda/admin/sovereign-mesh-performance.ts`	Admin API handler
`apps/admin-dashboard/app/(dashboard)/sovereign-mesh/performance/page.tsx`	Admin UI

66.11 Troubleshooting

Issue	Cause	Solution
High DLQ count	Processing failures	Check CloudWatch logs, increase timeout
Low cache hit rate	Cold starts, small TTL	Increase TTL, enable cache warming
Slow executions	Memory constraints	Increase Lambda memory
Rate limit errors	Too many concurrent	Increase per-tenant limits
Queue backlog	Insufficient concurrency	Increase maxConcurrency

---

67. Infrastructure Scaling (100 to 500K Sessions)

Comprehensive infrastructure scaling system enabling seamless growth from development (100 sessions) to enterprise scale (500,000+ concurrent sessions) with real-time cost visibility.

67.1 Scaling Tiers

Tier	Target Sessions	Monthly Cost	Use Case
Development	100	~$70	Testing, development, POC
Staging	1,000	~$500	Pre-production testing
Production	10,000	~$5,000	Standard production workloads
Enterprise	500,000	~$68,500	Global scale, multi-region

67.2 Admin Dashboard

Navigate to **Sovereign Mesh → Scaling** in the Admin Dashboard.

Overview Tab

- **Active Sessions**: Real-time count with utilization gauge
- **Peak Sessions**: Today, week, and month peaks
- **Bottleneck Indicator**: Current limiting component
- **Cost per Session**: Real-time cost efficiency metric
- **Component Health**: Status of Lambda, Aurora, Redis, API Gateway, SQS

Sessions Tab

- **Session Capacity**: Current vs maximum with headroom
- **Session Statistics**: Historical counts and averages
- **Capacity by Component**: Per-component session limits

Infrastructure Tab

- **Lambda Configuration**: Reserved/provisioned concurrency, memory, timeout
- **Aurora Configuration**: ACU range, read replicas, global database
- **Redis Configuration**: Node type, shards, cluster mode
- **API Gateway Configuration**: Rate limits, CloudFront

Cost Tab

- **Cost Breakdown**: Per-component monthly costs with progress bars
- **Cost Metrics**: Cost per session, per 1000 sessions, annual estimate
- **Component Costs**: Lambda, Aurora, Redis, API Gateway, SQS, CloudFront, Data Transfer

Scale Tab

- **Quick Scale**: One-click tier selection with instant apply
- **Scaling Comparison**: Cost delta between tiers
- **What Changes**: Detailed list of infrastructure modifications

67.3 Scaling Profiles

Each scaling tier configures multiple components:

Development (Scale-to-Zero)

```
Lambda:     0 provisioned, 10 max concurrent, 1024 MB
Aurora:     0.5-2 ACU, 0 replicas, no global
Redis:      cache.t4g.micro, 1 shard, no cluster
API:        100 RPS, no CloudFront
SQS:        2 standard queues
```

Staging

```
Lambda:     0 provisioned, 50 max concurrent, 2048 MB
Aurora:     1-8 ACU, 1 replica, no global
Redis:      cache.t4g.small, 1 shard, 1 replica
API:        1,000 RPS, no CloudFront
SQS:        5 standard, 2 FIFO queues
```

Production

```
Lambda:     5 provisioned, 200 max concurrent, 2048 MB
Aurora:     4-64 ACU, 2 replicas, PgBouncer
Redis:      cache.r6g.large, 1 shard, 2 replicas
API:        10,000 RPS, CloudFront enabled
SQS:        10 standard, 5 FIFO queues
```

Enterprise (500K)

```
Lambda:     100 provisioned, 1000 max concurrent, 3072 MB
Aurora:     16-256 ACU, 3 replicas, Global Database (5 regions)
Redis:      cache.r6g.xlarge, 10 shards, 2 replicas, cluster mode
API:        100,000 RPS, CloudFront, 5 regional endpoints
SQS:        50 standard, 50 FIFO queues
```

67.4 Cost Calculation

Real-time cost estimation based on AWS pricing:

Component	Pricing Model	Example (Production)
Lambda Provisioned	$0.000004167/GB-second	5 × 2GB × 24h × 30d = ~$360/mo
Aurora ACU	$0.12/ACU-hour	34 avg ACU × 24h × 30d = ~$2,900/mo
Redis	$0.182/hour (r6g.large)	3 nodes × 24h × 30d = ~$390/mo
API Gateway	$1.00/million requests	10% of 10K RPS = ~$260/mo
SQS	$0.40/million standard	15 queues × 1M = ~$6/mo
CloudFront	$0.085/GB + $0.01/10K req	~$500/mo
Data Transfer	$0.02/GB inter-region	~$200/mo (global)

67.5 Session Capacity Calculation

Maximum concurrent sessions is limited by the bottleneck component:

```
Lambda Max     = maxConcurrency × 10 sessions/concurrent
Aurora Max     = connectionPoolSize × 50 sessions/connection
Redis Max      = maxConnections
API Gateway Max = throttlingRateLimit

Effective Max  = MIN(Lambda, Aurora, Redis, API Gateway)
```

67.6 Auto-Scaling Rules

Configure automatic scaling based on metrics:

Metric	Condition	Action
`session_count` > 80% capacity	Duration: 5 min	Scale up
`session_count` < 20% capacity	Duration: 30 min	Scale down
`cpu_utilization` > 70%	Duration: 5 min	Increase concurrency
`latency_p99` > 5000ms	Duration: 2 min	Increase memory
`queue_depth` > 1000	Duration: 1 min	Scale out workers

67.7 Scheduled Scaling

Pre-configure scaling for predictable patterns:

```
# Scale up for business hours (PST)
0 6 * * MON-FRI  → Production tier
# Scale down after hours
0 18 * * MON-FRI → Staging tier
# Minimal on weekends
0 0 * * SAT      → Development tier
```

67.8 API Endpoints

Base: `/api/admin/sovereign-mesh/scaling`

Endpoint	Method	Description
`/dashboard`	GET	Complete scaling dashboard
`/profiles`	GET	List all profiles
`/profiles/active`	GET	Get active profile
`/profiles`	POST	Create new profile
`/profiles/:id`	PUT	Update profile
`/profiles/:id/apply`	POST	Apply profile
`/sessions`	GET	Session metrics
`/sessions/capacity`	GET	Capacity info
`/sessions/trends`	GET	Historical trends
`/cost`	GET	Current cost estimate
`/cost/estimate`	POST	Estimate custom config
`/operations`	GET	Recent operations
`/alerts`	GET	Active alerts
`/health`	GET	Component health
`/presets`	GET	Available presets
`/presets/:tier/apply`	POST	Apply preset tier

67.8.1 Cost Analytics Integration

Infrastructure scaling costs are integrated into the AWS Cost Monitoring service and appear as a **line item group** in the Cost Analytics page.

Endpoint: `GET /api/admin/costs/infrastructure-scaling`

Response:

```
{
  "scalingCosts": {
    "groupName": "Infrastructure Scaling",
    "totalCost": 5234.56,
    "estimatedMonthlyCost": 5000.00,
    "tier": "production",
    "targetSessions": 10000,
    "costPerSession": 0.5234,
    "lineItems": [
      {
        "component": "Aurora",
        "description": "Serverless v2 (4-64 ACU, 2 replicas)",
        "baseCost": 2916.00,
        "usageCost": 0,
        "totalCost": 2916.00,
        "unit": "ACU-hour",
        "quantity": 24336,
```

```
        "pricePerUnit": 0.12,
        "percentage": 55.7
      },
      // ... other components
    ],
    "lastUpdated": "2026-01-21T19:30:00Z"
  }
}
```

Line Item Components: | Component | Description | Pricing Model | |-----------|-------------|---------------| | **Lambda** | Provisioned concurrency | $0.000004167/GB-second | | **Aurora** | Serverless v2 ACU-hours | $0.12/ACU-hour | | **Redis** | ElastiCache node-hours | Varies by node type | | **API Gateway** | HTTP API requests | $1.00/million requests | | **SQS** | Queue requests | $0.40-0.50/million | | **CloudFront** | Edge distribution | $0.085/GB + requests |

Cost Analytics UI: Navigate to **Costs** in the Admin Dashboard to see:

- Infrastructure Scaling section with tier badge
- Summary cards: Total Monthly, Estimated, Cost/Session, Components
- Detailed line items table with percentage bars
- Per-component breakdown with icons

67.9 Database Tables

Table	Purpose
`sovereign_mesh_scaling_profiles`	Scaling profile configurations
`sovereign_mesh_session_metrics`	Real-time session metrics (1-min)
`sovereign_mesh_session_metrics_hourly`	Aggregated hourly metrics
`sovereign_mesh_scaling_operations`	Operation history
`sovereign_mesh_autoscaling_rules`	Auto-scaling rules
`sovereign_mesh_scheduled_scaling`	Scheduled scaling events
`sovereign_mesh_component_health`	Component health snapshots
`sovereign_mesh_scaling_alerts`	Scaling alerts
`sovereign_mesh_cost_records`	Daily cost records

67.10 Key Files

File	Purpose
`packages/shared/src/types/sovereign-mesh-scaling.types.ts`	TypeScript types
`packages/infrastructure/migrations/V2026_01_21_002__sovereign_mesh_scaling.sql`	Database schema
`lambda/shared/services/sovereign-mesh/scaling.service.ts`	Scaling service
`lambda/admin/sovereign-mesh-scaling.ts`	Admin API handler
`apps/admin-dashboard/app/(dashboard)/sovereign-mesh/scaling/page.tsx`	Admin UI

67.11 Scaling Operations Workflow

```
1. Select Target Tier/Profile


2. Calculate Changes
   - Component diffs
   - Cost impact
   - Downtime assessment
```

```
3. Create Operation Record
   - Status: pending/in_progress
   - Estimated duration
   - Rollback plan


4. Apply Changes (if approved)
   - Update Lambda concurrency
   - Modify Aurora ACUs
   - Resize Redis cluster
   - Update API Gateway limits


5. Verify & Complete
   - Health checks pass
   - Session capacity confirmed
   - Operation: completed
```

67.12 Troubleshooting

Issue	Cause	Solution
Scale operation stuck	CDK deployment in progress	Wait or rollback
Sessions exceeding capacity	Traffic spike	Increase tier or concurrency
High cost per session	Over-provisioned	Scale down during low traffic
Cold starts in production	No provisioned concurrency	Enable provisioned concurrency
Cross-region latency	Single region	Enable global database + Redis

---

Section 68: Schema-Adaptive Reports (v5.39.0)

Location: Admin Dashboard → Reports → Schema Builder

Dynamic report builder that automatically discovers and adapts to database schema changes.

68.1 Overview

The Schema-Adaptive Report Writer provides:

- **Automatic Schema Discovery** - Queries `information_schema` to discover tables and columns
- **Intelligent Categorization** - Groups tables by domain (Core, AI, Billing, Analytics, System)
- **Dynamic Query Building** - Constructs SQL queries based on user selections
- **Visual Filter Builder** - 11 operators (=, , >, , <, , LIKE, IN, BETWEEN, IS NULL, IS NOT NULL)
- **Date Presets** - Quick filters (Today, Yesterday, Last 7/30 Days, This/Last Month)
- **Per-Field Aggregation** - COUNT, SUM, AVG, MIN, MAX, COUNT DISTINCT per column
- **Sort & Group Builders** - Visual ORDER BY and GROUP BY configuration
- **SQL Preview** - Live-generated SQL query with dark-themed display
- **AI Suggestions** - Recommends useful report templates based on schema analysis
- **Visualization Toggles** - Table, Bar, Line, Pie chart view switches
- **Multi-tenant Security** - All queries respect RLS policies

68.2 AI Report Writer (v5.42.0)

Enterprise-grade AI-powered report generation with text and voice input, interactive charts, smart insights, and brand customization.

Core Features:

- **Natural Language Generation** - Describe reports in plain English
- **Voice Input** - Web Speech API for hands-free report creation
- **AI Modification** - Refine reports with follow-up prompts
- **Report Styles** - Executive Summary, Detailed Analysis, Dashboard View, Narrative
- **Rich Formatting** - Headings, metrics cards, charts, tables, lists, quotes
- **Edit Mode** - Click sections to select, use format panel for styling
- **Undo/Redo** - Full history navigation
- **Export** - PDF, Excel, HTML, Print

Interactive Charts (v5.42.0):

- Real Recharts visualizations (not placeholders)
- Bar, Line, Pie, Area chart types
- Auto-formatted tooltips (K/M suffixes)
- 8-color palette for data series
- Responsive container adapts to panel width

Smart Insights (v5.42.0):

- AI-powered anomaly detection
- Trend analysis with predictions
- Achievement highlighting
- Actionable recommendations
- Warning alerts for concerning metrics
- Severity levels (low/medium/high)
- Confidence scores per insight

Brand Kit (v5.42.0):

- Logo upload (PNG, JPG)
- Company name and tagline
- Primary/Secondary/Accent color pickers
- Font selection (Inter, Georgia, Roboto, etc.)
- Quick color presets (blue/green/purple/amber/slate)
- Live preview card
- Reset to defaults

Usage:

1. Navigate to Reports → AI Writer tab
2. Select report style (Executive, Detailed, Dashboard, Narrative)
3. Type or speak your report request
4. Review generated report in preview panel
5. Use modification prompt to refine ("Add security metrics section")
6. Toggle Edit Mode to click and modify sections
7. Use Format panel for styling (bold, italic, alignment)
8. Export to PDF/Excel/HTML or Print

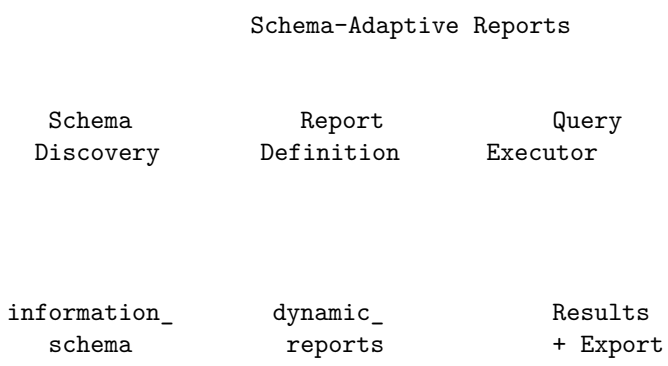
Voice Commands:

- Click microphone icon to start voice input
- Speak naturally: "Create a monthly usage report with cost breakdown"
- Voice automatically transcribes to text input

- Press Enter or click Generate to process

Report Sections: | Type | Description | |------|-------------| | `heading` | H1-H3 headings with hierarchical styling | | `paragraph` | Body text with muted foreground | | `metrics` | 4-column KPI cards with trends | | `chart` | Placeholder for bar/line/pie/area charts | | `table` | Data tables with headers | | `list` | Bullet point lists | | `quote` | Blockquote with left border |

68.3 Architecture



68.3 Schema Discovery

The service discovers:

Element	Description
Tables	All user-accessible tables
Columns	Column names, types, nullability
Primary Keys	Identified for each table
Foreign Keys	Relationships between tables
Indexes	Available indexes for optimization

68.4 Table Categories

Category	Tables Included
Core	tenants, users, sessions, api_keys
AI	models, prompts, responses, brain_plans
Billing	subscriptions, credits, invoices, payments
Analytics	events, metrics, usage_logs
System	configurations, audit_logs, health_checks

68.5 Report Definition

```typescript
interface DynamicReportDefinition {
  id?: string;
  name: string;
  description?: string;
  baseTable: string;
  fields: ReportField[];
  filters?: ReportFilter[];
```

```
  joins?: ReportJoin[];
  groupBy?: string[];
  orderBy?: { column: string; direction: 'asc' | 'desc' }[];
  limit?: number;
}

interface ReportField {
  column: string;
  alias?: string;
  aggregation?: 'count' | 'sum' | 'avg' | 'min' | 'max' | 'distinct';
  format?: 'text' | 'number' | 'currency' | 'percentage' | 'date' | 'datetime';
}
```

68.6 API Endpoints

Base: `/api/admin/dynamic-reports`

Method	Endpoint	Description
GET	/schema	Discover database schema with categorization
GET	/suggestions	AI-generated report suggestions
GET	/	List saved report definitions
POST	/	Save a new report definition
POST	/execute	Execute a report and return results
POST	/export	Export report results as CSV
DELETE	/:id	Delete a saved report

68.7 Request/Response Examples

Schema Discovery:

```
GET /api/admin/dynamic-reports/schema
```

```
Response:
{
  "schema": [
    {
      "category": "Core",
      "tables": [
        {
          "name": "users",
          "columns": [
            { "name": "id", "type": "uuid", "nullable": false, "isPrimaryKey": true },
            { "name": "email", "type": "text", "nullable": false },
            { "name": "created_at", "type": "timestamptz", "nullable": false }
          ]
        }
      ]
    }
  ]
}
```

Execute Report:

```
POST /api/admin/dynamic-reports/execute
{
```

```
  "baseTable": "users",
  "fields": [
    { "column": "created_at", "format": "date" },
    { "column": "id", "aggregation": "count", "alias": "user_count" }
  ],
  "groupBy": ["DATE(created_at)"],
  "orderBy": [{ "column": "created_at", "direction": "desc" }],
  "limit": 30
}

Response:
{
  "results": [
    { "created_at": "2026-01-21", "user_count": 145 },
    { "created_at": "2026-01-20", "user_count": 132 }
  ],
  "rowCount": 30,
  "executionTime": 45
}
```

68.8 Database Tables

```
-- Report definitions
CREATE TABLE dynamic_reports (
  id UUID PRIMARY KEY DEFAULT gen_random_uuid(),
  tenant_id UUID NOT NULL REFERENCES tenants(id),
  name TEXT NOT NULL,
  description TEXT,
  definition JSONB NOT NULL,
  created_by UUID REFERENCES users(id),
  created_at TIMESTAMPTZ DEFAULT NOW(),
  updated_at TIMESTAMPTZ DEFAULT NOW(),
  last_run_at TIMESTAMPTZ,
  run_count INTEGER DEFAULT 0
);

-- Execution history
CREATE TABLE dynamic_report_executions (
  id UUID PRIMARY KEY DEFAULT gen_random_uuid(),
  report_id UUID REFERENCES dynamic_reports(id),
  tenant_id UUID NOT NULL,
  executed_by UUID REFERENCES users(id),
  executed_at TIMESTAMPTZ DEFAULT NOW(),
  execution_time_ms INTEGER,
  row_count INTEGER,
  status TEXT DEFAULT 'completed',
  error_message TEXT
);

-- Scheduled reports
CREATE TABLE dynamic_report_schedules (
  id UUID PRIMARY KEY DEFAULT gen_random_uuid(),
  report_id UUID REFERENCES dynamic_reports(id),
  tenant_id UUID NOT NULL,
```

```
  schedule_cron TEXT NOT NULL,
  recipients JSONB,
  format TEXT DEFAULT 'csv',
  enabled BOOLEAN DEFAULT true,
  last_sent_at TIMESTAMPTZ,
  next_run_at TIMESTAMPTZ
);
```

68.9 Implementation Files

File	Purpose
packages/infrastructure/lambda/shared/services/schema-adaptive-reports.service.ts	Core service
packages/infrastructure/lambda/admin/dynamic-reports.ts	API handler
packages/infrastructure/migrations/V2026_01_21_003__dynamic_reports.sql	Database schema
apps/admin-dashboard/app/(dashboard)/reports/page.tsx	Admin UI with Schema

68.10 Security Considerations

- All queries run with tenant RLS context
- Schema discovery excludes system tables
- Parameterized queries prevent SQL injection
- Query timeout limits prevent resource exhaustion
- Audit logging for all report executions

Section 69: Cato Genesis (v5.39.0)

Location: Admin Dashboard → Cato → Genesis

Autonomous AI genesis and self-improvement configuration for the Cato consciousness system.

69.1 Overview

Cato Genesis enables:

- **Autonomous Decision-Making** - AI makes decisions within configured boundaries
- **Self-Improvement** - System optimizes its own behavior over time
- **Safety Guardrails** - Configurable thresholds and restrictions
- **Human Oversight** - Approval requirements for critical actions

69.2 Configuration

Setting	Default	Description
enabled	true	Enable Genesis engine
autonomyLevel	65%	Decision-making independence (0-100%)
safetyThreshold	85%	Confidence required for autonomous action
learningRate	0.7	How aggressively to learn from outcomes
explorationEnabled	true	Allow exploration of new strategies
selfImprovementEnabled	false	Allow self-optimization (requires approval)
humanOversightRequired	true	Require human approval for critical actions
maxActionsPerMinute	100	Rate limiting for autonomous actions

69.3 Autonomy Levels

Level	Range	Description
Restricted	0-30%	Most actions require approval
Monitored	31-70%	Routine actions autonomous, critical reviewed
Autonomous	71-100%	Full autonomy within safety bounds

69.4 Safety Guardrails

Allowed Actions:

- Read operations
- Analysis tasks
- Recommendations
- Non-destructive updates

Restricted Actions (require approval):

- Delete operations
- External API calls
- User data modifications
- System configuration changes

69.5 Metrics

Metric	Description
Total Decisions	Cumulative decisions made
Autonomous Actions	Actions taken without human input
Human Interventions	Times humans overrode decisions
Safety Violations	Actions blocked by guardrails
Learning Cycles	Self-improvement iterations
Avg Confidence	Mean decision confidence score

69.6 Dashboard Tabs

Tab	Purpose
Configuration	Enable/disable, basic settings
Autonomy Controls	Autonomy level, rate limits
Safety Guardrails	Threshold configuration, action restrictions
Learning & Evolution	Self-improvement settings, learning statistics

69.7 Implementation Files

File	Purpose
`apps/admin-dashboard/app/(dashboard)/cato/genesis/page.tsx`	Admin UI
`packages/infrastructure/lambda/shared/services/cato/genesis.service.ts`	Genesis service
`packages/infrastructure/lambda/admin/cato-genesis.ts`	API handler

Section 70: Cortex Memory System (v4.20.0)

Location: Admin Dashboard → Memory → Cortex

Enterprise-scale tiered memory architecture for AI context and knowledge management.

70.1 Overview

The Cortex Memory System provides three-tier storage replacing direct database access:

Tier	Technology	Latency	Retention	Use Case
Hot	Redis + DynamoDB	< 10ms	4 hours	Session context, Ghost Vectors
Warm	Neptune + pgvector	< 100ms	90 days	Knowledge graph, entity relationships
Cold	S3 + Iceberg	< 2s	7+ years	Historical archives, compliance records

70.2 Dashboard Features

Overview Page (`/cortex`):

- Tier health cards with status indicators
- Data flow metrics (promotions, archivals, retrievals)
- Active alerts with acknowledgment
- Zero-Copy mount manager
- Housekeeping task status

Quick Links:

- Graph Explorer (`/cortex/graph`)
- Conflicts (`/cortex/conflicts`)
- GDPR Erasure (`/cortex/gdpr`)
- Settings (`/cortex/settings`)

70.3 Hot Tier Configuration

Setting	Default	Description
`hot_redis_cluster_mode`	`true`	Enable Redis sharding
`hot_shard_count`	`3`	Number of shards
`hot_replicas_per_shard`	`2`	HA replicas
`hot_default_ttl_seconds`	`14400`	4 hours default TTL
`hot_overflow_to_dynamodb`	`true`	Large value overflow

70.4 Warm Tier Configuration

Setting	Default	Description
`warm_neptune_mode`	`serverless`	Serverless or provisioned
`warm_retention_days`	`90`	Days before archival
`warm_graph_weight_percent`	`60`	Graph weight in hybrid search
`warm_vector_weight_percent`	`40`	Vector weight in hybrid search

70.5 Graph-RAG Knowledge

The Warm tier uses hybrid Graph-RAG search:

```
Hybrid Score = (Vector Similarity × 40%) + (Graph Traversal × 60%)
```

Node Types: document, entity, concept, procedure (evergreen), fact (evergreen), golden_qa (verified answers)

Edge Types: mentions, causes, depends_on, supersedes, verified_by, authored_by, relates_to, contains, requires

70.5.1 Golden Rules (Override System)

Administrators can create high-priority rules that supersede all other data:

Rule Type	Description	Use Case
`force_override`	Always use this answer	"Max pressure is 100 PSI"
`ignore_source`	Never use this source	"Ignore Manual v1"
`prefer_source`	Prioritize this source	"Prefer 2026 specs"
`deprecate`	Mark as obsolete	"Manual v2024 superseded"

Chain of Custody: Every fact includes who verified it, when, and a digital signature for audit trail.

70.6 Zero-Copy Mounts & Stub Nodes

The Innovation: Connect to tenant data lakes without moving data. Creates **Stub Nodes** in the graph.

Source	Description	Connection
Snowflake	Data Share connection	OAuth + Data Share
Databricks	Delta Lake / Unity Catalog	Service Principal
S3	Customer S3 bucket	Cross-account IAM
Azure	Data Lake Gen2	Managed Identity

Stub Node Mechanism:

- Scans external storage metadata
- Creates lightweight graph nodes pointing to external content
- Content fetched **only** when Graph Traversal determines it's needed

Actions: Add Mount, Rescan, Delete

70.7 Curator Entrance Exams

Verify AI-extracted knowledge through SME validation:

Workflow:

1. AI ingests documents and extracts facts
2. System generates quiz questions from extracted facts
3. SME takes exam: Verify or Correct
4. Corrections automatically create Golden Rules
5. Verified facts get Chain of Custody signature

API:

```
# Generate exam for a domain
POST /api/admin/cortex/v2/exams
{
  "domainId": "hydraulics",
  "domainPath": "Engineering > Hydraulics",
```

```
  "questionCount": 10,
  "passingScore": 80
}

# Complete exam and process corrections
POST /api/admin/cortex/v2/exams/{examId}/complete
```

70.8 Live Telemetry (MQTT/OPC UA)

Inject real-time sensor data into AI context:

Protocol	Use Case	Example
MQTT	IoT sensors	`mqtt://broker:1883`
OPC UA	Industrial PLCs	`opc.tcp://plc:4840`
Kafka	Event streams	`kafka://cluster:9092`
WebSocket	Real-time dashboards	`wss://server/feed`

Configuration:

```
POST /api/admin/cortex/v2/telemetry/feeds
{
  "name": "pump_302_sensors",
  "protocol": "opc_ua",
  "endpoint": "opc.tcp://plc.factory.local:4840",
  "nodeIds": ["ns=2;s=Pump302.Pressure"],
  "contextInjection": true
}
```

70.9 Model Migration

One-click swap between AI models without losing Cortex knowledge.

See Model Migration section above for supported models and workflow.

70.10 Housekeeping (Twilight Dreaming)

Task	Frequency	Purpose
TTL Enforcement	Hourly	Expire Hot tier keys
Archive Promotion	Nightly	Move Warm → Cold
Deduplication	Nightly	Merge duplicate nodes
Graph Expansion	Weekly	Infer missing links
Conflict Resolution	Nightly	Flag contradictions
Iceberg Compaction	Nightly	Optimize Cold storage
Index Optimization	Weekly	Reindex vectors

Manual Trigger: Click play button next to any task

70.8 GDPR Erasure

GDPR Article 17 ”Right to be Forgotten” cascade deletion:

Tier	SLA	Method
Hot	Immediate	Redis key deletion
Warm	24 hours	Node status → deleted
Cold	72 hours	Tombstone records

Create Request: POST `/api/admin/cortex/gdpr/erasure`

70.9 Monitoring Thresholds

Hot Tier: | Metric | Warning | Critical | |--------|---------|----------| | Memory Usage | > 70% | > 85% | | Cache Hit Rate | < 90% | < 80% | | p99 Latency | > 5ms | > 10ms |

Warm Tier: | Metric | Warning | Critical | |--------|---------|----------| | Neptune CPU | > 70% | > 90% | | Graph Nodes | > 50M | > 100M |

70.10 API Endpoints

```
Base: /api/admin/cortex

GET    /overview                    Full dashboard data
GET    /config                      Tier configuration
PUT    /config                      Update configuration
GET    /health                      Tier health status
POST   /health/check                Trigger health check
GET    /alerts                      Active alerts
POST   /alerts/:id/acknowledge      Acknowledge alert
GET    /metrics                     Data flow metrics
GET    /graph/stats                 Node/edge counts
GET    /graph/explore               Search graph nodes
GET    /graph/conflicts             Unresolved conflicts
GET    /housekeeping/status         Task statuses
POST   /housekeeping/trigger        Run task manually
GET    /mounts                      Zero-Copy mounts
POST   /mounts                      Create mount
POST   /mounts/:id/rescan           Rescan mount
DELETE /mounts/:id                  Delete mount
GET    /gdpr/erasure                Erasure requests
POST   /gdpr/erasure                Create erasure request
```

70.11 Implementation Files

File	Purpose
`packages/shared/src/types/cortex-memory.types.ts`	Type definitions
`packages/infrastructure/migrations/V2026_01_23_002__cortex_memory_system.sql`	Database schema
`packages/infrastructure/lambda/shared/services/cortex/tier-coordinator.service.ts`	Orchestration
`packages/infrastructure/lambda/admin/cortex.ts`	Admin API
`apps/admin-dashboard/app/(dashboard)/cortex/page.tsx`	Dashboard UI

70.12 The Sovereign Cortex Moats

The Cortex Memory System creates six interlocking competitive moats that make customer departure operationally prohibitive:

Moat	Mechanism	Why Customers S
Semantic Structure	Knowledge Graph with explicit relationships vs competitor "buckets of text"	Moving millions c
Chain of Custody	Every critical fact digitally signed by SME via Entrance Exam	Losing audit trail
Tribal Delta	Golden Rules capture real-world exceptions ("15 days in Mexico City, not 30")	Encoded intuition
Sovereignty	Model-agnostic: Cortex is the asset, models are disposable CPUs	"Better model? P
Entropy Reversal	Twilight Dreaming deduplicates, resolves conflicts, compresses nightly	Competitors get s
Mentorship Equity	Gamified Curator Quiz creates psychological ownership	After 50 hours of

Administrative Implications:

- **Retention**: Monitor time invested per domain via Entrance Exam analytics
- **Value Demonstration**: Export Golden Rules count and relationship density for QBRs
- **Migration Prevention**: Highlight Chain of Custody signatures that would be lost

70.13 Related Documentation

- CORTEX-MEMORY-ADMIN-GUIDE.md - Full operations guide
- CORTEX-ENGINEERING-GUIDE.md - Technical reference

---

71. Semantic Blackboard & Multi-Agent Orchestration

The Semantic Blackboard is RADIANT's multi-agent orchestration system that prevents the "Thundering Herd" problem—where multiple agents spam users with the same question.

71.1 Overview

Feature	Description
Semantic Question Matching	Vector similarity search using OpenAI ada-002 embeddings
Answer Reuse	Auto-reply to agents with cached answers (86% cost reduction)
Question Grouping	Fan-out single answer to multiple waiting agents
Process Hydration	Serialize waiting agents to disk, resume on answer
Resource Locking	Prevent race conditions on shared resources
Cycle Detection	Prevent deadlocks from circular dependencies

71.2 Accessing the Dashboard

Navigate to **Blackboard** in the Admin Dashboard sidebar to access:

1. **Overview** - System explanation and architecture benefits
2. **Resolved Facts** - Previously answered questions with reuse counts
3. **Question Groups** - Pending groups waiting for a single answer
4. **Agents** - Active and hydrated agents
5. **Resource Locks** - Currently held locks
6. **Configuration** - System settings

71.3 Resolved Facts (Decisions)

The Facts tab shows all resolved questions that can be reused:

Column	Description
Question	The original question asked
Answer	The cached answer
Source	How the answer was obtained (user, memory, default, inferred)
Reused	Number of times this answer has been reused
Status	Valid or Invalid

Actions:

- **Invalidate** - Mark an answer as incorrect; affected agents are notified
- **Provide New Answer** - Replace with correct answer during invalidation

71.4 Question Grouping

When multiple agents ask similar questions within the grouping window (default: 60 seconds), they are grouped together:

1. First agent's question becomes the "canonical" question
2. Similar questions (85% cosine similarity) join the group
3. User answers once
4. Answer is fanned out to all grouped agents

Benefits:

- Reduces user interruptions by 60-80%
- Prevents duplicate HITL decisions
- Agents don't wait for individual answers

71.5 Process Hydration

Long-running agents are automatically serialized to disk when waiting:

Setting	Default	Description
Auto Hydration	Enabled	Automatically serialize waiting agents
Threshold	300 seconds	Wait time before hydration
S3 Storage	Enabled	Store large states in S3
Compression	gzip	Reduce storage size

Agent Lifecycle:

1. Agent starts → **Active**
2. Agent waits for user → **Waiting**
3. Wait exceeds threshold → **Hydrated** (state saved, process killed)
4. User answers → **Restored** (state loaded, execution resumes)

71.6 Resource Locking

Prevent race conditions when agents access shared resources:

Lock Type	Description
Read	Multiple readers allowed
Write	Exclusive access, blocks other writers
Exclusive	No other access allowed

Force Release: In emergencies, administrators can force-release locks. Use with caution as this may cause data inconsistencies.

71.7 Cycle Detection

The system automatically detects circular dependencies:

```
Agent A waits for Agent B
Agent B waits for Agent C
Agent C waits for Agent A  ← CYCLE DETECTED
```

Action on Detection:

1. Cycle is logged with full dependency chain
2. Oldest dependency is broken
3. Affected agent receives timeout error
4. Alert is raised in dashboard

71.8 Configuration Options

Setting	Default	Description
`similarity_threshold`	0.85	Minimum cosine similarity for matching
`enable_question_grouping`	true	Group similar questions
`grouping_window_seconds`	60	Wait time for similar questions
`enable_answer_reuse`	true	Auto-reply with cached answers
`answer_ttl_seconds`	3600	Answer expiry time
`enable_auto_hydration`	true	Auto-serialize waiting agents
`hydration_threshold_seconds`	300	Wait time before hydration
`enable_cycle_detection`	true	Detect dependency cycles
`max_dependency_depth`	10	Maximum dependency chain depth

71.9 API Endpoints

Base: `/api/admin/blackboard`

Method	Endpoint	Description
GET	`/dashboard`	Dashboard statistics
GET	`/decisions`	List resolved decisions
POST	`/decisions/{id}/invalidate`	Invalidate a decision
GET	`/groups`	Pending question groups
POST	`/groups/{id}/answer`	Answer a group
GET	`/agents`	Active agents
POST	`/agents/{id}/restore`	Restore hydrated agent
GET	`/locks`	Active resource locks
POST	`/locks/{id}/release`	Force release a lock
GET	`/config`	Configuration
PUT	`/config`	Update configuration
POST	`/cleanup`	Cleanup expired resources
GET	`/events`	Audit log

71.10 Troubleshooting

Issue	Cause	Resolution
Low reuse rate	Threshold too high	Lower `similarity_threshold` to 0.80
Too many groups	Window too long	Reduce `grouping_window_seconds`
Agents stuck in hydrated state	Answer never received	Manually restore or let expire
Lock contention	Long-running operations	Increase `default_lock_timeout_seconds`
Cycle detected frequently	Circular workflows	Review agent dependencies, refactor

71.11 Implementation Files

File	Purpose
`lambda/shared/services/semantic-blackboard.service.ts`	Core service
`lambda/shared/services/agent-orchestrator.service.ts`	Agent registry, locks
`lambda/shared/services/process-hydration.service.ts`	State serialization
`lambda/admin/blackboard.ts`	Admin API
`migrations/158_semantic_blackboard_orchestration.sql`	Database schema
`apps/admin-dashboard/app/(dashboard)/blackboard/page.tsx`	Admin UI

---

72. Services Layer & Interface-Based Access Control

The Services Layer ensures all access to RADIANT resources goes through defined interfaces (API, MCP, A2A) with proper authentication and authorization.

72.1 Overview

Interface	Purpose	Authentication
API	REST/HTTP endpoints for applications	API Key or JWT
MCP	Model Context Protocol for AI tools	API Key + Capability negotiation
A2A	Agent-to-Agent communication	API Key + mTLS (required by default)

72.2 API Keys with Interface Types

Navigate to **API Keys** in the Admin Dashboard to manage keys per interface type.

Creating a Key:

1. Click **Create Key**
2. Enter a descriptive name
3. Select **Interface Type**: API, MCP, A2A, or All
4. Configure scopes and expiration
5. For A2A: optionally specify agent ID and type
6. For MCP: optionally restrict allowed tools
7. Click **Create Key**
8. **Copy the key immediately** - it will not be shown again

Key Prefixes by Interface:

- `rad_api_` - API-only keys
- `rad_mcp_` - MCP-only keys
- `rad_a2a_` - A2A-only keys
- `rad_all_` - All-interface keys

72.3 A2A Agent Management

The A2A Agents tab shows all registered external agents:

Column	Description
Agent	Name and unique ID
Type	Agent category (orchestrator, worker, etc.)
Status	active, suspended, revoked, pending
Operations	Supported A2A operations
Requests	Total request count
Last Heartbeat	Most recent agent heartbeat

Agent Actions:

- **Suspend**: Temporarily disable agent access
- **Activate**: Re-enable suspended agent
- **Revoke**: Permanently revoke agent access

72.4 Interface Policies

Configure access rules per interface in the Policies tab:

Setting	Default	Description
`require_authentication`	true	Require valid API key
`require_mtls`	true (A2A)	Require mTLS certificate
`global_rate_limit_per_minute`	-	Interface-wide rate limit
`a2a_require_registration`	true	Agents must register first
`a2a_max_concurrent_connections`	100	Max concurrent A2A connections
`mcp_max_tools_per_request`	50	Max tools per MCP request

72.5 Key Sync Between Admin Apps

Keys created in either Radiant Admin or Think Tank Admin are automatically synced:

1. Key created in Radiant Admin → Queued for Think Tank Admin
2. Sync job processes pending items
3. Key appears in both admin apps

Sync Status:

- **Pending**: Awaiting sync
- **Synced**: Successfully synchronized
- **Failed**: Sync failed (will retry)

72.6 Database Access Restrictions

CRITICAL: No external agent can access RADIANT databases directly.

Cedar policies enforce that:

- All database operations require Service principal with `internal=true`
- API keys (api, mcp, a2a, all) are **forbidden** from direct DB access
- External agents must use the defined interfaces

72.7 API Endpoints

Base: `/api/admin/api-keys`

Method	Endpoint	Description
GET	`/dashboard`	Summary by interface type
GET	`/`	List all keys
POST	`/`	Create key with interface type
GET	`/:keyId`	Get key details
PATCH	`/:keyId`	Update key
DELETE	`/:keyId`	Revoke key
POST	`/:keyId/restore`	Restore revoked key
GET	`/agents`	List A2A agents
PATCH	`/agents/:id/status`	Update agent status
GET	`/policies`	Get interface policies
PUT	`/policies/:type`	Update policy
GET	`/audit`	Get audit log
POST	`/sync`	Process pending syncs

72.8 Implementation Files

File	Purpose
`migrations/V2026_01_24_001__services_layer_api_keys.sql`	Database schema
`lambda/admin/api-keys.ts`	Admin API handler
`lambda/gateway/a2a-worker.ts`	A2A protocol worker
`config/cedar/interface-access-policies.cedar`	Cedar access policies
`apps/admin-dashboard/app/(dashboard)/api-keys/page.tsx`	Radiant Admin UI
`apps/thinktank-admin/app/(dashboard)/api-keys/page.tsx`	Think Tank Admin UI

Section 73: Cortex Graph-RAG Knowledge Engine

Location: Admin Dashboard → Memory → Graph-RAG

Enterprise knowledge graph with vector embeddings for intelligent retrieval-augmented generation.

73.1 Overview

The Cortex Graph-RAG system provides persistent knowledge storage with semantic relationships:

Component	Technology	Purpose
Entities	PostgreSQL + pgvector	Knowledge nodes with embeddings
Relationships	PostgreSQL	Typed connections between entities
Chunks	PostgreSQL + pgvector	Text segments for RAG retrieval
Vector Search	HNSW Index	Fast approximate nearest neighbor

73.2 Dashboard Features

Overview Page (`/cortex/graph-rag`):

- Entity/relationship/chunk counts

- Graph health status (embedding service, vector index)
- Recent activity log
- Top accessed entities

Tabs:

- **Entities**: Browse, search, create, delete knowledge entities
- **Activity**: Recent operations log
- **Configuration**: Feature toggles and retrieval settings

73.3 Entity Types

Type	Description	Example
`person`	Human entities	"John Smith"
`organization`	Companies, groups	"Acme Corp"
`concept`	Abstract ideas	"Machine Learning"
`event`	Occurrences	"Q4 2025 Launch"
`location`	Places	"San Francisco HQ"
`document`	Source documents	"User Manual v3"
`topic`	Subject areas	"Hydraulics"

73.4 Relationship Types

Type	Description	Example
`is_a`	Type hierarchy	"Python is_a Programming Language"
`part_of`	Composition	"Chapter 1 part_of Manual"
`related_to`	General association	"AI related_to Machine Learning"
`works_for`	Employment	"John works_for Acme"
`located_in`	Geographic	"HQ located_in California"
`created_by`	Authorship	"Report created_by Jane"
`depends_on`	Dependency	"Feature depends_on API"

73.5 Configuration Options

Setting	Default	Description
`enableGraphRag`	true	Enable knowledge graph retrieval
`enableEntityExtraction`	true	Auto-extract entities from content
`enableRelationshipInference`	true	Auto-infer entity relationships
`enableAutoMerge`	true	Merge duplicate entities
`embeddingModel`	text-embedding-3-small	Model for vector embeddings
`entityExtractionModel`	gpt-4o-mini	Model for entity extraction
`defaultMaxResults`	10	Max results per query
`defaultMaxDepth`	3	Max graph traversal depth
`minRelevanceScore`	0.7	Minimum similarity score
`hybridSearchAlpha`	0.5	Weight for hybrid search

73.6 Vector Search

The system uses HNSW (Hierarchical Navigable Small World) indexing for fast vector similarity search:

```sql
-- Similarity search function
SELECT * FROM search_cortex_entities(
  p_tenant_id := 'tenant-uuid',
  p_embedding := '[vector]',
  p_limit := 10,
  p_min_similarity := 0.7
);
```

Hybrid Search combines:

- Vector similarity (configurable weight)
- Full-text search on name/description
- Graph traversal for relationship context

73.7 Graph Traversal

Retrieve entity neighbors using recursive CTE:

```sql
SELECT * FROM get_entity_neighbors(
  p_tenant_id := 'tenant-uuid',
  p_entity_id := 'entity-uuid',
  p_depth := 2,
  p_relationship_types := ARRAY['related_to', 'part_of']
);
```

73.8 Content Ingestion

Ingest content to automatically extract entities and relationships:

```
POST /api/admin/cortex/ingest
{
  "tenantId": "uuid",
  "source": {
    "type": "text",
    "content": "John Smith works at Acme Corp in San Francisco..."
  },
  "options": {
    "extractEntities": true,
    "extractRelationships": true,
    "createChunks": true
  }
}
```

73.9 API Endpoints

Base: `/api/admin/cortex`

Method	Endpoint	Description
GET	`/dashboard`	Full dashboard data
GET	`/config`	Get configuration
PUT	`/config`	Update configuration
GET	`/entities`	List entities
POST	`/entities`	Create entity
GET	`/entities/:id`	Get entity
PUT	`/entities/:id`	Update entity
DELETE	`/entities/:id`	Delete entity

Method	Endpoint	Description
GET	`/entities/:id/neighbors`	Get neighbors
GET	`/relationships`	List relationships
POST	`/relationships`	Create relationship
DELETE	`/relationships/:id`	Delete relationship
GET	`/chunks`	List chunks
POST	`/search`	Full-text search
POST	`/query`	Vector similarity search
POST	`/ingest`	Ingest content
POST	`/merge`	Merge entities
GET	`/stats`	Get statistics

73.10 Implementation Files

File	Purpose
`packages/shared/src/types/cortex-graph-rag.types.ts`	Type definitions
`packages/infrastructure/migrations/V2026_01_25_008__cortex_graph_rag.sql`	Database schema
`packages/infrastructure/lambda/admin/cortex-graph-rag.ts`	Admin API
`apps/admin-dashboard/app/(dashboard)/cortex/graph-rag/page.tsx`	Dashboard UI

73.11 Database Tables

Table	Purpose
`cortex_config`	Per-tenant configuration
`cortex_entities`	Knowledge entities with embeddings
`cortex_relationships`	Entity relationships
`cortex_chunks`	Text chunks for RAG
`cortex_activity_log`	Activity tracking
`cortex_query_log`	Query analytics

All tables have RLS policies for multi-tenant isolation using `app.current_tenant_id`.

Section 75: Complete Admin API Architecture (v5.52.6)

75.1 Overview

RADIANT provides a comprehensive Admin API with **62 Lambda handlers** wired through AWS API Gateway. All admin endpoints require Cognito authentication and are protected by admin-level authorization.

75.2 Handler Categories

Category	Count	Handlers
Cato Safety	5	cato, cato-genesis, cato-global, cato-governance, cato-pipeline
Memory Systems	4	cortex, cortex-v2, blackboard, empiricism-loop
AI/ML	7	brain, cognition, ego, raws, inference-components, formal-reasoning, ethics-free-reasoning
Security	5	security, security-schedules, api-keys, ethics, self-audit

Category	Count	Handlers
Operations	5	gateway, sovereign-mesh, sovereign-mesh-performance, sovereign-mesh-scaling, hitl-orches
Reporting	4	reports, ai-reports, dynamic-reports, metrics
Configuration	7	tenants, invitations, library-registry, checklist-registry, collaboration-settings, system, syst
Infrastructure	6	aws-costs, aws-monitoring, s3-storage, code-quality, infrastructure-tier, logs
Compliance	4	regulatory-standards, council, user-violations, approvals
Models	5	models, lora-adapters, pricing, specialty-rankings, sync-providers
Orchestration	2	orchestration-methods, orchestration-user-templates
Users	2	user-registry, white-label
Time & Translation	3	time-machine, translation, internet-learning
Learning	1	agi-learning

75.3 API Route Pattern

All admin handlers are accessible via:

`/api/admin/{handler-name}/*`

Example routes:

- `/api/admin/cato/dashboard` - Cato safety dashboard
- `/api/admin/cortex/memories` - Memory management
- `/api/admin/brain/dreams` - Dream state management
- `/api/admin/tenants/list` - Tenant list

75.4 Authentication

All admin endpoints require:

1. **Cognito JWT** - Valid authentication token
2. **Admin Role** - User must have admin privileges
3. **Tenant Context** - Tenant ID for RLS enforcement

75.5 Implementation

CDK Stack: `packages/infrastructure/lib/stacks/api-stack.ts`

Each handler follows the pattern:

```
const handlerLambda = this.createLambda(
  'HandlerName',
  'admin/handler-name.handler',
  commonEnv, vpc, apiSecurityGroup, lambdaRole
);
const resource = admin.addResource('handler-name');
resource.addProxy({
  defaultIntegration: new apigateway.LambdaIntegration(handlerLambda),
  defaultMethodOptions: {
    authorizer: adminAuthorizer,
    authorizationType: apigateway.AuthorizationType.COGNITO,
  },
});
```

75.6 Gap Resolution (v5.52.6)

In v5.52.6, a critical infrastructure audit identified that only ~31 of 62 admin Lambda handlers were wired to API Gateway. The remaining handlers existed but were returning 404 errors. All 62 handlers are now

properly connected.

Section 77: Expert System Adapters (v5.52.21)

77.1 Overview

Expert System Adapters (ESA) enable tenant-trainable domain intelligence through automatic LoRA adapter training. Unlike generic AI platforms that treat all tenants the same, ESA allows each tenant to build specialized AI expertise that continuously improves through interaction feedback.

Key Benefit: Zero ML expertise required—the system learns automatically from user interactions.

77.2 Tri-Layer Adapter Architecture

ESA implements a four-layer adapter stacking system:

```
W_Final = W_Genesis + (scale × W_Cato) + (scale × W_User) + (scale × W_Domain)
```

Layer	Name	Purpose	Management
0	Genesis	Base model weights	Frozen, never modified
1	Cato	Global constitution, tenant values	Pinned in memory, never evicted
2	User	Personal preferences, style	LRU eviction when memory constrained
3	Domain	Specialized expertise	Auto-selected by domain detection

77.3 Admin Dashboard

Location: `/models/lora-adapters`

The LoRA Adapters page provides:

- **Summary Cards**: Global adapters, User adapters, Invocations (24h), Average latency
- **Tri-Layer Diagram**: Visual representation of adapter stacking
- **Configuration Tab**: Enable/disable adapters, scale settings, auto-selection
- **Adapters Tab**: Registry by layer with activation toggles
- **Warmup Tab**: Manual warmup triggers and history

77.4 Configuration Options

Setting	Default	Description
Enable LoRA Adapters	Off	Master toggle for adapter stacking
Use Global Adapter (Cato)	On	Include global constitution adapter
Use User Adapter	On	Include personal preference adapter
Global Scale	1.0	Scaling factor for global adapter (0-2)
User Scale	1.0	Scaling factor for user adapter (0-2)
Auto Selection	Off	Automatically select best adapter
Rollback Enabled	On	Fall back to base model on failure
LRU Eviction	On	Evict least-recently-used adapters
Max Adapters in Memory	50	Maximum loaded adapters
Warmup Interval	15 min	How often to pre-load adapters

77.5 Implicit Feedback Learning

ESA automatically captures 11 feedback signals from user behavior:

Signal	Weight	Meaning
Copy Response	+0.80	User copied the output
Thumbs Up	+1.00	Explicit positive feedback
Follow-up Question	+0.30	Partial success, needs more
Long Dwell Time	+0.40	User engaged with response
Share Response	+0.50	User shared the output
Save Response	+0.50	User bookmarked output
Regenerate Request	-0.50	Response wasn't satisfactory
Rephrase Question	-0.50	Original missed the mark
Quick Dismiss	-0.40	User quickly moved on
Abandon Conversation	-0.70	Complete failure
Thumbs Down	-1.00	Explicit negative feedback

77.6 Training Pipeline

Training occurs automatically based on configurable thresholds:

Setting	Default	Description
Min Candidates	25	Total candidates before training
Min Positive	15	Minimum positive examples
Min Negative	5	Minimum negative examples
Training Frequency	Weekly	How often to train
Auto Optimal Time	On	Detect best training time

77.7 Domain Auto-Selection

When a query arrives, ESA scores available adapters:

```
Score = (0.3 × DomainMatch) + (0.1 × SubdomainBonus) + (0.25 × SatisfactionScore)
      + (0.1 × VolumeScore) + (0.05 × ErrorRate) + (0.2 × RecencyScore)
```

Adapter selected if Score 0.5

77.8 API Endpoints

Base Path: `/api/admin/learning`

Endpoint	Method	Purpose
`/config`	GET	Get learning configuration
`/config`	PUT	Update learning configuration
`/domain-adapters`	GET	List domain adapters
`/domain-adapters/{domain}`	GET	Get active adapter for domain
`/training/queue`	GET	View training queue status
`/training/trigger`	POST	Manually trigger training
`/performance/{adapterId}`	GET	Get adapter performance metrics

77.9 Implementation Files

File	Purpose
migrations/108_enhanced_learning.sql	Database schema
lambda/shared/services/enhanced-learning.service.ts	Core learning service
lambda/shared/services/lora-inference.service.ts	Tri-layer inference
lambda/shared/services/adapter-management.service.ts	Adapter selection
lambda/admin/enhanced-learning.ts	Admin API handler
apps/admin-dashboard/app/(dashboard)/models/lora-adapters/page.tsx	Admin UI
docs/EXPERT-SYSTEM-ADAPTERS.md	Strategic vision document

Section 76: PostgreSQL Scaling Infrastructure (v5.52.20)

76.1 Overview

Problem: When 6 AI models execute in parallel per request, each Lambda opens a database connection. At 100 concurrent requests × 6 parallel writes = 600 connections—exceeding Aurora's limits and causing transaction conflicts.

Solution: OpenAI-inspired PostgreSQL scaling patterns deployed automatically for Tier 2+ installations.

76.2 Components

Component	Purpose	Tier
RDS Proxy	Connection pooling, Lambda cold-start optimization	2+
Async Write Queue	SQS-based batch writes for model results	2+
Redis Hot-Path Cache	Read-after-write consistency, rate limiting	2+
Time-Based Partitioning	Monthly partitions for logs/usage tables	All
Materialized Views	Pre-computed dashboard metrics	All
Optimized RLS Policies	Index-friendly tenant isolation	All

76.3 RDS Proxy Configuration

Connection limits are tier-based for optimal resource usage:

Tier	Max Connections %	Idle Timeout	Use Case
1	60%	1800s	Development
2	70%	1800s	Starter
3	80%	1200s	Growth
4	85%	900s	Scale
5	90%	600s	Enterprise

76.4 Async Write Pattern

Model execution results are written asynchronously to avoid blocking request latency:

```
Request Flow:
User → Lambda → 6 AI Models (parallel) → SQS Queue → Batch Writer → PostgreSQL
                      ↓
               Redis Cache (immediate read-after-write)
```

Queue Configuration:

- Encrypted with tenant KMS key
- 14-day message retention
- 300-second visibility timeout
- Dead letter queue after 3 failures

Batch Writer Lambda:

- Processes up to 100 messages per batch
- Tier-based concurrency (5-100 concurrent executions)
- Bulk INSERT for 10-50x efficiency

76.5 Redis Caching

Hot-path operations use Redis for immediate consistency:

Operation	Cache TTL	Purpose
Model results	1 hour	Read-after-write consistency
Rate limits	Per window	Tenant/resource throttling
Session state	30 min	Lambda-to-Lambda context

Tier-Based Cluster Sizing:

Tier	Node Type	Shards	Replicas
1	cache.t4g.micro	1	0
2	cache.t4g.small	1	1
3	cache.r6g.large	2	1
4	cache.r6g.xlarge	3	2
5	cache.r6g.2xlarge	5	2

76.6 Time-Based Partitioning

High-volume tables are partitioned by month:

Table	Partition Key	Retention
`model_execution_logs_partitioned`	`created_at`	24 months
`usage_records_partitioned`	`timestamp`	24 months

Partitions are:

- Auto-created 3 months ahead
- Archived after 24 months
- Managed via `manage_time_partitions()` function

76.7 Materialized Views

Dashboard metrics are pre-computed on schedule:

View	Refresh	Dashboard Use
`tenant_daily_usage_summary`	15 min	Usage cards
`model_performance_summary`	1 hour	Model health
`tenant_cost_summary`	1 hour	Billing

View	Refresh	Dashboard Use
`user_activity_summary`	1 hour	Engagement
`platform_health_stats`	5 min	Admin overview
`model_popularity_ranking`	1 hour	Model selection

76.8 Monitoring

Critical metrics to watch:

Metric	Warning	Critical	Action
RDS Proxy connections	$< 20\%$	$< 10\%$	Reduce Lambda concurrency
Aurora CPU	$> 70\%$	$> 80\%$	Add read replicas
SQS queue age	> 30s	> 60s	Increase batch writer concurrency
Query P95 latency	> 300ms	> 500ms	Optimize queries
Redis memory	$> 70\%$	$> 80\%$	Scale cluster

76.9 Implementation Files

CDK Constructs: | File | Purpose | |------|---------| | `lib/constructs/database-scaling.construct.ts` | RDS Proxy CDK construct | | `lib/constructs/async-write.construct.ts` | SQS + batch writer CDK construct | | `lib/constructs/redis-cache.construct.ts` | ElastiCache Redis CDK construct | | `lib/stacks/data-stack.ts` | Integration (tier 2+) |

Lambda Handlers & Services: | File | Purpose | |------|---------| | `lambda/scaling/batch-writer.ts` | Batch writer Lambda handler with partial failure reporting | | `lambda/scaling/model-result-cache.service.ts` | Redis cache service for read-after-write | | `lambda/scaling/postgresql-scaling.service.ts` | Application-level PostgreSQL scaling orchestration |

Database Migrations (5 total): | Migration | Purpose | |-----------|---------| | `V2026_01_25_001__postgresql_scaling_rls.` | Optimized RLS with SELECT wrapper; batch staging; rate limiting | | `V2026_01_25_002__postgresql_scaling_partition` | Monthly partitioning; partition management functions | | `V2026_01_25_003__postgresql_scaling_materialized_views.s` | 6 materialized views; refresh orchestration | | `V2026_01_25_004__postgresql_scaling_strategic_indexes.sql` | BRIN/GIN/covering indexes; slow query tracking; index health | | `V2026_01_25_005__postgresql_scaling_read_replica_` | Read replica routing; session affinity; hot/cold paths |

76.10 Strategic Indexing

Index Type	Tables	Purpose
BRIN	`model_execution_logs_partitioned`, `usage_records_partitioned`	100x smaller than B-tree for time-se
Partial	All log tables	Hot-path queries (recent, pending, fa
Covering	Dashboard queries	Index-only scans eliminate table loo
GIN	JSONB metadata columns	Efficient containment queries
Expression	Date truncation	Pre-computed daily/hourly grouping

76.11 Read Replica Routing

Automatic query routing based on type and consistency requirements:

Query Type	Target	Consistency
Writes	Primary	Strong
Reads (within 5s of write)	Primary	Strong (session affinity)

Query Type	Target	Consistency
Dashboard reads	Any replica	Eventual
Analytics queries	Dedicated replica	Eventual
Materialized view reads	Any replica	Eventual

76.12 Slow Query Tracking

Automatic capture of queries exceeding 500ms:

- Query hash for deduplication
- Execution plan capture
- Aggregated statistics in `query_performance_hints`
- Index suggestions via `suggest_indexes()` function

76.13 Maintenance Functions

Function	Schedule	Purpose
`refresh_priority_materialized_views()`	Every 15 min	Dashboard metrics
`refresh_all_materialized_views()`	Every hour	All materialized views
`ensure_future_partitions(3)`	Daily	Create next 3 months of partitions
`perform_scheduled_maintenance()`	Daily	Vacuum, analyze, cleanup
`analyze_index_health()`	Weekly	Identify unused/inefficient indexes

76.14 Admin Dashboard UI

The PostgreSQL Scaling monitoring dashboard is available at:

`/infrastructure/postgresql-scaling`

Dashboard Tabs:

Tab	Features
Overview	Connection history, materialized view status, real-time refresh controls
Queues	Batch writer queue status, pending/processing/failed/completed counts, retry failed button
Replicas	Read replica health, lag monitoring, primary/replica status, weights
Partitions	Partition statistics per table, row counts, sizes, ensure future partitions button
Slow Queries	Top slow query patterns, index suggestions, recent slow queries with timing
Maintenance	Manual maintenance triggers, scheduled task overview, maintenance history

Summary Cards:

- **Connections**: Active/Max with utilization percentage
- **Queue Status**: Pending count with health indicator
- **Replicas**: Healthy/Total with overall health badge
- **Query Latency**: P95 latency with P50/P99 breakdown

Admin API Endpoints (Base: `/api/admin/scaling`):

Endpoint	Method	Purpose
`/dashboard`	GET	Complete dashboard data
`/connections`	GET	Connection pool metrics
`/queues`	GET	Batch writer queue status

Endpoint	Method	Purpose
`/queues/retry-failed`	POST	Retry failed batch writes
`/queues/clear-completed`	DELETE	Clear completed writes
`/replicas`	GET	Read replica health
`/partitions`	GET	Partition statistics
`/partitions/ensure-future`	POST	Create future partitions
`/slow-queries`	GET	Slow query analysis
`/indexes`	GET	Index health analysis
`/indexes/suggestions`	GET	Index suggestions
`/materialized-views`	GET	MV status
`/materialized-views/refresh`	POST	Trigger MV refresh
`/tables`	GET	Table statistics
`/maintenance/run`	POST	Run maintenance
`/maintenance/history`	GET	Maintenance history
`/rate-limits`	GET	Rate limiting status

Version History

Version	Date	Changes
5.52.26	2026-01-25	OAuth 2.0 Provider & Developer Portal (PROMPT-41A); RFC 6749 compliant authorization serve
5.52.22	2026-01-25	PostgreSQL Scaling Admin Dashboard; Full visibility into queues, connections, replicas, partitions,
5.52.21	2026-01-25	Expert System Adapters documentation; Strategic vision document; Moat #6D documentation; Tri
5.52.20	2026-01-25	PostgreSQL Scaling Infrastructure; RDS Proxy for connection pooling; Async write pattern with SQ
5.52.6	2026-01-24	Complete CDK Wiring Audit; ALL 62 admin Lambda handlers now wired to API Gateway includi
5.52.5	2026-01-24	Services Layer Implementation; API Keys with interface types (API, MCP, A2A); A2A Protocol W
5.52.4	2026-01-24	Semantic Blackboard Admin Dashboard; CDK API route for blackboard Lambda; Complete admin
5.52.0	2026-01-23	Comprehensive UI Audit; Replaced mock data with real API calls; Fixed 17 console.log stubs in Ma
5.46.0	2026-01-23	Cortex Memory System v4.20.0; Three-tier memory architecture (Hot/Warm/Cold); Graph-RAG k
5.42.0	2026-01-22	AI Reports API complete implementation; OpenAPI 3.1 spec (`docs/api/openapi-admin.yaml`); Pe
5.39.0	2026-01-21	Schema-Adaptive Reports; Dynamic Report Builder; Cato Genesis page; Think Tank Admin naviga
5.38.0	2026-01-21	Sovereign Mesh Performance Optimization; Infrastructure Scaling (100-500K sessions); SQS dispatc
5.37.0	2026-01-21	RAWS v1.1 - Model Selection System; 13 weight profiles; 7 domains with compliance; 8-dimension s
5.34.0	2026-01-20	HITL Orchestration Extensions; Semantic Deduplication with pgvector embeddings; Scout HITL In
5.33.0	2026-01-20	HITL Orchestration Enhancements (PROMPT-37); SAGE-Agent Bayesian VOI; MCP Elicitation S
5.32.0	2026-01-20	Sovereign Mesh Completion; Unit tests for notification and snapshot services; Think Tank Admin in
5.31.0	2026-01-20	The Sovereign Mesh (PROMPT-36); Agent Registry with OODA execution; App Registry (3,000+
5.30.0	2026-01-20	Code Quality & Test Coverage Visibility; Delight service unit tests; JSON safety migration tracking
5.29.0	2026-01-20	Gateway Admin Controls; Persistent statistics with timestamps; Admin dashboard UI; Think Tank
5.28.0	2026-01-20	Multi-Protocol Gateway v3.0; Go Gateway; NATS JetStream; Cedar authorization; Resume tokens
5.20.0	2026-01-18	User Violation Enforcement System; Regulatory compliance tracking; Escalation policies; Appeal w
5.19.0	2026-01-18	White-Label Invisibility (Moat #25); Full branding customization; Custom domains; Response tran
5.7.0	2026-01-17	Deployment Safety (cdk watch DEV-only rule, environment guards, credential setup)
5.6.0	2026-01-12	Genesis Infrastructure (Kaleidos reactor integration, SDS/PDSA compliance, SSF physical-to-digita
5.5.0	2026-01-10	Polymorphic UI (PROMPT-41); ViewRouter component; Terminal/MindMap/DiffEditor views; Ge
5.4.0	2026-01-10	Cognitive Architecture (PROMPT-40); Ghost Memory TTL/semantic key; Economic Governor retr
5.3.0	2026-01-10	Semantic Blackboard; Multi-Agent Orchestration; MCP Primary Interface; Process Hydration; Cycl
5.0.2	2026-01-08	The Grimoire (procedural memory); Economic Governor (cost optimization); Self-optimizing archite
4.20.3	2026-01-08	Mission Control GA; MCP Hybrid Interface; Domain Risk Policies
4.20.2	2026-01-07	Fixed RLS tenant bleed
4.20.0	2026-01-06	Initial Mission Control release

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