

Enhanced Design Document for Distributor Data Extraction Ingestion

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1 Overview

This design document covers the extraction ingestion component of our ETL pipeline. In our architecture, distributors integrate with our system via two primary methods:

- **Direct Extraction Ingestion:** Where our system automatically provisions the correct resources based solely on the three supplied parameters: `--erp-type`, `--client-id`, and `--data-type`.
- **SFTP Ingestion:** Where distributors SFTP their data to our environment (this method is handled separately).

The design detailed here pertains only to the **direct extraction ingestion** method. This process extracts distributor data and deposits it into a pre-dropzone S3 bucket. At this stage, a minor transformation is applied: column names are standardized according to our global data dictionary and the output files are converted to Parquet format. More complex transformations occur later in the pipeline.

2 System Architecture

2.1 Entry Point and Application Hosting

- **Program Class:**
 - **Main Method:**
 - * Parses command-line options (e.g., `--erp-type`, `--client-id`, `--data-type`) using `System.CommandLine`.
 - * Sets up the dependency injection container and configures services.
 - * Resolves the primary extraction ingestion service (`ERPService`) from the DI container and triggers the extraction process.

- **CreateHostBuilder Method:**
 - * Configures the host with HashiCorp Vault, FerretDB services, core providers, registries, and builder components.
 - * Configures **IHttpClientFactory** with resilience policies for API-based integrations.
 - * Sets up feature flags, metrics collection, and health checks.

2.2 Extraction Ingestion Orchestration

- **ERPSERVICE Class:**
 - Acts as the orchestrator for the extraction ingestion process.
 - Retrieves credentials from HashiCorp Vault and configuration from FerretDB, respectively.
 - Dynamically resolves components for data extraction based on ERP type.
 - Uses **IHttpClientFactory** for managing HTTP connections in API mode.
 - Supports two extraction modes:
 - * **API Mode:** For ERPs that expose APIs.
 - * **Database Mode:** For ERPs that require direct database access.
 - Supports both batch processing and incremental extraction with change data capture (CDC).
 - Applies a minimal transform:
 - * Standardizes column names according to our global data dictionary.
 - * Applies data quality validations against predefined rules.
 - * Converts all files to Parquet format with optional compression.
 - Deposits the extracted (and minimally transformed) data into a pre-dropzone S3 bucket.
 - Tracks data lineage for audit and compliance purposes.
 - (Note: Subsequent, more complex transformations are performed later in the overall ETL pipeline.)

2.3 External Dependencies

- **Infrastructure Services:**
 - **IVaultService:** Retrieves ERP credentials from HashiCorp Vault with least privilege access.
 - **IFerretDBService:** Fetches ERP configuration data from FerretDB.
 - **IAmazonS3:** Uploads the extracted data into the pre-dropzone S3 bucket.
 - **IFeatureFlagService:** Manages feature flags for gradual rollout of functionality.
 - **ICatalogService:** Integrates with data catalog for metadata management.

- **.NET Libraries:**
 - **System.CommandLine:** For command-line parsing.
 - **Microsoft.Extensions.Hosting & DI:** For hosting and dependency injection.
 - **System.Text.Json:** For JSON serialization/deserialization.
 - **IHttpClientFactory:** For managing HttpClient instances in API extraction mode.
 - **VaultSharp:** For interacting with HashiCorp Vault.
 - **MongoDB.Driver:** For FerretDB interactions (FerretDB uses MongoDB wire protocol).
 - **Polly:** For resilience patterns including circuit breakers and bulkheads.
 - **OpenTelemetry:** For distributed tracing and metrics.
 - **FluentValidation:** For data contract validation.

3 Design Patterns and Advanced Resilience Strategies

3.1 Dependency Injection (DI)

- **Usage:**
 - Decouples service construction from business logic.
 - Registers Vault client, FerretDB connection, providers, registries, builder components, and the main extraction service in the DI container.
 - Configures IHttpClientFactory and related services.
- **Benefits:**
 - Enhances testability and maintainability.
 - Promotes separation of concerns.

3.2 Registry Pattern

- **Components:**
 - ERPRegistry, ExtractorRegistry, TransformationRegistry, and UploaderRegistry.
- **Usage:**
 - Centralizes lookup for ERP-specific factories and strategies.
 - Dynamically resolves connectors, extractors, transformers, and uploaders based on ERP type or data type.
- **Benefits:**
 - Simplifies addition of new ERP integrations.
 - Reduces direct dependencies between the extraction process and concrete implementations.

3.3 Abstract Factory Pattern

- **Component:**
 - The `IERPFactory` interface (managed via `ERPRegistry`).
 - `IHttpClientFactory` for HTTP client management.
- **Usage:**
 - Encapsulates creation of ERP-specific components (e.g., connectors and jobs).
- **Benefits:**
 - Supports multiple ERP systems with varying implementations without altering extraction logic.

3.4 Builder Pattern

- **Components:**
 - **APIRequestBuilder & AuthenticationBuilder:**
 - * Provide fluent interfaces to construct complex API request objects.
 - **DatabaseQueryBuilder:**
 - * Dynamically constructs SQL queries for ERPs requiring direct database access.
 - **ExtractConfigBuilder:**
 - * Builds extraction configurations supporting both full and incremental extracts.
- **Usage:**
 - The `DatabaseQueryBuilder` collects parameters and produces a `DatabaseQuery` object with a `GenerateSql` method.
 - The `APIRequestBuilder` works with `IHttpClientFactory` to construct properly configured HTTP requests.
 - The `ExtractConfigBuilder` creates configurations for different extraction modes.
- **Benefits:**
 - Enhances readability and modularity.
 - Supports multiple extraction modes seamlessly.

3.5 Strategy Pattern

- **Components:**
 - Interfaces such as `IExtractor`, `ITransformer`, and `IValidator`.

- **Usage:**
 - Encapsulate different implementations for data extraction, transformation, and validation.
 - Registries select the appropriate strategy at runtime.
- **Benefits:**
 - Provides flexibility to extend or change algorithms without impacting the overall system.

3.6 Decorator Pattern

- **Components:**
 - **VaultCredentialProviderDecorator:**
 - * Adds caching behavior to Vault credential retrieval.
 - **MetricsDecorator:**
 - * Wraps core services to collect performance metrics.
 - **EncryptionDecorator:**
 - * Adds field-level encryption for sensitive data.
 - **DataQualityDecorator:**
 - * Adds data quality checks to transformations.
- **Usage:**
 - Enhances existing components with additional functionality without modifying their core logic.
- **Benefits:**
 - Improves performance through caching.
 - Provides observability and enhances security.
 - Ensures data quality through validation.

3.7 Circuit Breaker Pattern

- **Components:**
 - **VaultCircuitBreaker, FerretDBCircuitBreaker, S3CircuitBreaker**
- **Usage:**
 - Prevents cascading failures by breaking the circuit when dependencies fail.
 - Automatically restores service when dependencies recover.

- **Benefits:**
 - Enhances system resilience during partial outages.
 - Prevents overwhelming failing services with requests.

3.8 Bulkhead Pattern

- **Components:**
 - Separate connection pools for different ERP types and operations.
 - Isolated resource pools for critical vs. non-critical operations.
- **Usage:**
 - Isolates failures to prevent system-wide degradation.
 - Allocates resources based on operation criticality.
- **Benefits:**
 - Prevents resource exhaustion.
 - Improves system stability during partial failures.

3.9 Exponential Backoff with Jitter

- **Usage:**
 - Implements intelligent retry strategies for all external service calls.
 - Adds randomization to prevent thundering herd problems.
- **Benefits:**
 - Prevents overwhelming recovering services.
 - Distributes retry attempts evenly over time.

4 Detailed Component Descriptions

4.1 Program Class

- **Main Method:**
 - Parses Nomad-supplied command-line arguments.
 - Builds the DI container via `CreateHostBuilder`.
 - Resolves and invokes `ERPService.ProcessERPData`.
 - Handles global errors for graceful failure.

- **CreateHostBuilder Method:**

- Configures services including Vault client, FerretDB connection, providers, registries, and builder components.
- Sets up resilience policies with circuit breakers and bulkheads.
- Configures feature flags, metrics collection, and health checks.
- Sets up OpenAPI documentation generation.

4.2 ERPService Class

- **Responsibilities:**

- Orchestrates the extraction ingestion process.
- Retrieves credentials and ERP configuration.
- Dynamically resolves ERP-specific components using registries.
- Chooses between API or Database extraction modes based on the ERP configuration.
- Supports both batch and incremental extraction modes.
- Applies a minor transformation with data quality validation.
- Deposits the transformed data into a pre-dropzone S3 bucket.
- Tracks data lineage for audit and compliance.

- **Key Method – ProcessERPData:**

- **Credential & Configuration Retrieval:**

- * Uses `ICredentialProvider` to obtain short-lived, least-privilege credentials.
- * Uses `IConfigurationProvider` to obtain ERP settings.

- **Dynamic Component Resolution:**

- * Uses registries to resolve ERP-specific factories, extractors, transformers, and uploaders.

- **Integration Modes:**

- * **API Mode:**

- Builds an API request via `APIRequestBuilder` with mutual TLS if supported.
- Extracts data via `IExtractor.Extract` with circuit breaker protection.

- * **Database Mode:**

- Builds a SQL query using `DatabaseQueryBuilder`.
- Extracts data via `IExtractor.ExtractFromDatabase` with connection isolation.

- **Extraction Modes:**

- * **Full Extract:** Retrieves all data for the specified type.
- * **Incremental Extract:** Retrieves only changed data since the last extraction.

- **Self-Healing:**
 - * Implements automatic recovery procedures for common failure scenarios.
- **Subsequent Steps:**
 - * Applies the minor transform with data quality validation.
 - * Records data lineage metadata.
 - * Uploads the resulting data into a pre-dropzone S3 bucket via `IDataUploader`.

4.3 Providers

- **VaultCredentialProvider:**
 - Retrieves and deserializes credentials from HashiCorp Vault.
 - Implements caching with TTL-based invalidation.
 - Supports dynamic secret rotation with configurable TTL.
 - Generates least-privilege, operation-specific credentials.
- **FerretDBConfigProvider:**
 - Fetches ERP configuration from FerretDB and maps it to an `ERPConfiguration` object.
 - Uses MongoDB driver since FerretDB implements MongoDB wire protocol.
 - Supports read-preference strategies for replica sets.
 - Implements schema evolution for backward compatibility.

4.4 Data Uploader – `S3DataUploader`

- **Responsibilities:**
 - Formats and uploads the minimally transformed data into S3.
 - Applies data compression for efficient storage and transfer.
 - Converts files to Parquet format and ensures standardized column names.
 - Encrypts sensitive fields before upload.
 - Records data lineage metadata.
- **Key Methods:**
 - **Upload:** Manages the upload process with checksums and integrity verification.
 - **FormatData:** Applies the transformation with data quality checks.
 - **TrackLineage:** Records data provenance information.

4.5 Data Quality and Validation

- **DataContractValidator:**
 - **Responsibilities:**
 - * Validates data against predefined schemas and rules.
 - * Reports quality issues with detailed diagnostics.
 - * Enforces data governance policies.
 - **Key Methods:**
 - * **ValidateSchema:** Ensures data adheres to expected structure.
 - * **ValidateValues:** Checks data values against business rules.
 - * **GenerateReport:** Creates detailed validation reports.
- **DataMaskingService:**
 - **Responsibilities:**
 - * Identifies and masks sensitive information (PII).
 - * Supports various masking techniques (hashing, tokenization, etc.).
 - * Maintains referential integrity across masked datasets.
 - **Key Methods:**
 - * **IdentifySensitiveFields:** Automatically detects potential PII.
 - * **ApplyMasking:** Applies appropriate masking techniques.
 - * **VerifyMasking:** Ensures masking effectiveness.

4.6 HashiCorp Vault Integration

- **VaultService:**
 - **Responsibilities:**
 - * Manages connection to HashiCorp Vault with circuit breaker protection.
 - * Retrieves secrets with proper authentication.
 - * Handles secret versioning and rotation.
 - * Generates dynamic, least-privilege credentials.
 - **Key Methods:**
 - * **GetSecret:** Retrieves a secret by path.
 - * **GetDynamicSecret:** Retrieves a dynamic secret with lease management.
 - * **RenewToken:** Handles token renewal to maintain access.
 - **Configuration:**
 - * Support for multiple authentication methods (AppRole, Token, K8s).
 - * Automatic token renewal.
 - * Secret caching with TTL-based invalidation.
 - * Mutual TLS for secure communication.

- **VaultConfiguration:**
 - Stores settings such as **Address**, **AuthMethod**, **RoleId**, **SecretId**, and authentication paths.
 - Includes retry and timeout settings with exponential backoff and jitter.

4.7 FerretDB Integration

- **FerretDBService:**
 - **Responsibilities:**
 - * Manages connection to FerretDB using MongoDB driver.
 - * Executes queries and maps results to domain models.
 - * Handles connection pooling and resilience.
 - * Supports schema evolution for backward compatibility.
 - **Key Methods:**
 - * **GetConfiguration:** Retrieves configuration by ERP type and client ID.
 - * **UpdateConfiguration:** Updates configuration documents.
 - * **ExecuteQuery:** Executes a MongoDB query and returns the results.
 - * **GetSchemaVersion:** Retrieves schema version information.
 - **Configuration:**
 - * Support for replica sets and read preferences.
 - * Connection pooling with bulkhead isolation.
 - * Automatic retry with exponential backoff and jitter.
 - * Circuit breaker protection against cascading failures.
- **FerretDBConfiguration:**
 - Stores settings such as **ConnectionString**, **Database**, **Collection**, and authentication credentials.
 - Includes timeout and retry settings.
 - Defines bulkhead configuration for connection isolation.

4.8 Feature Flag Management

- **FeatureFlagService:**
 - **Responsibilities:**
 - * Manages feature flags for gradual rollout of new features.
 - * Supports A/B testing and canary releases.
 - * Provides runtime configuration without deployment.
 - **Key Methods:**

- * **IsFeatureEnabled**: Checks if a feature is enabled for a specific context.
- * **GetFeatureConfiguration**: Retrieves configuration for an enabled feature.
- * **RecordFeatureUsage**: Tracks feature usage for analytics.
- **Configuration**:
 - * Support for user, client, and global targeting.
 - * Time-based and percentage-based rollouts.
 - * Integration with monitoring for impact assessment.

4.9 Metrics and Observability

- **MetricsService**:
 - Collects performance metrics on key operations.
 - Integrates with Prometheus for metrics collection.
 - Supports custom dimensions for detailed analysis.
 - Records histogram metrics for latency distribution.
- **HealthCheckService**:
 - Provides health status of dependencies (Vault, FerretDB, S3).
 - Implements circuit breaker pattern for degraded services.
 - Exposes health endpoints for monitoring.
 - Supports self-healing procedures for common issues.
- **TracingService**:
 - Provides distributed tracing across system components.
 - Integrates with OpenTelemetry for standardized telemetry.
 - Correlates logs, metrics, and traces for holistic observability.
 - Supports sampling strategies for high-volume production environments.

4.10 Data Lineage and Governance

- **DataLineageService**:
 - **Responsibilities**:
 - * Tracks data origin, transformations, and destinations.
 - * Records metadata about extraction processes.
 - * Supports audit requirements and compliance verification.
 - **Key Methods**:
 - * **StartLineageRecord**: Creates a new lineage tracking record.
 - * **RecordTransformation**: Logs applied transformations.
 - * **CompleteLineageRecord**: Finalizes the lineage record.

- **Integration:**
 - * Connects with data catalog for metadata management.
 - * Provides lineage visualization through API.
 - * Supports data governance and compliance reporting.

4.11 Configuration Models

- **ERPConfiguration:**
 - Stores settings such as `BaseUrl`, `CompanyId`, `WarehouseId`, `RequiredHeaders`, and `timeout/retry` settings.
 - **Fields for Database Access:**
 - * `AccessType`: Enum (`API` or `Database`).
 - * `ConnectionString`: For direct database connections.
 - * `Schema`: Database schema.
 - * `BatchSize`: Number of records to fetch per batch.
 - **Fields for Incremental Extract:**
 - * `SupportsCDC`: Whether the ERP supports Change Data Capture.
 - * `CDCConfiguration`: Settings for CDC-based extraction.
 - * `WatermarkColumn`: Column used for incremental extraction.
- **ERPCredentials:**
 - Holds secure API keys and client secrets.
 - Includes operation-specific scoped credentials.
 - Supports dynamic credential generation.
- **UploadConfiguration:**
 - Used by the data uploader to configure the S3 upload.
 - Includes compression settings and encryption options.
 - Defines metadata for data catalog integration.
- **ResilienceConfiguration:**
 - Defines circuit breaker thresholds and recovery periods.
 - Configures retry policies with exponential backoff and jitter.
 - Specifies bulkhead isolation settings for resource pools.

4.12 Development and Test Support

- **LocalDevelopmentEnvironment:**
 - Provides containerized dependencies (Vault, FerretDB, S3-compatible storage).

- Supports mock ERP implementations for testing.
- Includes sample datasets for development.
- **IntegrationTestHarness:**
 - Facilitates automated testing against mock ERPs.
 - Supports scenario-based testing of the extraction process.
 - Includes performance benchmarking capabilities.

5 Pseudo-code for Nomad Integration

```

/// <summary>
/// Entry point for the ERP data extraction and ingestion process.
/// Processes command-line arguments from Nomad and orchestrates the ETL workflow.
/// </summary>
Main:
    // Parse Nomad-supplied command-line arguments:
    //   --erp-type, --client-id, --data-type
    options = parseArguments(["--erp-type", "--client-id", "--data-type"])

    // Build the host container with dependency injection configured
    host = createHostBuilder().build()

    // Register health checks for dependencies
    host.registerHealthChecks()
        .addCheck<VaultHealthCheck>("vault")
        .addCheck<FerretDBHealthCheck>("ferretdb")
        .addCheck<S3HealthCheck>("s3")

    // Setup OpenAPI documentation
    host.configureOpenApi(options => {
        options.Title = "Distributor Data Extraction API";
        options.Version = "v1";
        options.Description = "API for extracting distributor data from various ERP systems"
    })

    // Retrieve the ERPService from the DI container
    erpService = host.getService<ERPService>()

    // Trigger the extraction ingestion process with the supplied parameters
    erpService.ProcessERPData(options.erpType, options.clientId, options.dataType)

```

```

/// <summary>
/// Configures and builds the host with all necessary services.
/// </summary>
CreateHostBuilder:
    return HostBuilder()
        .ConfigureServices(services =>
        {
            // Configure Vault client with circuit breaker
            services.AddSingleton<IVaultClient>(provider =>
            {
                var vaultOptions = new VaultClientSettings(
                    "https://vault.example.com:8200",
                    new AppRoleAuthMethodInfo(roleId, secretId)
                );
                vaultOptions.RetrySettings = new RetrySettings {
                    Enabled = true,
                    MaxAttempts = 5,
                    BackoffType = BackoffType.ExponentialWithJitter
                };
                return new VaultClient(vaultOptions);
            });

            // Configure FerretDB connection with bulkhead isolation
            services.AddSingleton<IMongoClient>(provider =>
            {
                var settings = MongoClientSettings.FromConnectionString(
                    "mongodb://ferretdb.example.com:27017"
                );
                settings.RetryWrites = true;
                settings.RetryReads = true;
                settings.ServerSelectionTimeout = TimeSpan.FromSeconds(5);
                settings.MaxConnectionPoolSize = 100;
                return new MongoClient(settings);
            });

            // Configure feature flag service
            services.AddSingleton<IFeatureFlagService, FeatureFlagService>();

            // Register providers with caching decorators
            services.AddSingleton<ICredentialProvider, VaultCredentialProvider>();
            services.Decorate<ICredentialProvider, CachedCredentialProviderDecorator>();

```

```

services.AddSingleton<IConfigurationProvider, FerretDBConfigProvider>();

// Register data quality and validation services
services.AddSingleton<IDataContractValidator, DataContractValidator>();
services.AddSingleton<IDataMaskingService, DataMaskingService>();

// Register data lineage service
services.AddSingleton<IDataLineageService, DataLineageService>();

// Register registries
services.AddSingleton<IERPRegistry, ERPRegistry>();
services.AddSingleton<IExtractorRegistry, ExtractorRegistry>();
services.AddSingleton<ITransformationRegistry, TransformationRegistry>();
services.AddSingleton<IUploaderRegistry, UploaderRegistry>();

// Register builders
services.AddSingleton<IAPIRequestBuilder, APIRequestBuilder>();
services.AddSingleton<IDatabaseQueryBuilder, DatabaseQueryBuilder>();
services.AddSingleton<IAuthenticationBuilder, AuthenticationBuilder>();
services.AddSingleton<IExtractConfigBuilder, ExtractConfigBuilder>();

// Register S3 client for data upload
services.AddAWSService<IAmazonS3>();

// Register core service with decorators for cross-cutting concerns
services.AddSingleton<ERPService>();
services.Decorate<ERPService, MetricsERPServiceDecorator>();
services.Decorate<ERPService, DataQualityDecorator>();
services.Decorate<ERPService, EncryptionDecorator>();

// Configure HTTP clients with resilience policies using Polly
services.AddHttpClient("default")
    .AddTransientHttpErrorPolicy(builder =>
        builder.WaitAndRetryAsync(
            retryCount: 3,
            sleepDurationProvider: retryAttempt =>
                TimeSpan.FromSeconds(Math.Pow(2, retryAttempt)) +
                TimeSpan.FromMilliseconds(new Random().Next(0, 1000)), // Jitter
            onRetry: (outcome, timespan, retryAttempt, context) => {
                // Log retry attempt
                logger.LogWarning($"Retry {retryAttempt} for {context.PolicyKey}");
            }
        )
    );

```



```

    ))
    .AddCircuitBreakerPolicy(builder =>
        builder.CircuitBreakerAsync(
            handledEventsAllowedBeforeBreaking: 5,
            durationOfBreak: TimeSpan.FromSeconds(30),
            onBreak: (outcome, breakDelay) => {
                logger.LogError($"Circuit broken for {breakDelay.TotalSeconds}s!");
            },
            onReset: () => {
                logger.LogInformation("Circuit reset!");
            }
        )
    );

    // Add OpenTelemetry tracing
    services.AddOpenTelemetryTracing(builder => {
        builder
            .SetResourceBuilder(ResourceBuilder.CreateDefault().AddService("erp-extractor"))
            .AddSource("erp-extractor")
            .AddHttpClientInstrumentation()
            .AddMongoDBInstrumentation()
            .AddAspNetCoreInstrumentation()
            .AddJaegerExporter();
    });
});

/// <summary>
/// Processes ERP data extraction and performs initial transformation.
/// </summary>
/// <param name="erpType">The type of ERP system to extract from</param>
/// <param name="clientId">The client identifier</param>
/// <param name="dataType">The type of data to extract</param>
/// <remarks>
/// This method handles both API and Database extraction modes. For API mode,
/// it constructs appropriate API requests with authentication. For Database mode,
/// it builds and executes SQL queries. In both cases, the extracted data is:
/// 1. Minimally transformed (column standardization)
/// 2. Validated against data contracts
/// 3. Converted to Parquet format with compression
/// 4. Uploaded to a pre-dropzone S3 bucket
/// </remarks>
ERPService.ProcessERPData(erpType, clientId, dataType):
    Log "Starting ETL extraction ingestion for client [clientId] using ERP [erpType]"

```

```

/// <summary>Start metrics collection for this operation</summary>
using (metricsTimer = MetricsService.StartTimer("erp_process_data",
                                                { "erp_type": erpType, "client_id": clientId }))
using (tracer = TracingService.StartTrace("ProcessERPData"))
{
    /// <summary>Start data lineage tracking</summary>
    lineage = DataLineageService.StartLineageRecord(erpType, clientId, dataType)

    /// <summary>Check feature flags for enabled features</summary>
    bool useIncrementalExtract = FeatureFlagService.IsFeatureEnabled("IncrementalExtract", clientId)
    bool useCompression = FeatureFlagService.IsFeatureEnabled("Compression", clientId)
    bool useFieldEncryption = FeatureFlagService.IsFeatureEnabled("FieldEncryption", clientId)

    /// <summary>Retrieve least-privilege credentials from HashiCorp Vault</summary>
    credentials = CredentialProvider.GetLeastPrivilegeCredentials(erpType, clientId, dataType)

    /// <summary>Retrieve configuration from FerretDB</summary>
    erpConfig = ConfigurationProvider.GetConfiguration(erpType, clientId)

    /// <summary>
    /// Lookup common components via registries:
    /// - ERP-specific factory (for connectors and jobs)
    /// - Data extractor (for API or DB extraction)
    /// - Data transformer (to standardize columns and convert to Parquet)
    /// - Data validator (to validate data quality)
    /// - Data uploader (to upload data to the pre-dropzone S3 bucket)
    /// </summary>
    factory = ERPRegistry.GetFactory(erpType, clientId)
    extractor = ExtractorRegistry.GetExtractor(erpType)
    transformer = TransformationRegistry.GetStrategy(erpType, dataType)
    validator = ValidatorRegistry.GetValidator(erpType, dataType)
    uploader = UploaderRegistry.GetUploader("s3")

    /// <summary>Build extraction configuration based on mode</summary>
    extractConfig = ExtractConfigBuilder.New()
        .ForERP(erpType)
        .ForClient(clientId)
        .ForDataType(dataType)
        .UseIncrementalExtract(useIncrementalExtract && erpConfig.SupportsCDC)
        .WithLastExtractTime(useIncrementalExtract ? GetLastExtractTime(erpType, clientId) : null)
        .WithBatchSize(erpConfig.BatchSize)
        .Build()
}

```

```

/// <summary>
/// Handle database extraction mode
/// Builds and executes SQL queries for direct database access
/// </summary>
if erpConfig.AccessType == Database then:
    queryBuilder = DatabaseQueryBuilder()
        .ForERP(erpType)
        .WithConnectionString(erpConfig.ConnectionString)
        .WithSchema(erpConfig.Schema)
        .WithTable(dataType + "_table")
        .WithColumns("id", "created_at", "data")

    if useIncrementalExtract && erpConfig.SupportsCDC:
        queryBuilder.WithWhere(erpConfig.WatermarkColumn, ">", extractConfig.LastExt
    else:
        queryBuilder.WithWhere("is_processed", false)

    query = queryBuilder
        .WithOrderBy("created_at")
        .WithLimit(erpConfig.BatchSize)
        .WithCommandTimeout(erpConfig.TimeoutSeconds)
        .Build()

    Log "Executing database query: " + query.GenerateSql()

    // Use bulkhead isolation for database connection
    using (bulkhead = BulkheadPolicy.Execute(erpType + "-database", () => {
        extractedData = extractor.ExtractFromDatabase(query, extractConfig)
        return extractedData
    }))

/// <summary>
/// Handle API extraction mode
/// Constructs and executes authenticated API requests with resilience
/// </summary>
else:
    authBuilder = AuthenticationBuilder()
        .WithApiKey(credentials.ApiKey)
        .WithClientId(credentials.ClientId)
        .WithClientSecret(credentials.ClientSecret)

    if erpConfig.SupportsMutualTLS:

```

```

        authBuilder.WithClientCertificate(credentials.ClientCertificate)

auth = authBuilder.Build()

requestBuilder = APIRequestBuilder()
    .ForERP(erpType)
    .WithEndpoint(erpConfig.BaseUrl + "/api/v2/sales")
    .WithMethod(GET)
    .WithAuthentication(auth)
    .WithHeaders(erpConfig.RequiredHeaders)

if useIncrementalExtract && erpConfig.SupportsCDC:
    requestBuilder.WithQueryParameters({
        "companyId": erpConfig.CompanyId,
        "warehouse": erpConfig.WarehouseId,
        "pageSize": erpConfig.PageSize.ToString(),
        "changedSince": extractConfig.LastExtractTime.toISOString()
    })
else:
    requestBuilder.WithQueryParameters({
        "companyId": erpConfig.CompanyId,
        "warehouse": erpConfig.WarehouseId,
        "pageSize": erpConfig.PageSize.ToString()
    })

request = requestBuilder
    .WithRetryPolicy(erpConfig.MaxRetries)
    .WithTimeout(erpConfig.TimeoutSeconds)
    .Build()

Log "Executing API request to " + erpConfig.BaseUrl + "/api/v2/sales"

// Execute with circuit breaker protection
extractedData = CircuitBreakerPolicy
    .ForService("erp-api-" + erpType)
    .Execute(() => extractor.Extract(request, extractConfig))

/// <summary>Validate data against contract</summary>
Log "Validating extracted data against contract"
validationResult = validator.Validate(extractedData)

if !validationResult.IsValid:

```

```

// Handle data quality issues based on severity
if validationResult.HasCriticalIssues():
    throw new DataContractException(
        "Critical data quality issues detected: " +
        validationResult.GetCriticalIssuesSummary()
    )
else:
    // Log warnings but continue processing
    Log "Warning: Data quality issues detected: " + validationResult.GetIssuesSummary()

/// <summary>Transform the extracted data with data lineage tracking</summary>
Log "Starting data transformation"
transformedData = transformer.Transform(extractedData)
lineage.RecordTransformation("ColumnStandardization", "Standardized columns according to schema")

/// <summary>Apply field encryption for sensitive data if enabled</summary>
if useFieldEncryption:
    transformedData = EncryptionService.EncryptSensitiveFields(
        transformedData,
        GetSensitiveFieldsConfig(erpType, dataType)
    )
    lineage.RecordTransformation("FieldEncryption", "Encrypted sensitive fields")

/// <summary>Apply masking for non-production environments</summary>
if environmentType != Production:
    transformedData = DataMaskingService.ApplyMasking(
        transformedData,
        GetDataMaskingConfig(erpType, dataType)
    )
    lineage.RecordTransformation("DataMasking", "Applied data masking for non-production")

/// <summary>
/// Configure and execute the S3 upload operation
/// Data is stored in a pre-dropzone bucket with standardized path structure
/// </summary>
currentTimestamp = getCurrentTimestamp()

uploadConfig = new UploadConfiguration(
    Bucket: "erp-data-" + clientId,
    Key: erpType + "/" + dataType + "/" + currentTimestamp + "/data.parquet",
    Format: Parquet,
    Compress: useCompression,

```

```

        CompressionType: useCompression ? "SNAPPY" : null,
        Metadata: {
            "erp_type": erpType,
            "client_id": clientId,
            "data_type": dataType,
            "extract_timestamp": currentTimestamp,
            "lineage_id": lineage.Id,
            "extract_mode": useIncrementalExtract ? "incremental" : "full",
            "record_count": transformedData.Count,
            "schema_version": "1.2"
        }
    )

    Log "Starting data upload to S3 pre-dropzone"
    uploadResult = uploader.Upload(transformedData, uploadConfig)

    /// <summary>Update data catalog with metadata</summary>
    CatalogService.UpdateDatasetMetadata(
        datasetId: erpType + "-" + clientId + "-" + dataType,
        metadata: {
            "lastUpdated": currentTimestamp,
            "recordCount": transformedData.Count,
            "fileLocation": uploadResult.Location,
            "fileSize": uploadResult.Size,
            "schemaVersion": "1.2",
            "lineageId": lineage.Id
        }
    )

    /// <summary>Complete lineage record</summary>
    lineage.SetDestination(uploadResult.Location)
    lineage.CompleteLineageRecord()

    /// <summary>Update last extract time for incremental extracts</summary>
    if useIncrementalExtract:
        StoreLastExtractTime(erpType, clientId, dataType, currentTimestamp)

    Log "Extraction ingestion process completed successfully"
}

```

6 Advanced Error Handling and Recovery

- **Error Classification:**
 - Categorizes errors as transient or persistent.
 - Applies different recovery strategies based on error type.
 - Records error patterns for proactive monitoring.
- **Self-Healing Procedures:**
 - **Common Issue Resolution:**
 - * Automatic token renewal for expired credentials.
 - * Connection pool refresh for stale connections.
 - * Temporary file cleanup for storage-related issues.
 - **Degraded Mode Operation:**
 - * Falls back to full extract if incremental extract fails.
 - * Disables optional features during high load.
 - * Implements progressive backoff for system recovery.
- **Comprehensive Logging:**
 - Structured logging with correlation IDs across components.
 - Context-enriched log entries for easier debugging.
 - Log level adjustment based on operation criticality.
 - Integration with log aggregation systems.

7 Security and Compliance

- **Least Privilege Access:**
 - Dynamic generation of operation-specific credentials.
 - Short-lived tokens with minimal required permissions.
 - Credential scoping based on operation context.
 - Role rotation and separation of duties.
- **Data Protection:**
 - Field-level encryption for sensitive data.
 - Data masking for non-production environments.
 - Secure credential management with HashiCorp Vault.
 - Mutual TLS for secure service communication.
- **Audit and Compliance:**
 - Comprehensive data lineage tracking.

- Access and operation audit logging.
- Compliance validation against regulatory requirements.
- Regular security posture assessment.

8 Development and Operations Support

- **Local Development Environment:**

- Docker Compose setup with all dependencies.
- Mock ERPs for integration testing.
- Configuration templates for different scenarios.
- Development tools for data visualization and debugging.

- **Deployment and Infrastructure:**

- GitOps-based deployment pipelines.
- Infrastructure as Code for all components.
- Canary deployment support for risk mitigation.
- Blue-green deployment capability for zero downtime.

- **Documentation and Knowledge Sharing:**

- OpenAPI documentation for all service interfaces.
- Architecture decision records (ADRs) for design choices.
- Runbooks for common operational procedures.
- Automated documentation generation from code.