Multi-Level Security (MLS) Data Gateway for Agile and Secure Enterprise Data Sharing and Integration

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Motivation: The Need for Enterprise-Level Agile Data and Analysis Capabilities in MLS Environments

- Data management in space systems needs to evolve
  - *From data silos with system-specific, pre-determined (waterfall-like) data management*
  - *To enterprise-level, agile data integration and analysis capabilities*
- Next-generation space data-centric architectures must also support agile and effective data sharing and integration in Multi-Level Security (MLS) environments
  - *MLS environments: Data reside at different levels of security, and policy-based data dissemination among security levels is required*
- A common scenario in the space enterprise: A user in a lower-level security enclave needs access to data residing in a higher-level security enclave
- The MLS environment should:
  - *Allow the user to issue generic queries for the necessary data*
  - *Enforce policies on:*
    - What queries are allowed to pass from the low side to the high side
    - What query results are allowed to pass from higher to lower security enclaves

Characteristics of Enterprise Data

- Enterprise data is distributed
  - *Data are owned and best managed by various organizations (systems)*
  - *Legacy systems need to be easily integrated into enterprise level data management*
- Emergent use cases require on-demand data analytics
  - *Run enterprise data analytics on data from diverse resources managed by various organizations*
- **Enterprise and its data tenants are in multiple security enclaves**
  - *Support the ability to access and integrate data from multiple enclaves*
- Enterprise data is dynamic
  - *The velocity of data flowing from data sources (e.g., sensors) is constantly changing*
- Enterprise Data is diverse
  - *Enterprise data may be structured, semi-structured, unstructured, or streaming data*
  - *Enterprise data solutions must blend all these data types with machine-learning data to gain holistic views and actionable insights and to optimize mission operations*

Challenging Issues for Data Integration and Sharing in MLS Environments

- Multiple data access and data sharing protocols make on-demand, programmatic-based data protection more difficult
- In current systems, data sharing among different MLS enclaves has used custom rather than general-purpose solutions
- Until recently, there has been little support for automatic, policy-based and generic data protection in MLS environments
- There is a lack of mature technologies and products for automated and timely sharing of data in MLS environments
- Commercial off-the-shelf (COTS) MLS Guard tools:
  - *A hardware or software Guard enables or restricts the access or transfer of data between security domains based on a predetermined security policy*
  - *Guards for MLS environments don't provide high-level interfaces*
    - Typically offer limited and lower level data access protocols (e.g., Extensible Markup Language (XML))
  - *The latest generation of Guard products provide programmatic data protection assertions and offer support for a few(but limited number of) higher level protocols*

A General Approach to Alleviate the Challenges of Data Sharing in MLS Environments

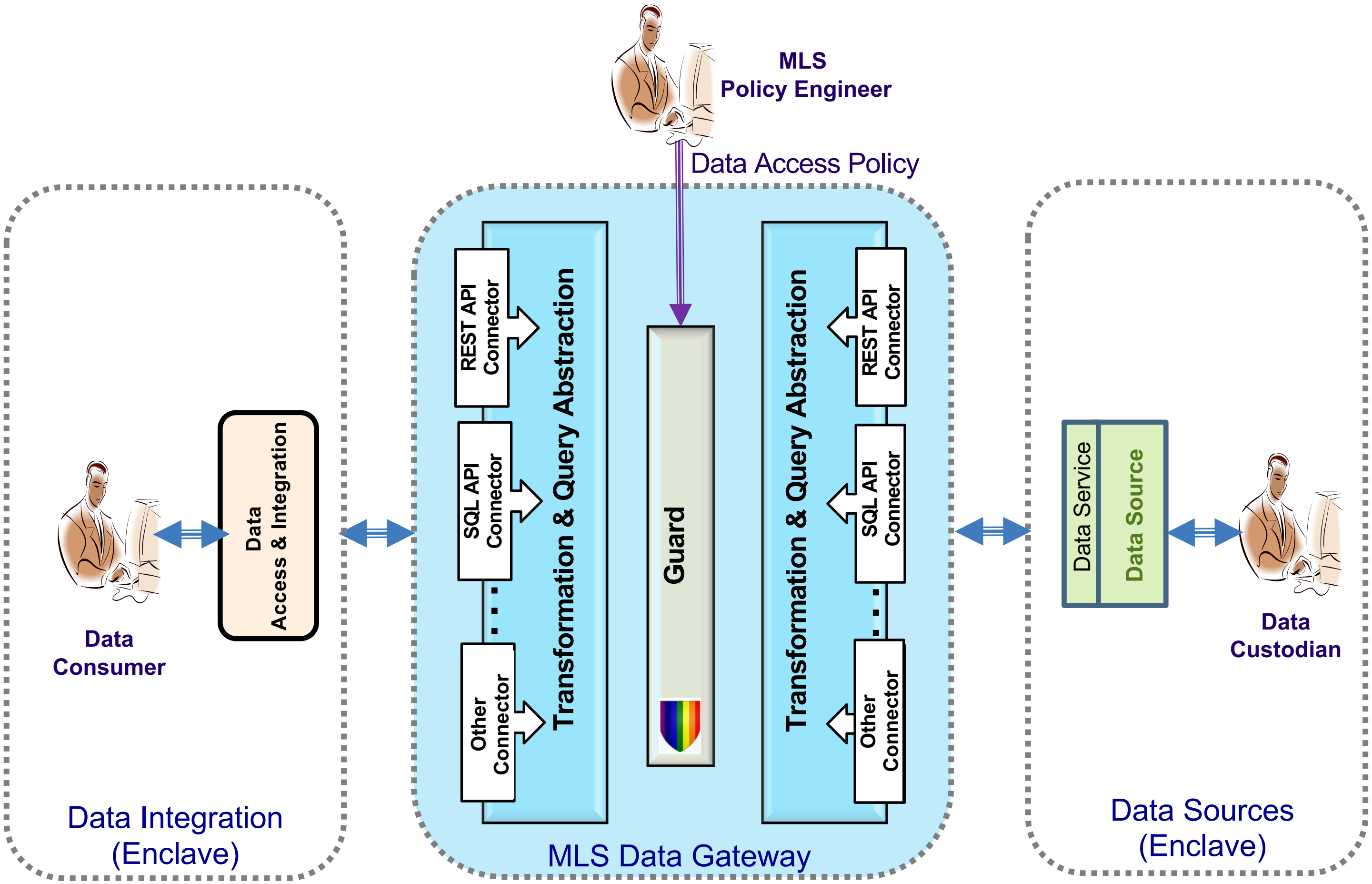
Solution should include several elements:

- Should use a **uniform approach for data integration and sharing** in both single security domains as well as in multi-level security domains
- Should **extend the use of data integration tools and techniques that were developed for a single enclave to multiple enclaves**, with the tools being MLS-aware
- Should support **policy-driven data protection** that provides automatic (whenever possible) data sharing among enclaves with the required level of data protection
- Should help **abstract a physical data source** and its specific characteristics
- Should provide **fine and coarse granularity data access control**
  - *Access control for data should be at both (i) the macro level (on the data set), as well as (ii) the more granular data item (data entity) level*

Proposed Solution: MLS Data Gateway

- A **Data Gateway** is a software and hardware solution that:
  - *Connects to multiple data systems*
  - *Provides a single, central point of access to safely access data with the necessary data protection*
- A Data Gateway acts as a bridge that provides secure data transfer between environments or enclaves
- An **MLS Data Gateway** supports agile and effective data sharing and analysis in multi-level security (MLS) environments, where:
  - *Data reside at different levels of security*
  - *Policy-based data dissemination among security levels is required*

Anatomy of an MLS Data Gateway



Basic Characteristics of an MLS Data Gateway

An MLS Data Gateway includes:

- **Guard:** specialized hardware and/or software that provides a controlled interface to **enable or restrict the access or transfer** of data between **two or more security domains** based on a predetermined **security policy**

- **Connectors** for standard data access protocols:
  - REST API
  - SQL queries

- **Transformation and Query Abstraction** component:
  - ***Translate*** *from the incoming data access protocol to the protocol required by the Guard (e.g., XSD (XML Schema Definition))*
  - *Incoming request (e.g., a data access request from a consumer in Enclave 1 for data stored in Enclave 2) is transparently transformed into the format required by gateway*
  - *Then transformed again into the format required by the other enclave*

- MLS Gateway can also provide data filtering capabilities
  - *Allowing data filtering at a much higher level of granularity*

Use Cases for Enterprise Data Integration in MLS Environments

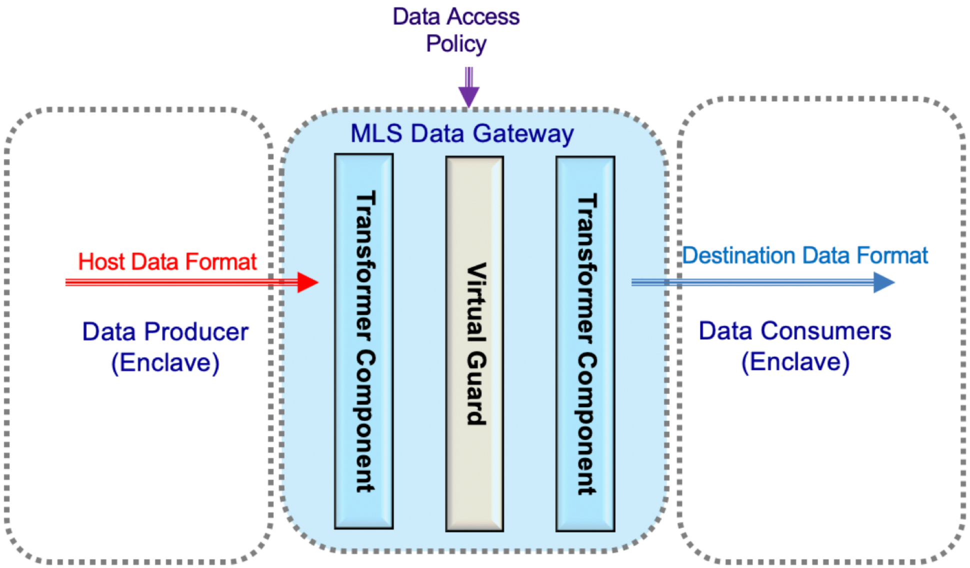
- Use Case A: One-Way Data Sharing among Multiple Security Domains
  - *Programmatic transfer of data from one security domain to another with policy-based data protection*

- Use Case B: Data Integration Via Data Virtualization Products
  - *Support for enterprise data integration with data sources residing in different security domains using COTS data integration products*

- Use Case C: Data Integration Via Data Semantics Layer
  - *Support for data sematic layer-based integration for data fusion, with the data sources residing in multiple security domains*

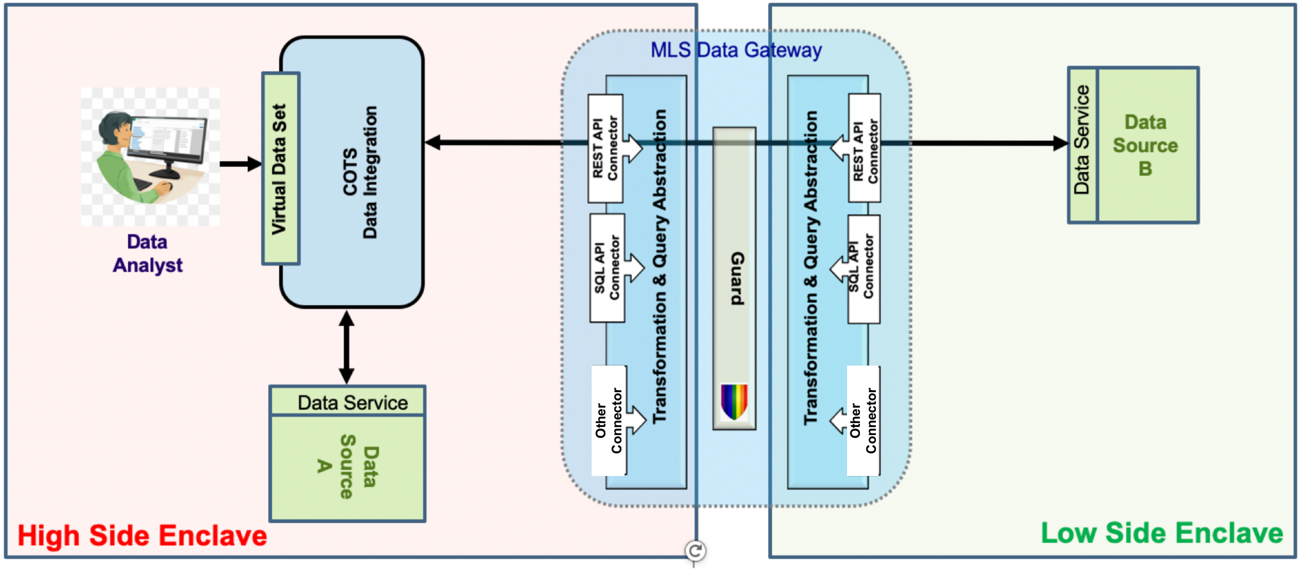
- Use Case D: Data Access Using Standard SQL-Based Data Access and Query
  - *Support for data sharing using standard SQL queries when the data requester and data sources are in different security domains*

Use Case A: One-Way Data Sharing in MLS Environments



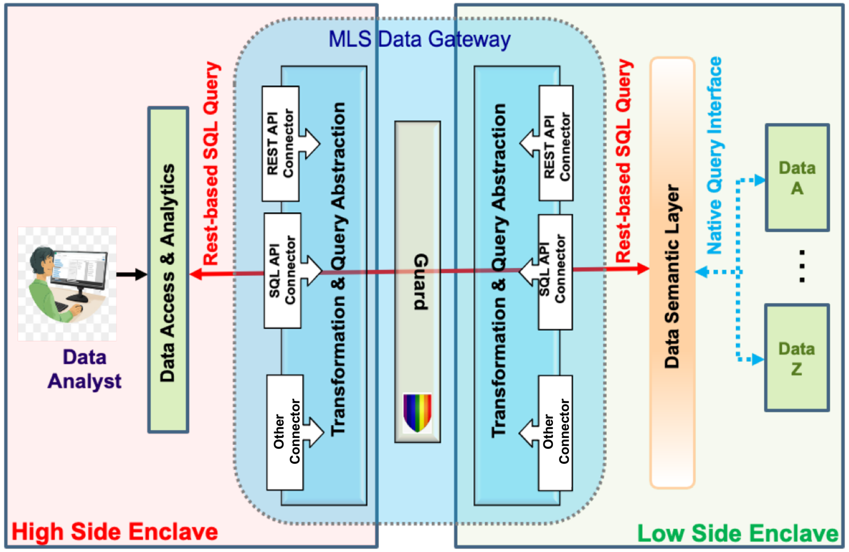
- Data may be shared with multiple consumers residing in multiple security domains
- Data access policies may be based on both data content as well as data tags and are enforced by an MLS Guard
- Current hardware or virtual MLS Guard technologies and tools provide data protection support for a small set of data formats (most commonly XML)
- Our solution encapsulates the MLS Guard with the Data Transformer component
  - The Transformer component is responsible for transforming the data from the host data format to XML (and vise versa)
- The combination of Transformer and MLS Guard (denoted in this project as the **MLS Data Gateway**) allows **data sharing with defined access policies** between enclaves with different levels of security

Use Case B: Data Integration Via Data Virtualization



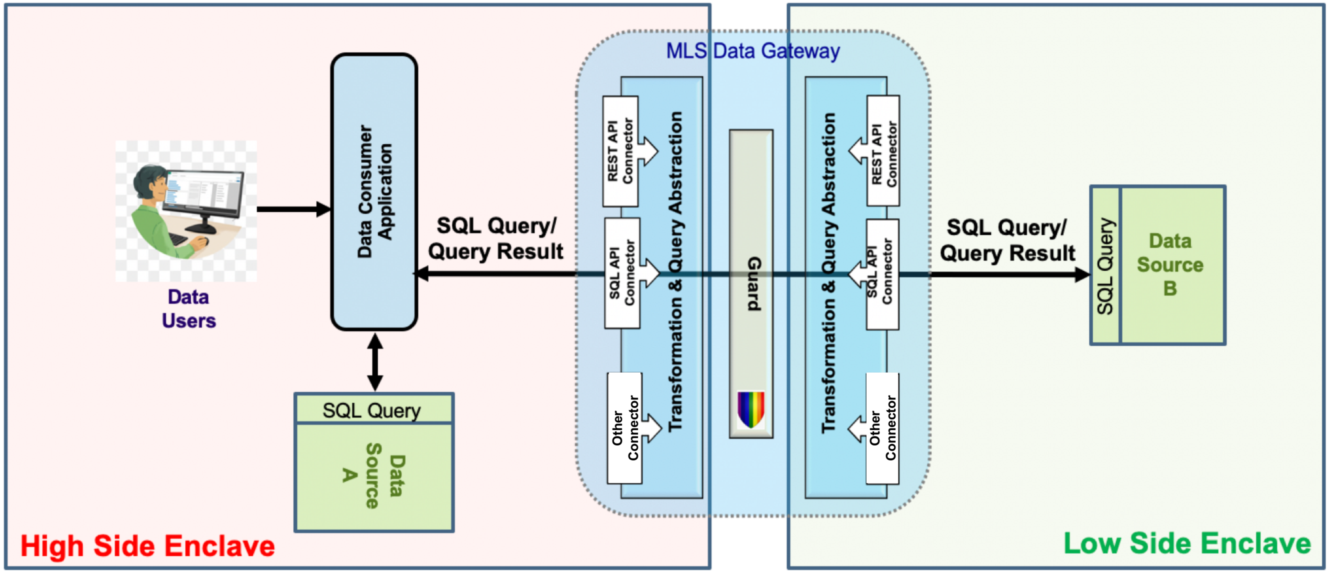
- Enterprise level data integration, where the data sources from multiple systems can be correlated and fused, is a critical element of enterprise data analysis and management
- Emerging COTS data virtualization products are leading technologies for data integration, but they only support integration for data sources that reside at the same security level
- Integration of COTS data virtualization products with the MLS Data Gateway would allow programmatic and safe data integration and virtualization in MLS environments
- Use case: The data analyst discovers available data sources located locally or in other security enclaves and then accesses and integrates those sources using the COTS data virtualization tool
- The Data Gateway provides policy-based access to the remote data source(s) that reside in other security domains

Use Case C: Data Integration Via Data Semantics Layer



- A semantic layer is a unified representation of various data sources that helps data consumers access data autonomously using common data access interfaces
  - *Provides level of abstraction for data consumers that hides fragmentation of data sources*
  - *Unfortunately, COTS data semantics products support data integration for data sources that reside at the same security level*
- The integration of COTS Data Semantic Layer products with the MLS Data Gateway would support programmatic and safe semantic-based data integration in MLS environments
- Use Case: The data consumer accesses the Semantic Layer via REST-based query requests; the endpoint of the Data Semantics Layer is managed by the Data Gateway
- The Data Semantic Layer provides semantic-based access to diverse data sources
- MLS Data Gateway is responsible for (i) data protection policies (ii) filtering of query results

Use Case D: Data Access Using SQL-Based Queries



- SQL-based queries to retrieve raw or processed data are most popular data access protocol
  - *Unfortunately, there is no support for SQL queries in COTS Guard products*
- The integration of an SQL-based data consumer application with the MLS Data Gateway would support programmatic and safe data integration in MLS environments
- Use case: Data analyst accesses data via SQL queries when the data requester and data sources reside in different security domains
- The SQL query for Data Source B is intercepted by the SQL Connector/Transformer (part of the MLS Data Gateway) and delivered to the Guard as an XML message
- After passing the Guard, the message is transformed back to SQL format by Transformer
- The SQL message is delivered to the data source, which then returns the query results through the MLS gateway to the data consumer application

Summary

- The new generation of data centric architectures must support agile and effective **data sharing and analysis in multi-level security (MLS) environments**, where:
  - *Data reside at different levels of security*
  - *Policy-based data dissemination among security levels is required*

- MLS Data Gateway Architecture and prototype have demonstrated the feasibility of secure, policy-based, agile/dynamic methods of data integration among enclaves with different security levels
  - *Completed these prototype implementations of use cases for data sharing:*
    - One Way Data Sharing among multiple security domains
    - Data Integration Via Data Virtualization products
    - Data Integration Via Data Semantics Layer products
    - Data Access Using Standard SQL Based Data Access and Query

- A key insight from these use cases: The MLS Data Gateway **integrates seamlessly with:**
  - ***Existing commercial data integration, virtualization and semantic layer-based tools***
  - ***Standard data sharing and interaction protocols*** *(e.g., SQL queries) in an MLS environment*

- This seamless integration **makes advanced data integration and sharing capabilities that were originally developed for a single security enclave available for use in MLS environments**