DS-3002: Data Systems

Overview of Data Warehouse Systems

Prof. Jon Tupitza – Spring 2022

UNIVERSITY of VIRGINIA

Modern Data Platform: Solution Scenarios

Big (Unstructured and/or Poly-Schematic) Data Integration and Advanced Analytics

"We want to integrate all our data into our data warehouse"

Modern Data Warehousing

"We're trying to predict which of our customers will churn"

Advanced Analytics

"We're trying to get insights from our devices in real-time"

Real-Time Analytics

Modern Data Platform: Data Services Pipeline

INGEST

Data Orchestration & Monitoring

Data Integration

STORE

Unstructured Data Storage

Data Lake Storage

PREPARE

Data Cleansing, Transformation & Streaming

Databricks

SERVE

Data Modeling, Serving & Storing

Data Warehouse

PREDICT

Reporting, BI, Predictive Analytics & AI

Machine Learning

DELIVER

MLOps Integration: CI/CD Pipelines, Version Control, Monitoring, Test Automation, Infrastructure as Code, Containers, Microservices

DevOps

The Data Warehouse Process

How to Approach Designing and Building a Data Warehouse

The Four-Step Dimensional Design Process

A Time-Honored and Tested Methodology for Delivering Data Marts & Data Warehouses

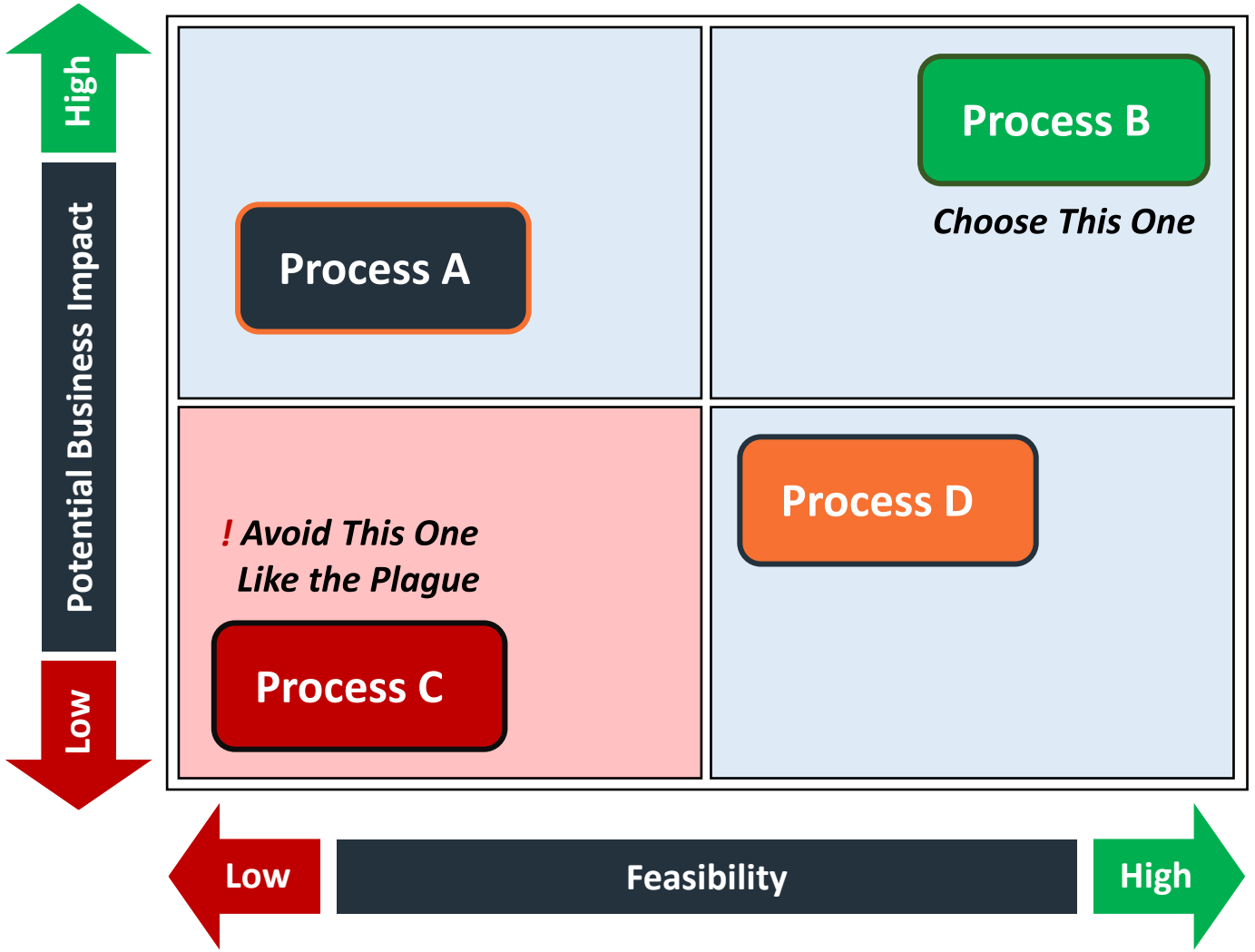
1. Select the Business Process	2. Declare the Grain	3. Identify the Dimensions	4. Identify the Facts
• Prioritize Business Processes that Have Significant Business Impact, and that can be Easily Delivered	• Determine What Level of Detail Must Be Available	• Categorical Values Describing Each Business Process	• Numeric Values that Quantify Each Business Process
• Attempting to Boil-the-Ocean Increases the Risk of Project Failure	• Greater Atomicity Provides Greater Analytic Flexibility	• Defines How Transactions are Viewed or Filtered	• Defines How Transactions Are Summarized
	• Aggregated Data Limits Access to Transaction Detail	• Should Have the Same Meaning Across Processes	• Facts Must Be True-to-the-Grain

The Data Warehouse Toolkit, by Ralph Kimball

Selecting Business Processes: Prioritizing Requirements

Quadrant Analysis for Prioritizing Requirements:

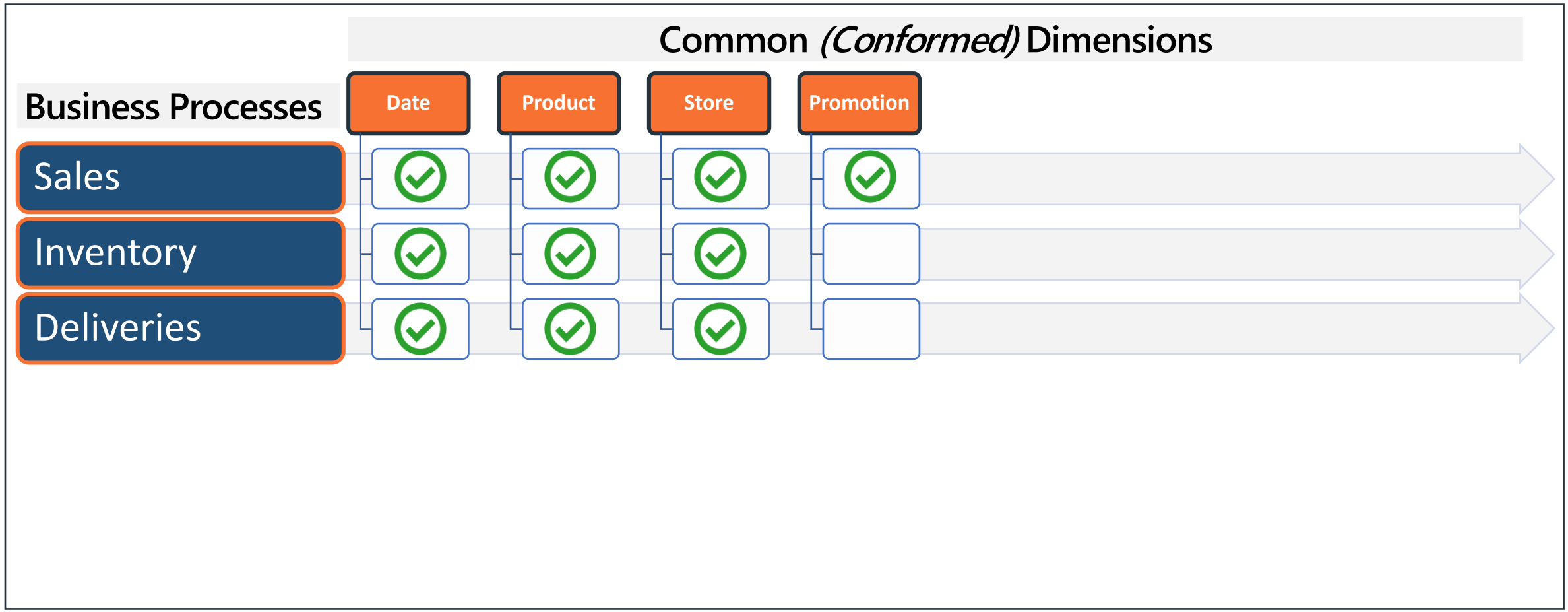
- **Business Process A:**
  - High Potential Business Impact
  - Extremely Difficult to Implement
- **Business Process B:**
  - **High Potential Business Impact**
  - **Highly Feasible**
- **Business Process C:**
  - Very Little Business Impact
  - Extremely Difficult to Implement
- **Business Process D:**
  - Little Business Impact
  - Highly Feasible



The Data Warehouse Toolkit, by Ralph Kimball

Identifying Dimensions: Data Warehouse Bus Matrix

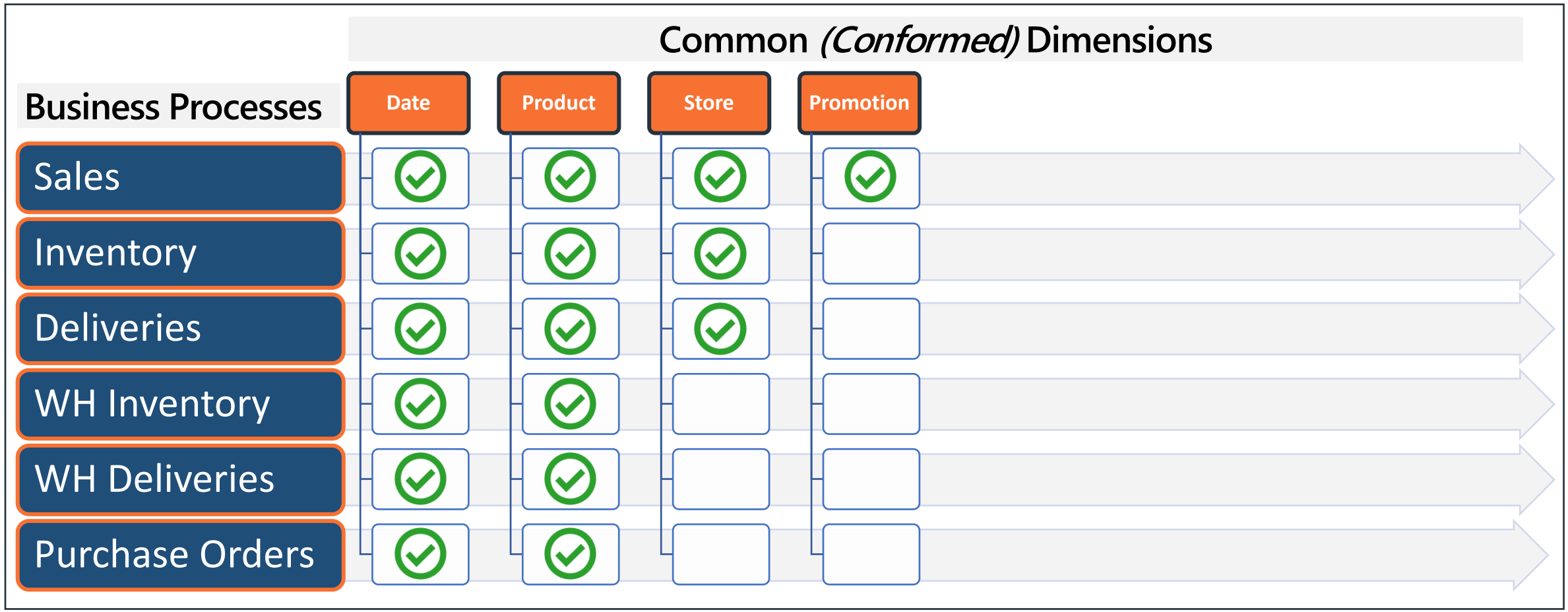
Using the Same Dimensions Across Multiple Business Processes Enforces a Unified View of the Truth



The Data Warehouse Toolkit, by Ralph Kimball

Identifying Dimensions: Data Warehouse Bus Matrix

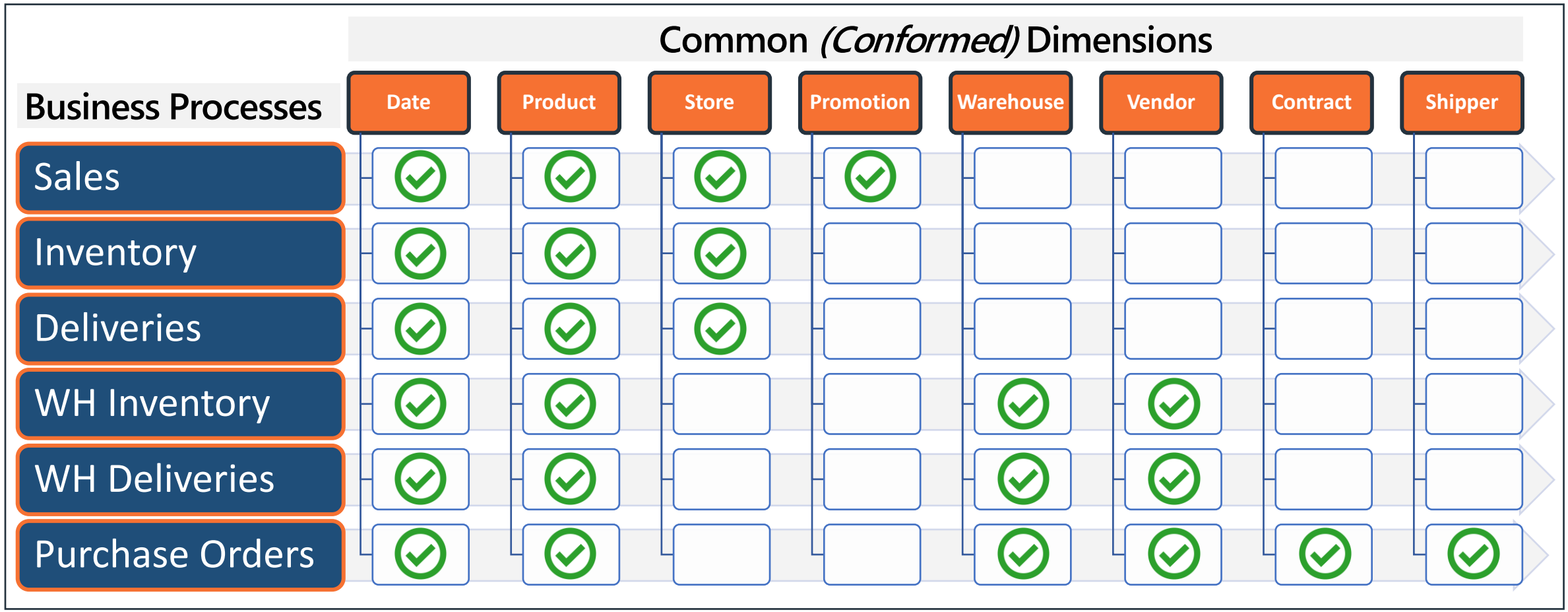
Using the Same Dimensions Across Multiple Business Processes Enforces a Unified View of the Truth



The Data Warehouse Toolkit, by Ralph Kimball

Identifying Dimensions: Data Warehouse Bus Matrix

Using the Same Dimensions Across Multiple Business Processes Enforces a Unified View of the Truth



The Data Warehouse Toolkit, by Ralph Kimball

Data Integration

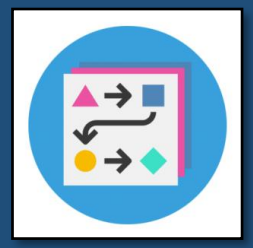
How to Approach Populating a Data Warehouse

Data Processing: Extract-Transform-Load (ETL)

Frequently, Data Must Be Moved from Sources to a Database and/or Data Lake

Extract

- This is the step where sensors wait for upstream data sources to land. Once available, we transport the data from their source locations to further transformations.



Transform

- The heart of any ETL job: apply business logic, perform actions such as filtering, grouping, and aggregation to translate raw data into analysis-ready datasets.

Load

- Load the processed data and transport to a final destination. Can now be consumed directly by end-users or treated as yet another upstream dependency.

Data Processing Paradigms: Latency Requirements

Latency & Response:

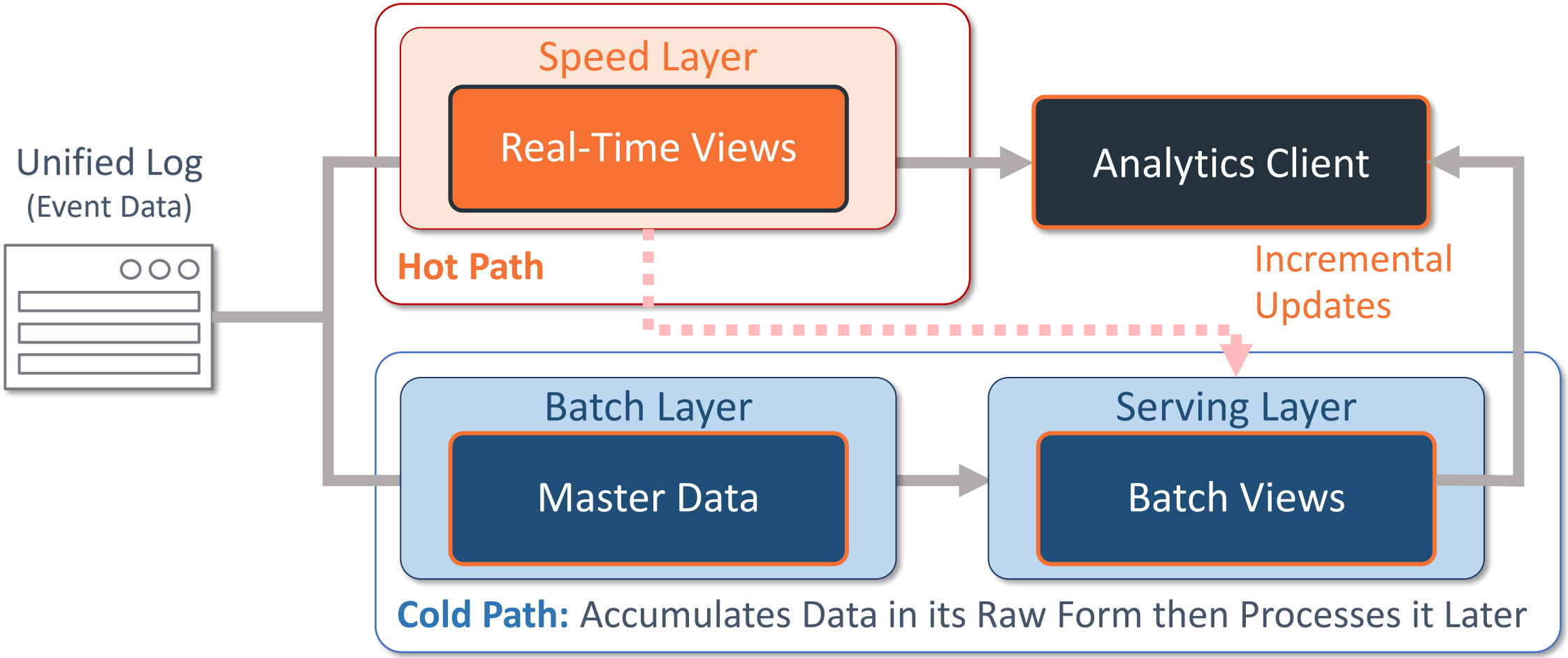
The speed at which clients require new insights determines the frequency at which new data must be processed

1. Batch
2. Continuous/Streaming
3. Real-time

Low-Latency Real-Time	Real-Time	Micro-Batch	Batch
• Spark-less, highly-available prediction server	• Prediction server with Spark	• Structured Streaming	• Spark batch processing

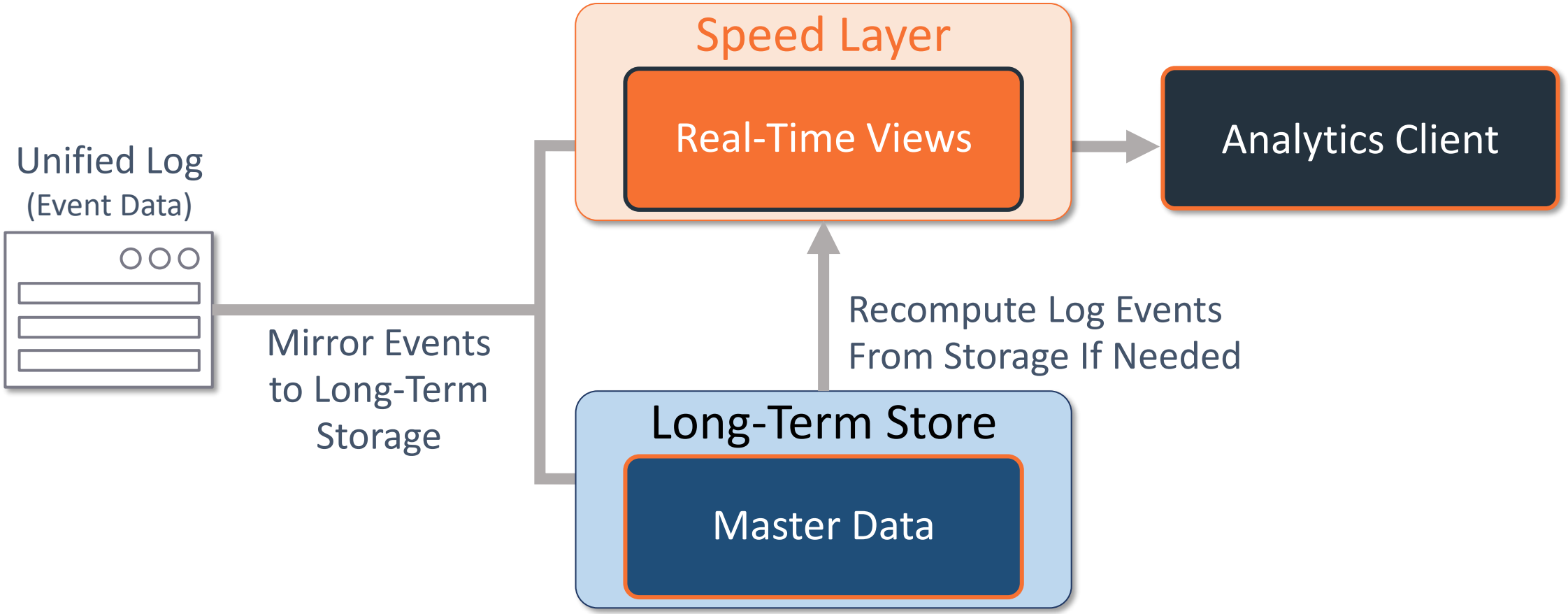
Data Processing Paradigms: Lambda Architecture

All Data Flows Through One of Two Paths: Hot or Cold



Data Processing Paradigms: Kappa Architecture

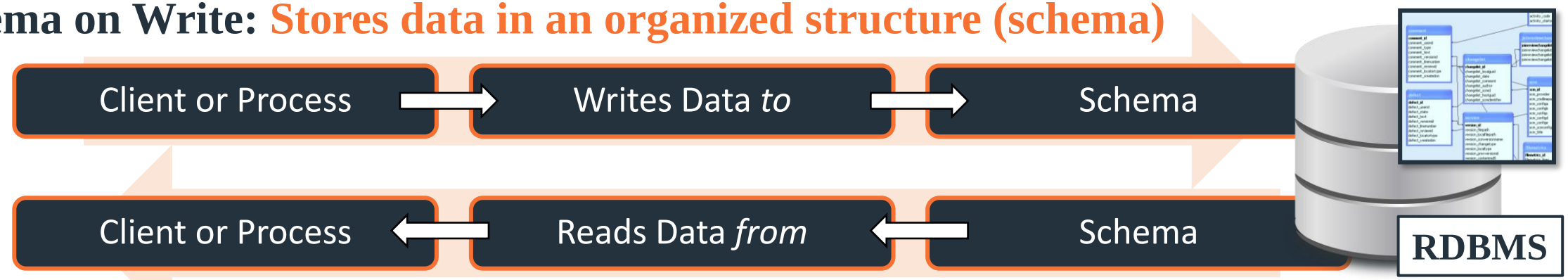
All Data Flows Through One of Two Paths: Hot or Cold



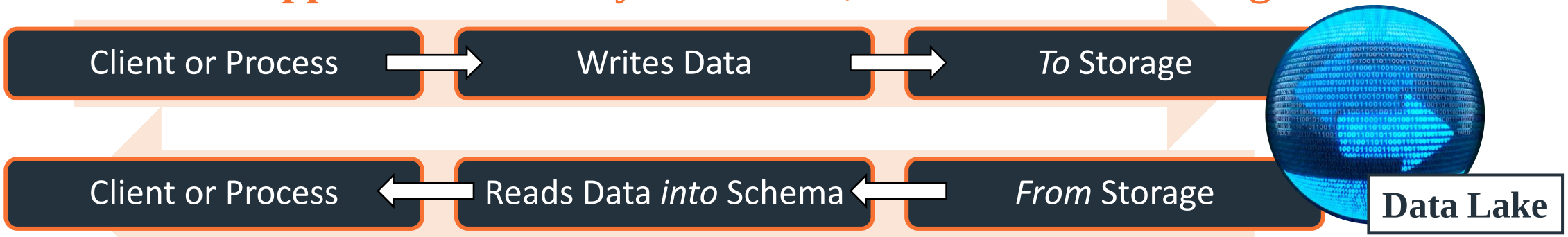
Paradigms: Data Storage and Retrieval

Schema on Write versus Schema on Read

Schema on Write: **Stores data in an organized structure (schema)**

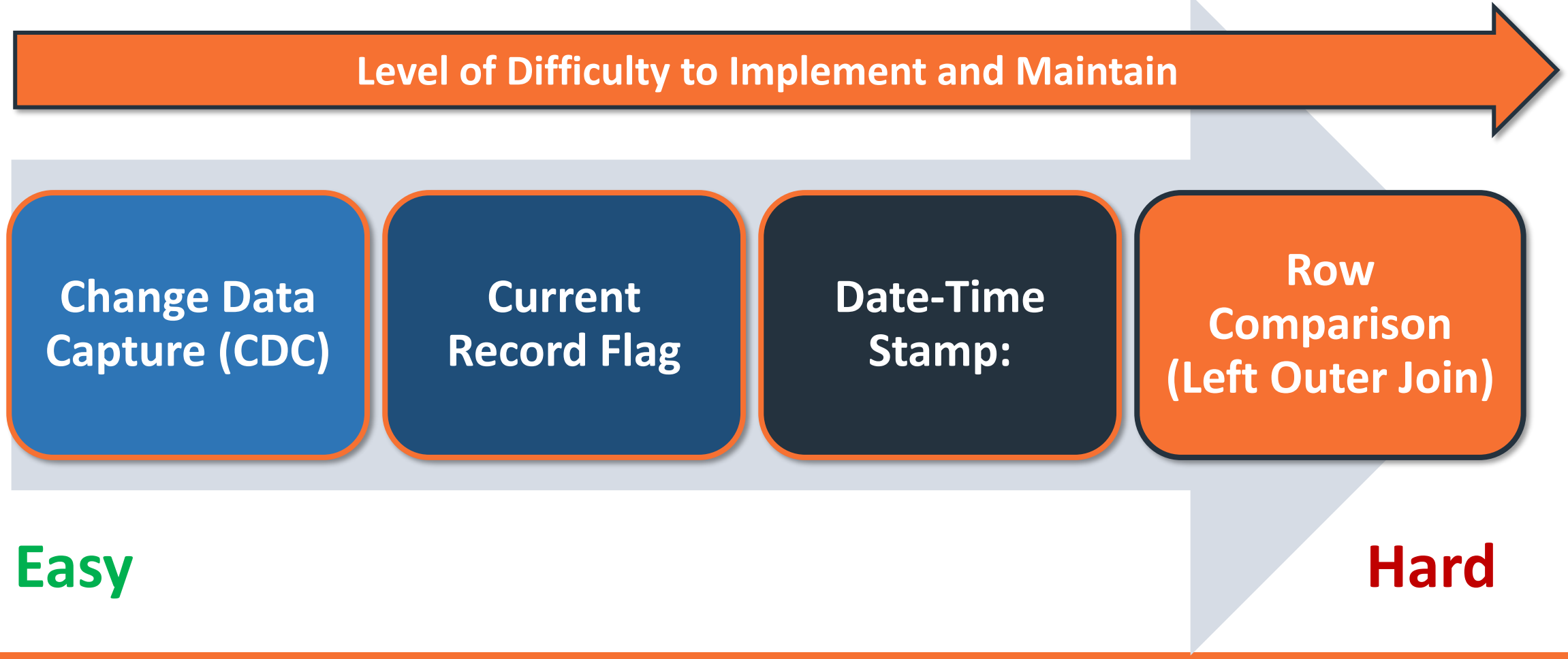


Schema on Read: **Applies schema only when read, data stored in its original format**



ETL Processing: Incremental Extraction

Techniques for Minimizing Data Movement: Extract Only the Changes



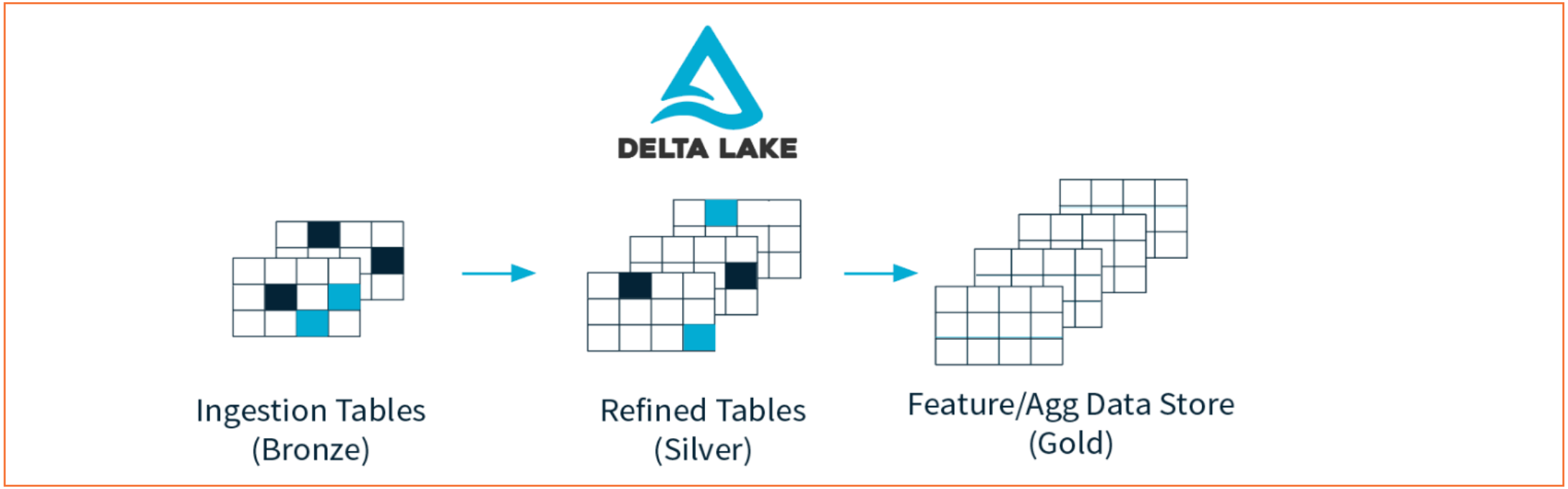
Data Integration Patterns: Dimensional Data

Slowly Changing Dimension Update Strategies: Handling Variable Rates of Change

SCD Type 0	SCD Type 1	SCD Type 2	SCD Type 3
• Data in the Column Never Changes: Ever! • Only for Static Reference Data	• No History is Maintained • Existing Values are Overwritten by New Values • **UPDATE**	• Historic Values are Maintained • New Values are Written to a New Row • *IsCurrent* Flag • **INSERT**	• A New Current Value Column is Created in the Existing Record • Original Column is Also Retained

Easier to Implement and Maintain ← → **More Difficult to Implement and Maintain**

Databricks: Delta Lake at Scale



ACID Transaction Guarantees
Atomic, Consistent, Isolated, Durable

Versioned Parquet Files
Delta transaction log keeps track of all operations

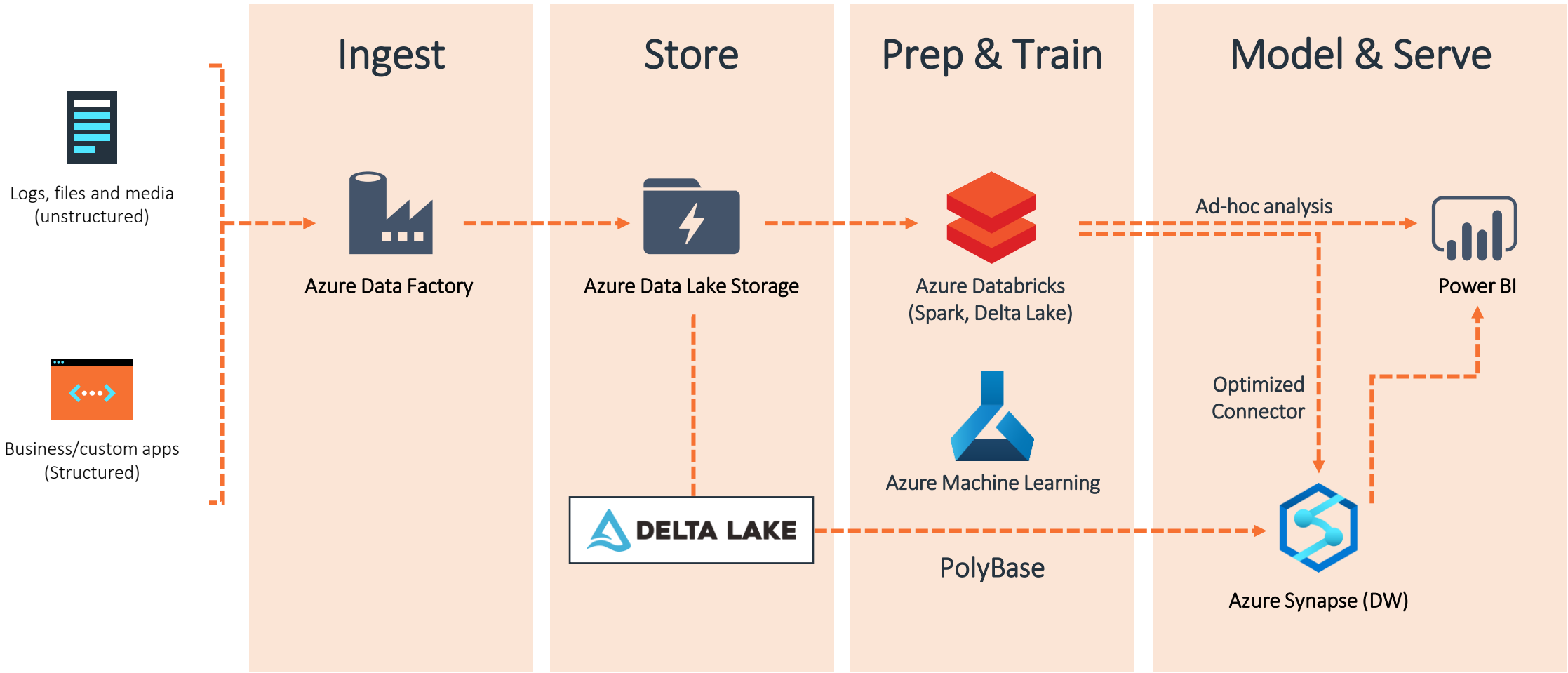
Efficient Upserts
MERGE, DELETE, UPDATE

Time Travel
Audit history, pipeline debugging, data reproducibility

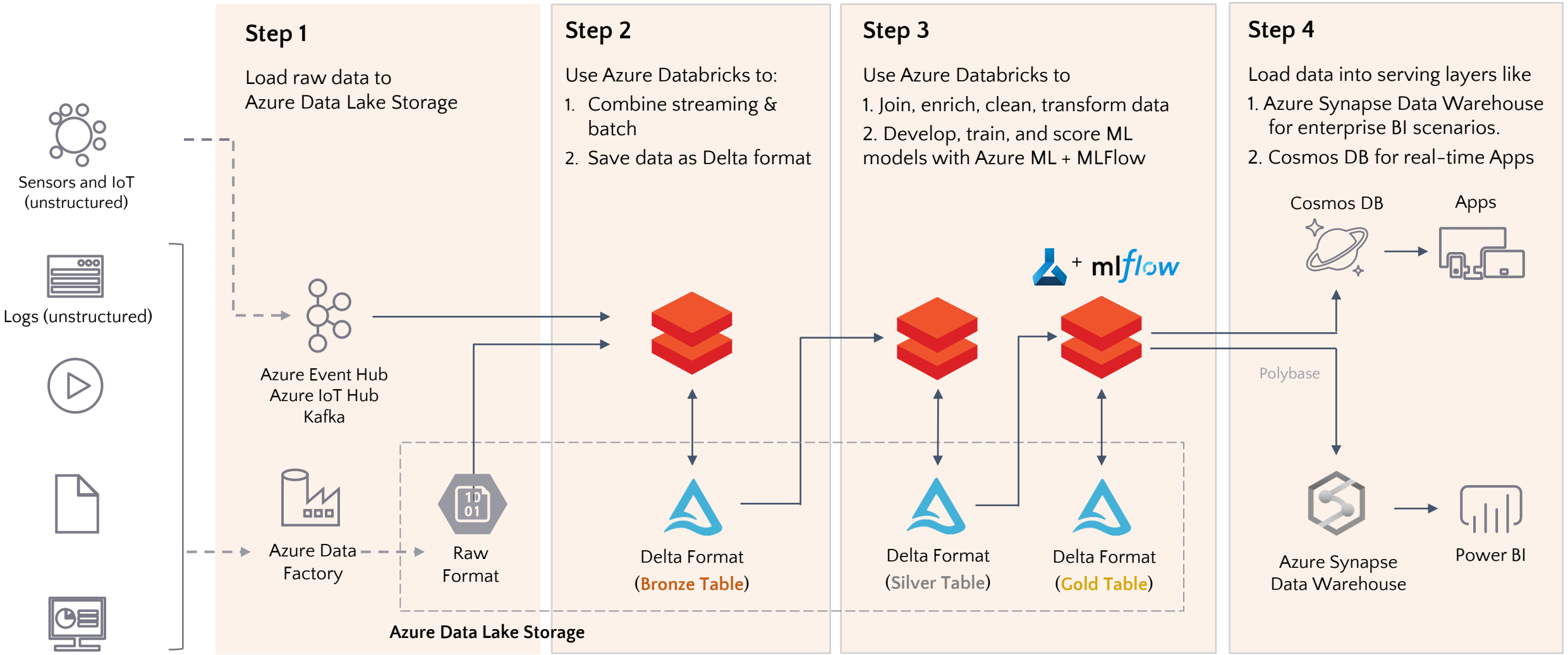
Small file compaction with no interrupt to availability
OPTIMIZE and VACUUM

Z-Order partitioning with up to 100x perf
New multidimensional partitioning enables data skipping

Data Engineering… for Data Science



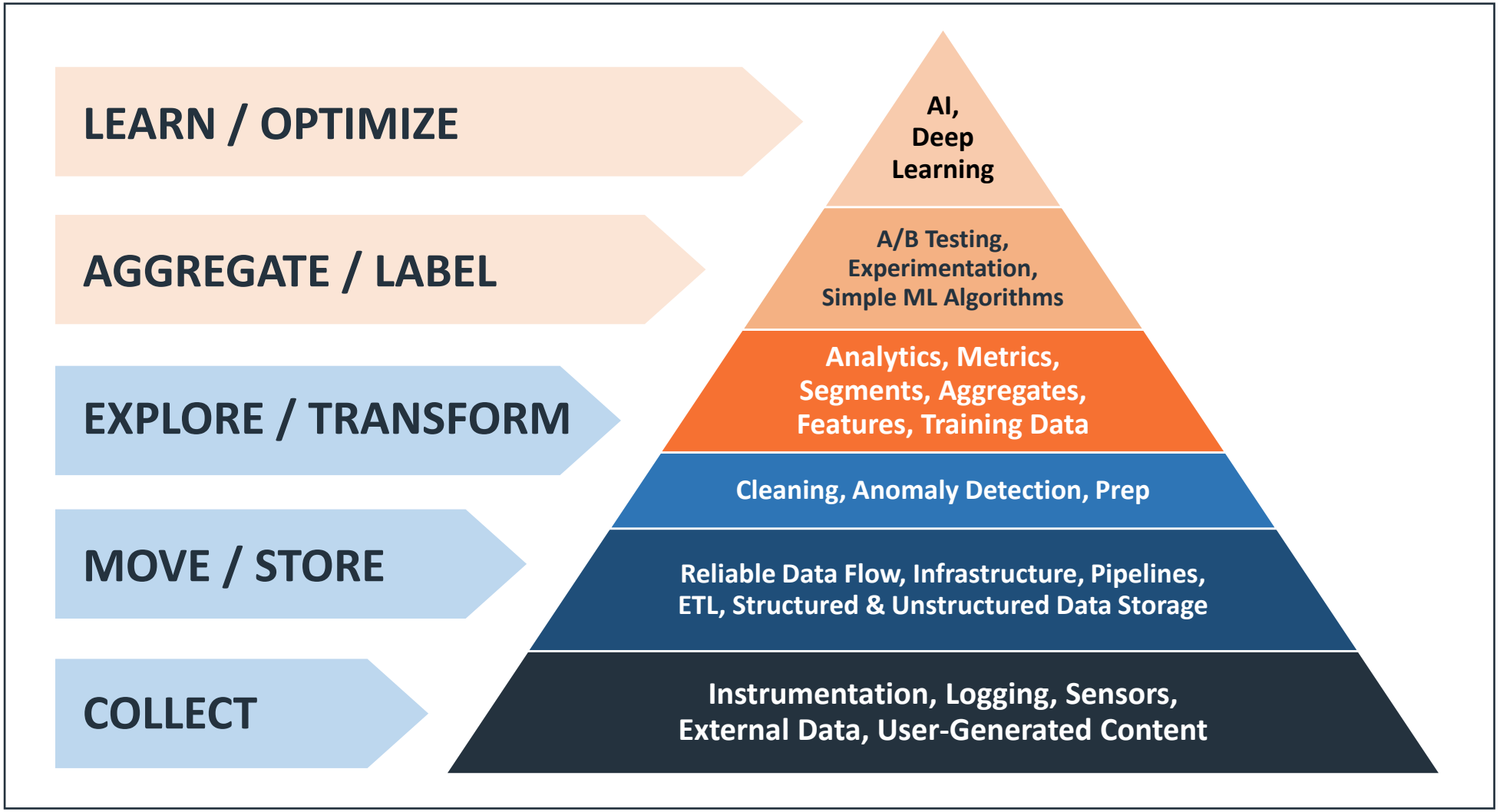
Design Pattern: Modern Data Warehousing



Q & A

A Survey of Data Management Systems

The Data Science: Hierarchy of Needs



Architectures: Data Lakehouse vs. Data Mesh

How to…

Considerations for Building Data Warehouses