Big Data in Capital Markets

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Outline

- Introduction to modern financial markets
  - Basic concept and terminology
- Data collection and analysis challenges for the regulators
  - MIDAS
  - CAT
- Electronic trading and objectives of market participants
- Typical automated trading system
  - Trading model development process
- Implications for DBMS

US Stock Market Structure Today

Execution Venues	Number of Venues	Volume %
Exchanges	14	66%
Dark Pools	Around 50	13%
Internalization	200+	21%

- Orders submitted via 2000+ Broker Dealers
- Regulated by SEC, SROs (FINRA and exchanges)
- Daily Volumes
  - $50-100 billion notional value traded
  - 5-10 billion shares traded
  - **2-6** billion orders submitted
  - Only ~1% of orders get executed

Inside an Exchange – Order Events

- Incoming
  - New Order (symbol, side, price, size, order type, etc.)
  - Order Cancel
  - Order CancelReplace / Modify
- Outgoing
  - Acknowledgements (New, Canceled, Modified)
  - Rejects
  - Executions

Market Data

- Rich data - anonymized stream of order events
  - Shows new orders, order modifications, cancellations and executions
  - Not all orders are there (marketable, hidden orders, etc.)
  - Most transparent paradigm
  - Increment based data – need full replay to reconstruct state of the market
- Order book snapshots
  - Aggregated by price level
  - Usually truncated to few best price levels

Race to the Bottom
High Frequency Trading (HFT)

- Fast systems
  - Exchange response time <100 µsec
  - Fastest trading systems ~15 µsec
  - CPU cache usage optimization
  - Exchanges can produce millions market data msg/sec
  - Dealing with data bursts - FPGAs, GPUs, etc.
- Dealing with geographic distribution
  - Multiple data centers and co-locations
  - Microwave NY to CHI and in NY metro
  - New transatlantic cable

Challenges for Regulators

- Health of the market structure
  - How HFT affects the markets?
  - What are the effects of dark pools on the markets?
  - What exactly is happening to a retail order?
- Effects of recent and potential rule changes
  - How would minimum time-in-force for orders affect liquidity?
  - How tick sizes affects visible/dark liquidity?
- Understanding unusual market events
  - Flash crash (5/6/2010)
  - Knight Capital Group breakdown (8/1/2012)

MIDAS - Market Information Data Analytics System

- Developed by Tradeworx – a 14 year old trading firm and financial technology provider
- System originally developed for use by trading firms (in-house and as a service)
- MIDAS went on-line at SEC in January 2013
- Currently 100+ daily users
- Examples of usage include:
  - Mini flash-crash analysis
  - Rule change impact assessment
  - Detection of abnormal patterns in message traffic

MIDAS - Data Capture

- “Big Data”
  - Stocks, options and futures
  - 6 co-located datacenters
  - 15 different protocols
  - 1 terabyte data / day
  - Millions of messages / second
  - 1 µsec raw to normalized
- Network
  - Min 10 Gbps fiber network
  - Microwave link between metro NY and CHI

Data Capture Challenge – Accurate Timing

- Why relative timing is important?
  - Price protection rule
  - Need to see complete picture from any venue
- Why is it difficult?
  - Relative clock drift
  - Distance between data centers
- Solution
  - GPS time synch

MIDAS – Storage

- AWS VPC
- Forced Amazon into FedRAMP certification
- Normalized compressed text
  - Optimized for consecutive replay
  - Redundant storage with two file organization strategies:
    - Segregated by symbol, ordered by time
    - Whole universe segregated by time slice, ordered by time

MIDAS – Analysis Level 1

- **Graphical order book viewer**
  - Graphical representation of the book
  - TIVO functionality with microsecond resolution
  - combines books from any number of sources
  - allows “point-of-view” aggregation

MIDAS – Analysis Level 2

- **Interval-based data research platform**
  - Proprietary language for clustering and partitioning of data into fixed length bars
  - Standard statistical tool set optimized for time series analysis
  - Interfaces for Python, R, SAS, etc.

MIDAS – Analysis Level 3

- **Tick data research platform**
  - Replay framework for continuous tick-level data
  - C++ call-back based API
  - State-of-the-art multi-exchange simulator

"*for the growing team of quant types now employed at the SEC, MIDAS is becoming the world's greatest data sandbox*." – SEC Chairman Elisse Walter

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CAT – Consolidated Audit Trail System

- Mandated by Securities Exchange Act Rule 613, which was adopted by the SEC in July 2012.
- Bidding process for CAT is currently under way:
  - Process is run by SROs (national securities exchanges and national securities associations) - see http://catnmsplan.com/
  - RFP Responses due 6/30/2013

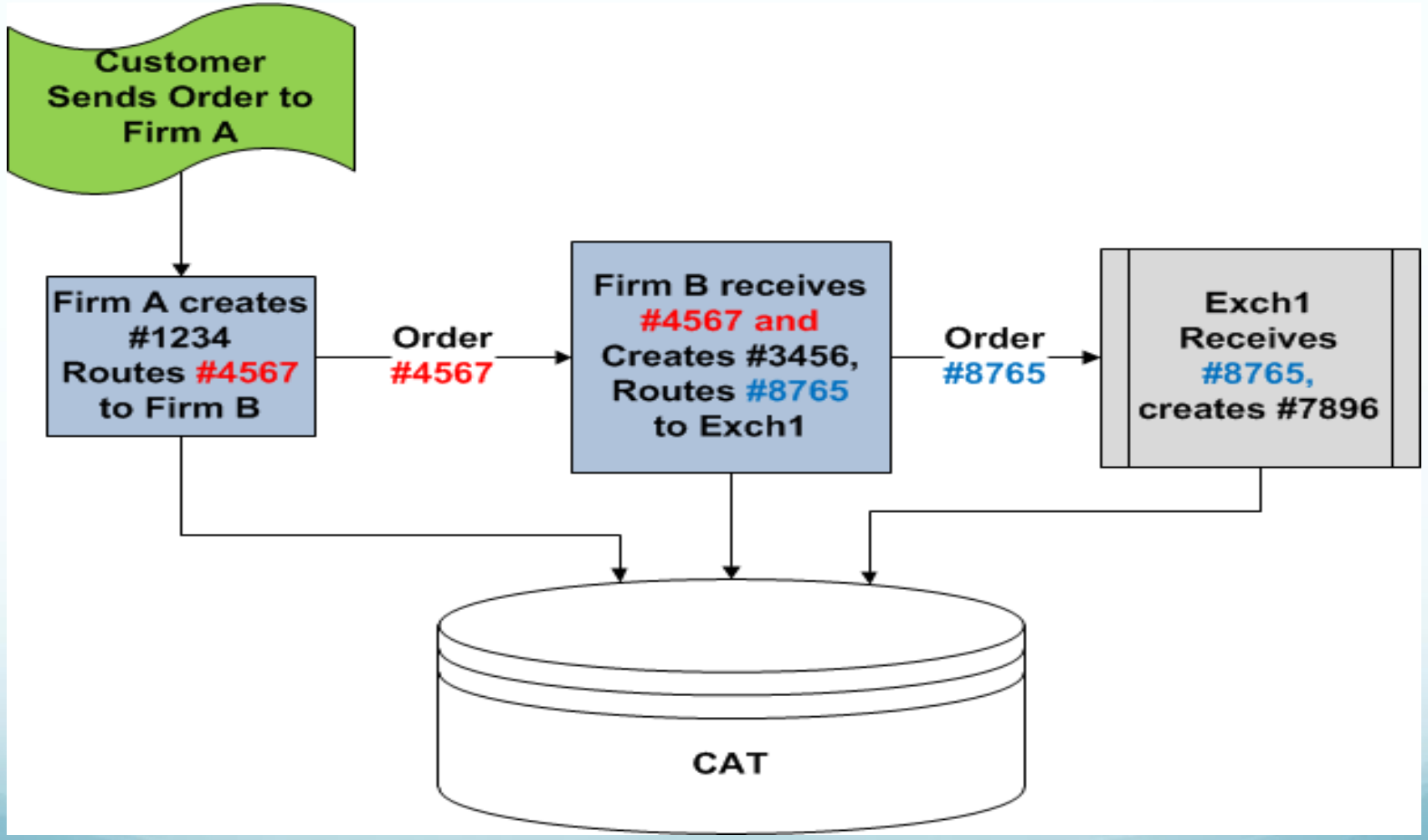
CAT – Scope of Data

CAT will consolidate comprehensive public and non-public data about the market into a single system.

Non-public information to be collected by CAT:

- Customer and account information
- Identities of the parties for every order and trade
- Activity on public markets not published in market data (marketable, hidden orders, etc.)
- Order events for customer-BD interaction
- Ability to trace the lifecycle of the order

Order Routing Scenario



CAT-Order-ID problem

- A series of unique order identifiers assigned by CAT Reporters are linked together by the CAT to create the lifecycle of an order and assigned a single CAT-Order-ID for the lifecycle.
- Simple problem, but very search intensive with severe time constraint

CAT – Data Collection and Validation

- Protocols will be specified by CAT implementer
- Will be collecting data from 2000+ participants
- The initial data checks required by the CAT include, but are not limited to:
  - Data format validation and syntax check
  - Identification of unregistered accounts
  - Identification of unregistered market participant identifiers
  - Identification of unlinked lifecycle events
- 4 hour validation window – needs to process 5mln records/sec!

CAT – Data Repository

- Rolling 5 year period on-line + 2 years of archived data

	Year 1	Year 2	Year 3	Year 4	Year 5
Estimated daily data size	5 TB	13 TB	16 TB	20 TB	24 TB
Estimated daily records	22bn	58bn	71bn	89bn	107bn
Accumulated total size of central repository	2 PB	6 PB	10 PB	15 PB	21 PB

CAT - Query and Extraction

- Online Query Tool
  - require a minimum set of criteria, including date/time range, symbol, Customer ID(s), CAT-Order-ID(s), etc.
  - must support approximately 3,000 registered users
- Bulk Data Extraction
  - bulk extraction and download of data, based on a specified date/time range, market, security, Customer ID and the size of the resulting data set
- Different levels of access depending on user role and function

MIDAS vs CAT

	MIDAS	CAT
Scope of data	• US stocks, futures and options • Public market data only	• US stocks and options • Market data (public and non-public) • Customer data
Users	• Trading firms • SEC	• SEC • SROs
Data Inputs	• Real-time capture (6 data centers) • Focus on accurate timings	• Mostly batch submissions (2000+ submitters) • Focus on validation
Repository	• Compressed text on a public cloud	• TBD, likely an analytical database
Usage paradigm	• Analytical toolset	• Online query tools • Bulk data extraction

Beyond CAT

"*My long-term vision is a consolidated audit trail that spans products, markets and the globe*" – SEC Chairman Elisse Walter

Further Topics

- Market participants and their trading objectives
- Types of financial data and its usage. How big is Big?
- How does typical automated trading system work?
- What is trading model?
- Trading model development dataflow
- Implications of Big Data In Electronic Trading for DBMS

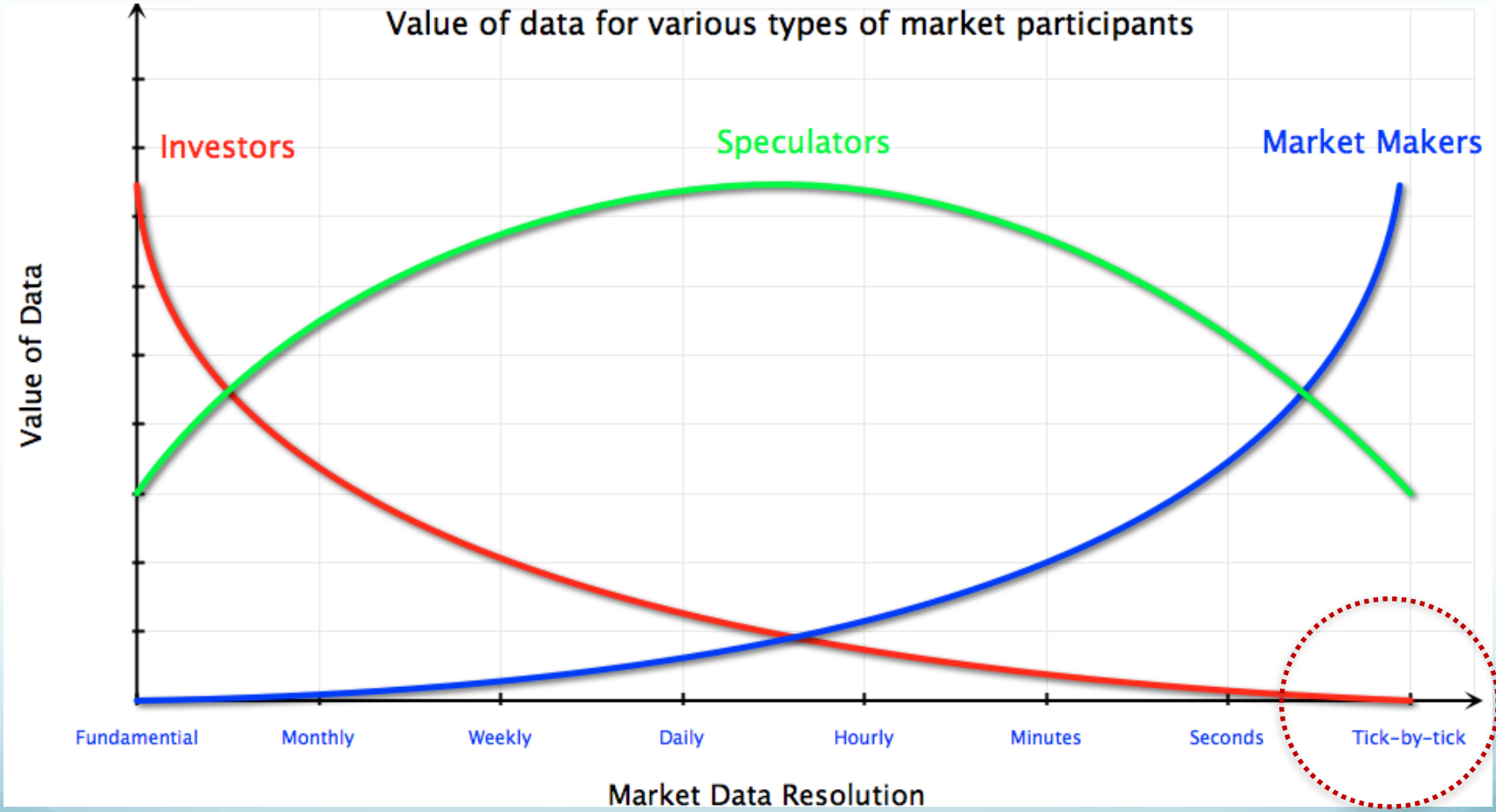
Market Participants

Type	Example	Orders/day	Hold Time	Price Sensitivity	Returns/ transact
Investors	Pension Funds Retail Investors	1s - 100s	Months- Years	Low	High
Speculators	Hedge Funds, Day Traders	100s -1000s	Seconds - Months	Low-High	Low-High
Market Makers	Prop Shops, NYSE DMM	1000s - MMs	Subseconds - Days	High	Very Low

Types Of Data

- Reference Data, a.k.a. Securities Master (ticker symbol, exchange, security description, corporate actions, etc.)
- Fundamental Data (corporate financials, analyst reports, filings, etc.)
- Market Data (orders, trades)
- News (earnings reports, economic news, etc.)
- Social Media (market sentiment, twits, Robinhood, etc.)

Who is interested in what?



How Big is Market Data?

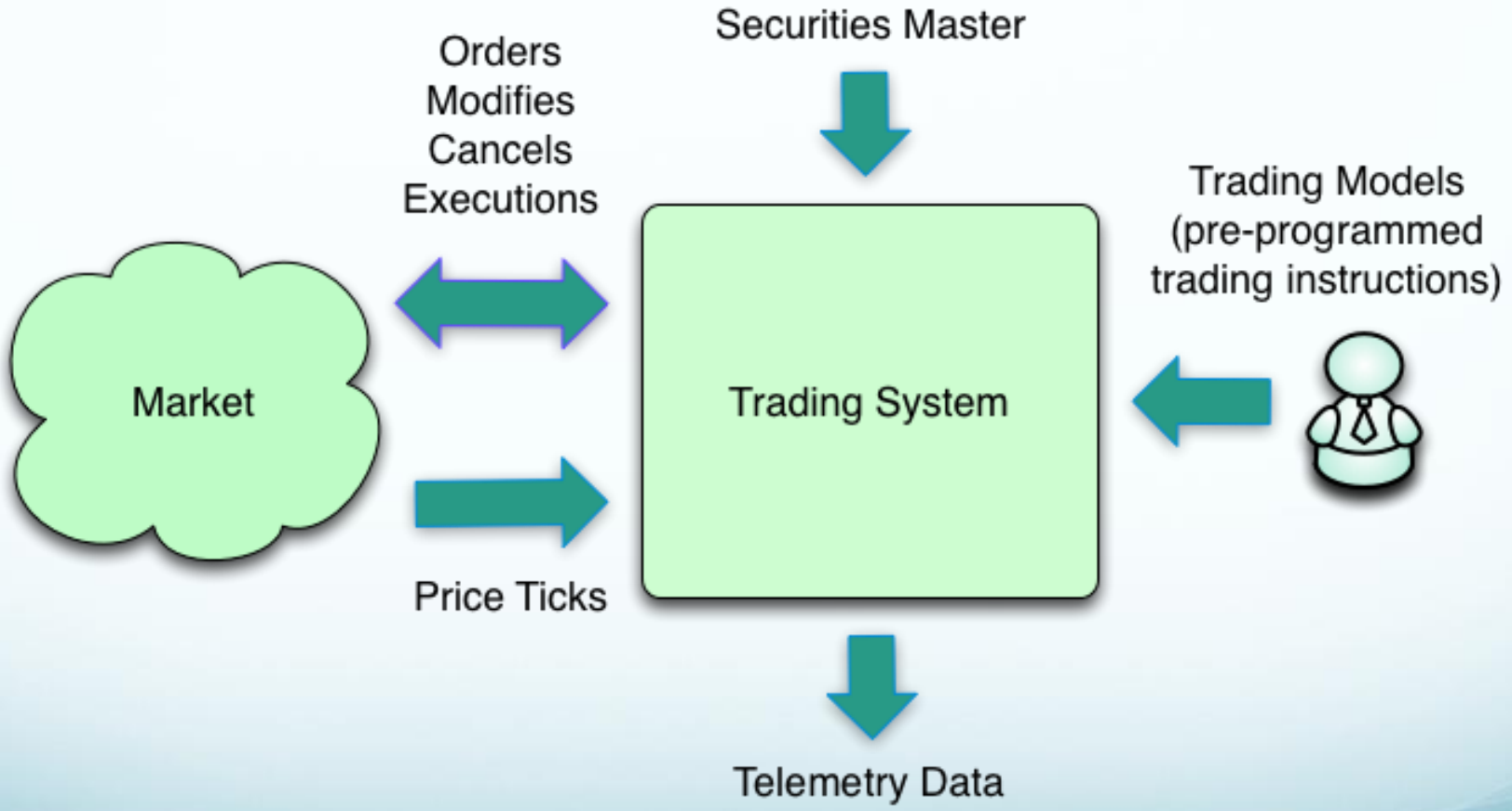
OPRA projections for 2014:

- 14.7 million MPS
- 24.6 billion messages/day
- Output rate for a single line 1 million MPS

ARCA data feed in Feb 2013 observed:

- 1 sec peak: 98.18 Mbps
- 10ms peak: 945.42 Mbps (a lot of microbursts)

Typical Automated Electronic Trading System



What Is Trading Model?

- Trading model is a set of pre-programmed trading instructions that implement a particular trading strategy, e.g.:

  - Statistical arbitrage
  - Trend following
  - Mean reversion
  - Scalping
  - Market-making
  - etc.

Statistical Arbitrage as an example of trading strategy

- There are inherent relationships between prices of some securities (e.g., SP500 ETF vs. its component stocks; equity option and its underlying stock)
- There are statistical relationships between stocks in the same sector (e.g., PEP vs. KO, airline carriers)
- Securities prices/returns are often highly correlated
- …but markets are not perfectly efficient: there are temporary anomalies in relative pricing of correlated securities

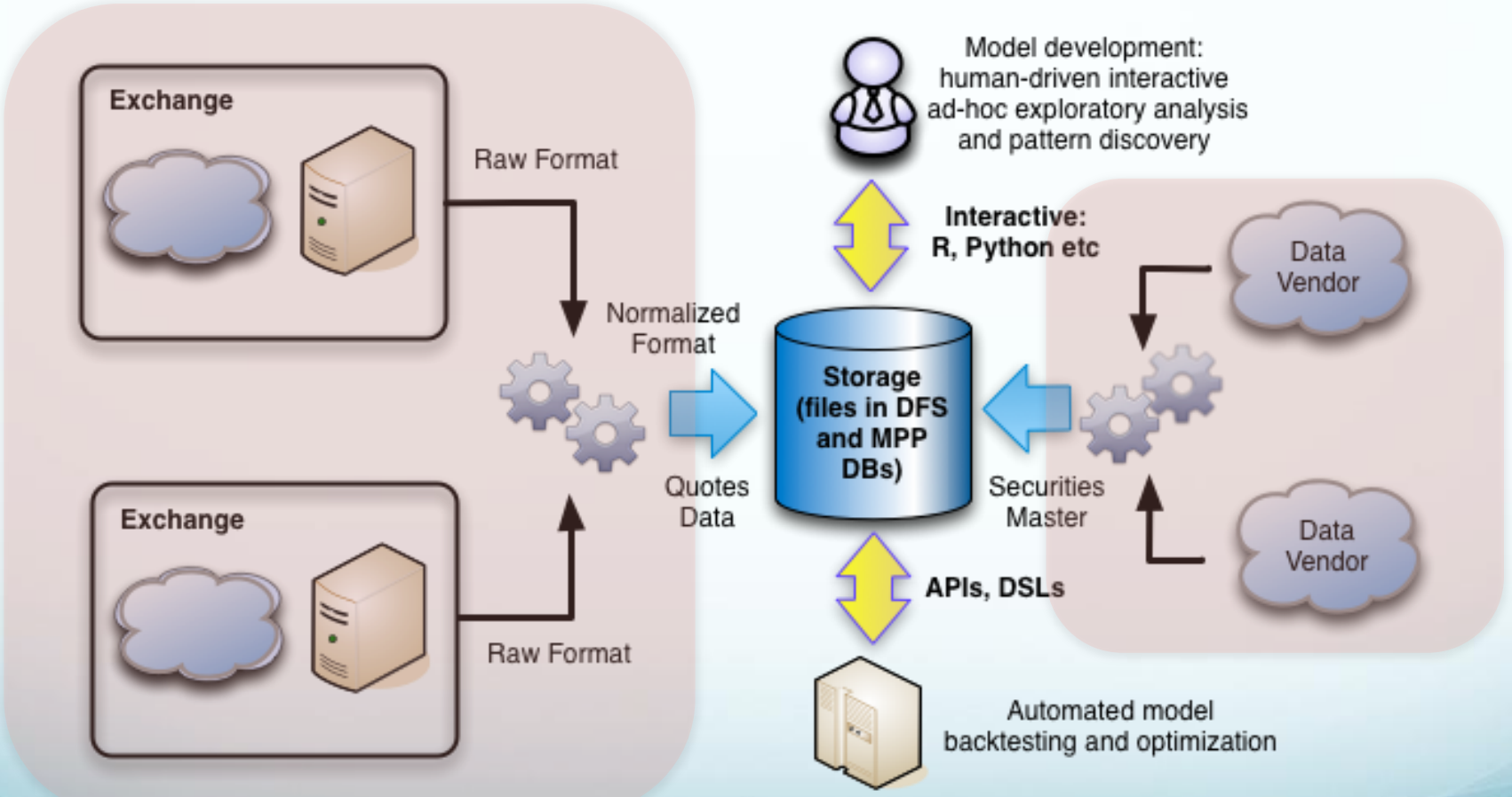
Statistical Arbitrage as an example of trading strategy (continued)

- Typical Stat Arb strategy considers a basket(s) of hundreds (sometimes thousands) of correlated securities and is seeking to capitalize on short-term temporary relative-pricing anomalies

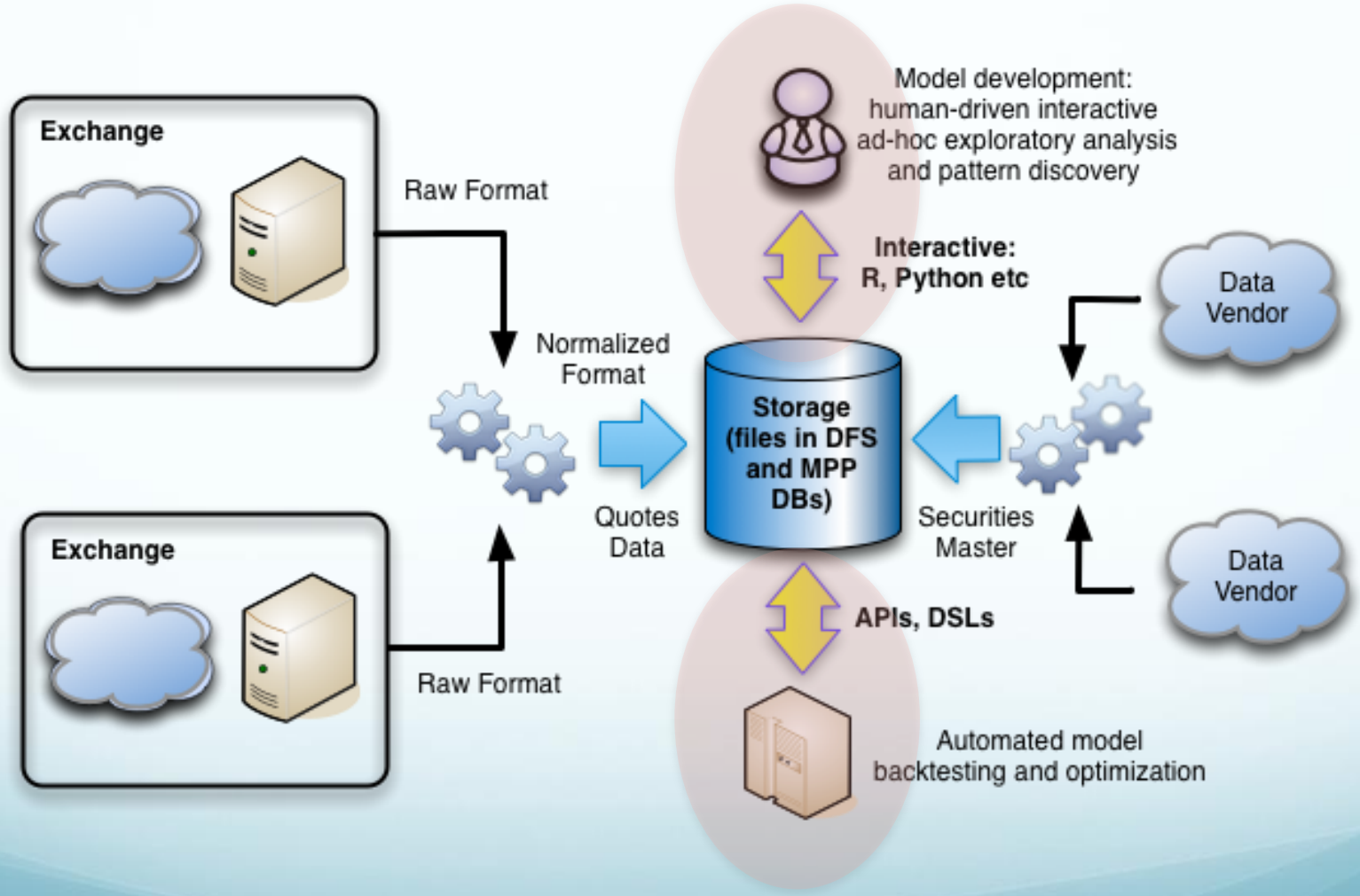
  - employs complex statistical methods;
  - involves a lot of high-resolution market data;
  - is computationally extensive;

So, how do they develop trading models?

Trading Model Development Dataflow



Trading Model Development Dataflow



Model Development Process Design Requirements Summary

Enabling ***humans*** to generate new ideas (exploratory analysis)

- Human-centric
- Ad-hoc
- Interactive

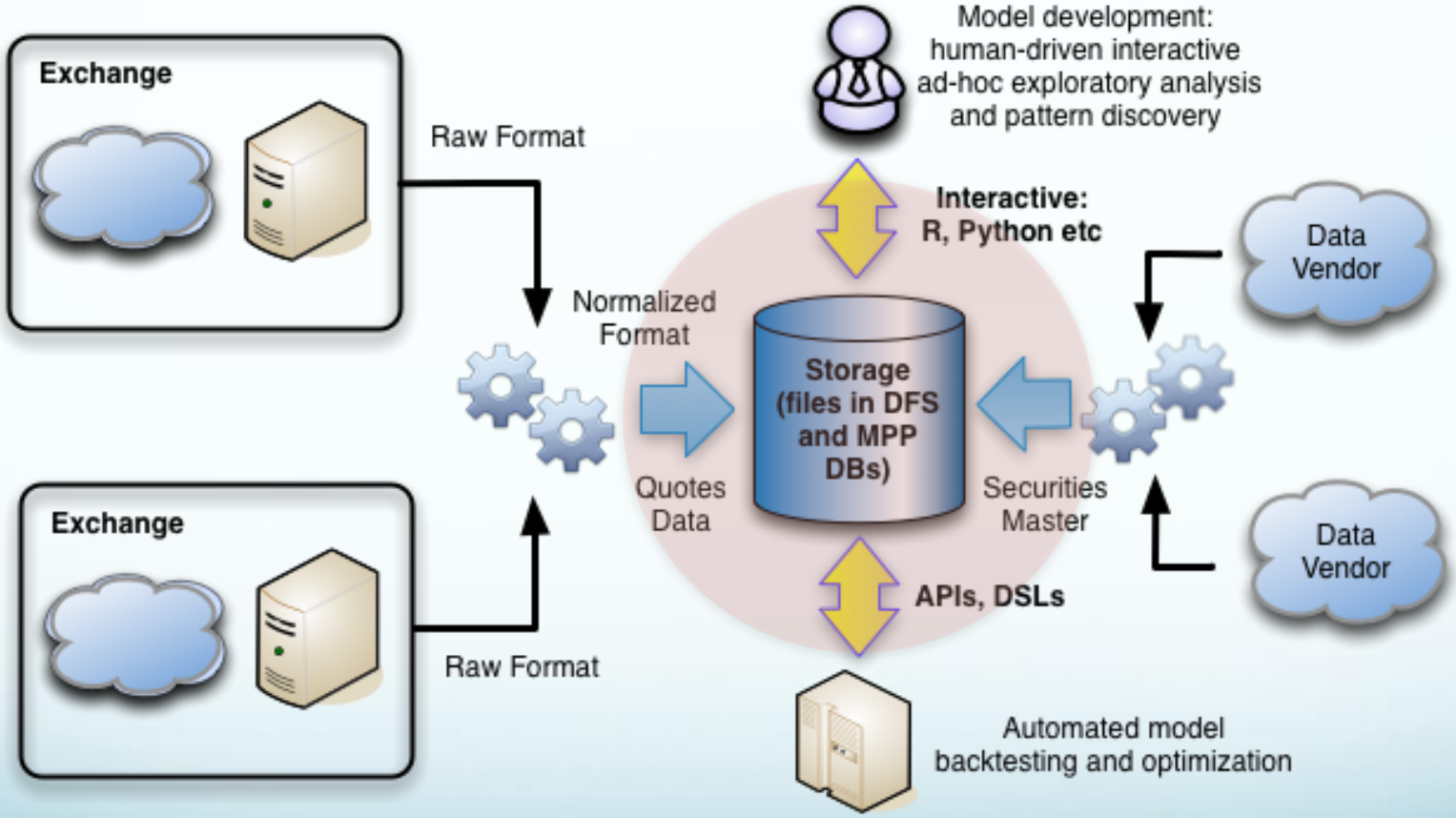
Enabling ***machines*** to validate and optimize ideas

- Machine-centric
- Not interactive
- Highly automated tick data “replay”
- Many iterations with various combinations of model parameters

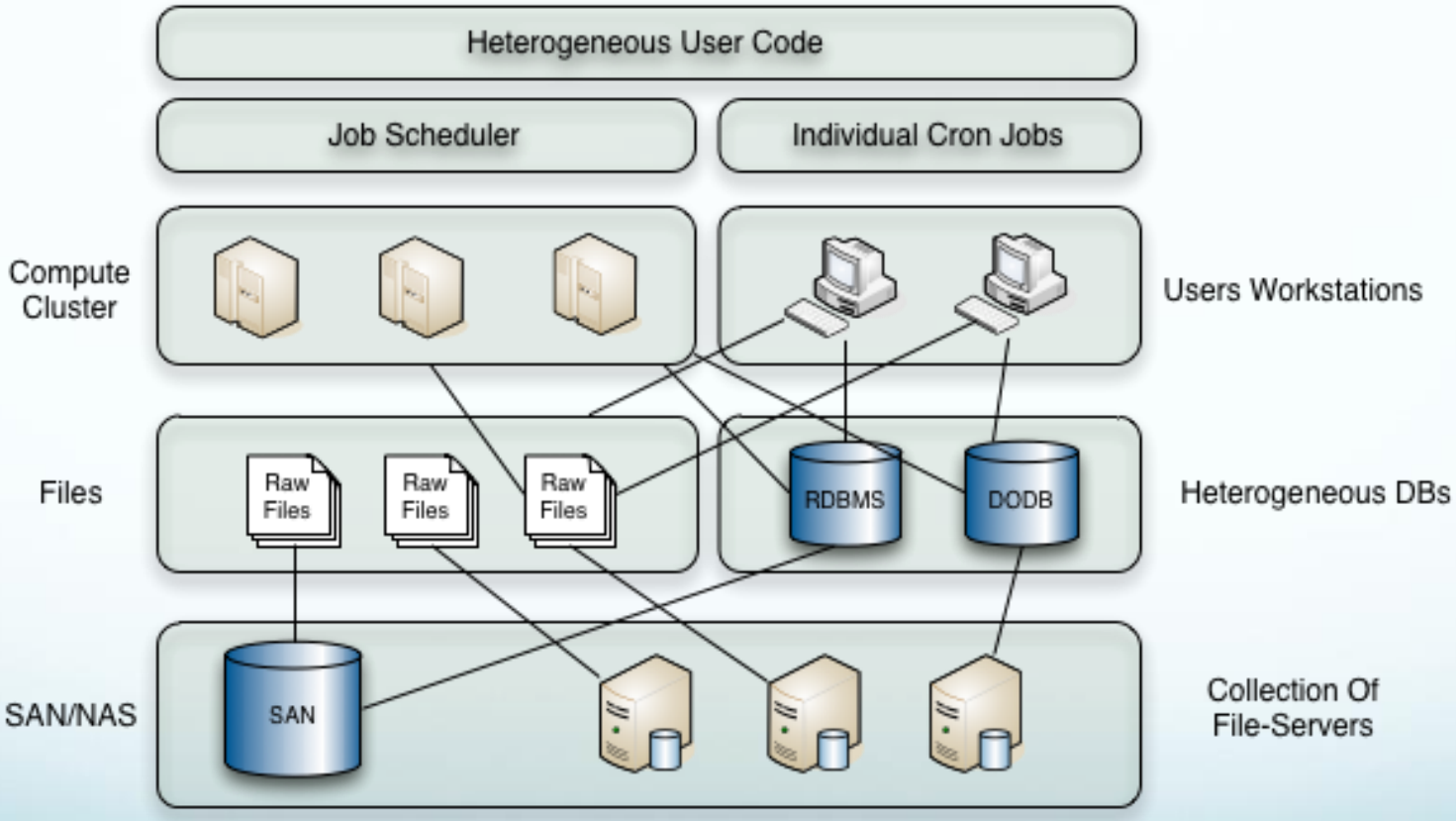
Idea development process must be efficient!

- Minimizing time-to-value requires:
  - variety and volume of available data
  - efficient queries (easy to write, quick response)
  - interactive ad-hoc analysis (R, SciPy, NumPy, visualization)
  - idea has to be easily expressible and sharable with other people; machines need to understand it too (DSL)
  - large chunk of quants' time spent in data preparation, not in analysis; decouple data processing and analytics

Trading Model Development Dataflow



Core Data System Zoomed-In: It's a very complex (and costly!) operational environment



So, what does it all mean for DBMS?

Financial Data Characteristics

- Tick Data
  - well-structured (when transformed into normalized format)
  - good fit for relational DB (for ad-hoc interactive analysis)
  - good fit for scientific formats, like HDF5 files (for automated back-testing)
- Securities Master
  - multi-structured
  - good fit for document-oriented DB
- Fundamental Data
  - multi- or loosely-structured
  - may benefit from a semantic data model/catalog
  - semantic DB

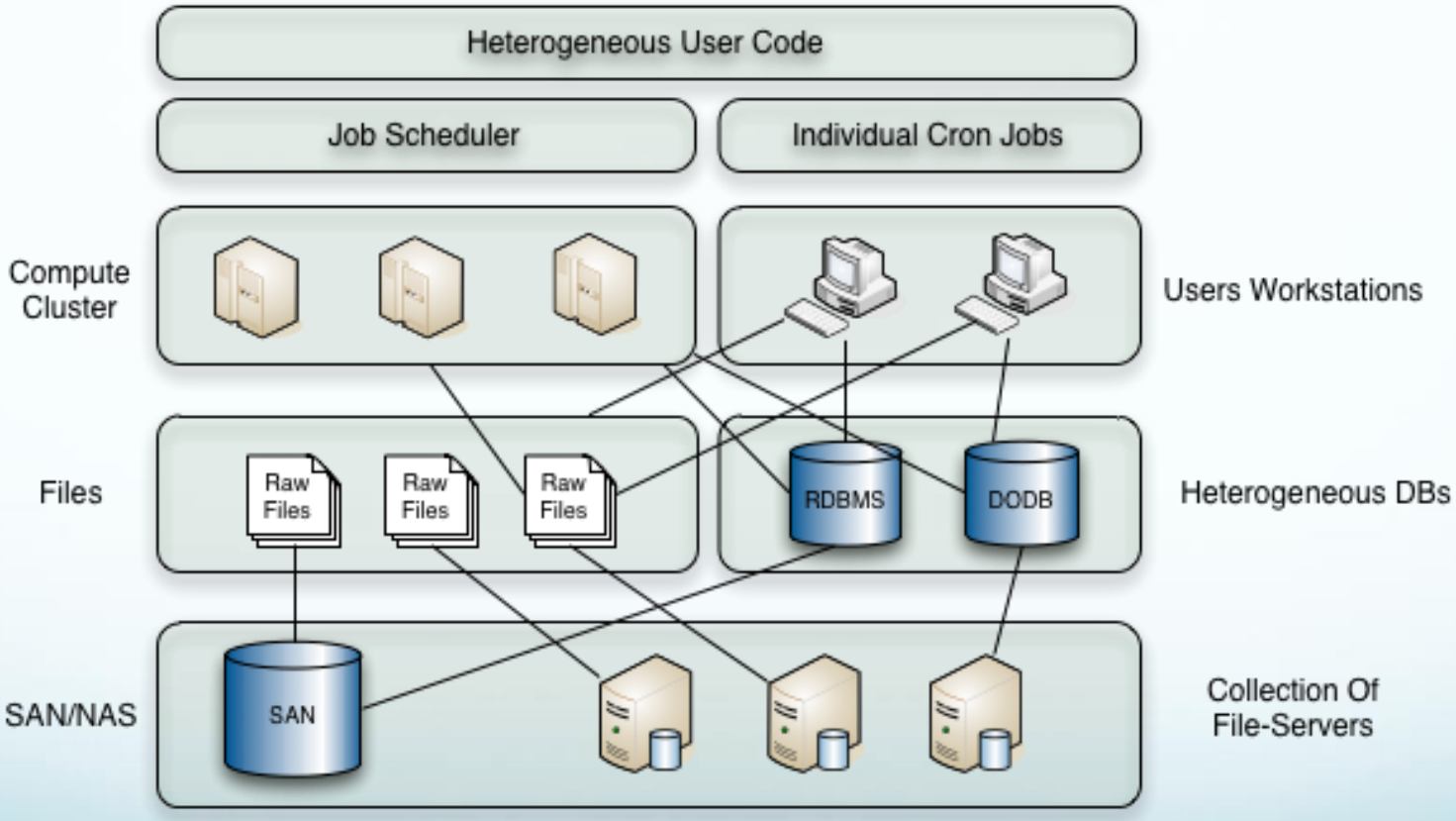
More Tick Data Characteristics

- normalized format -> well-structured
- time-series -> deterministic records order -> seq disk I/O (mostly) with efficient read-ahead
- can be easily segmented by date/exchange/ticker
- WHERE predicates are mostly predictable (date, exchange, ticker)
- key record attributes (date, exchange, ticker) are low cardinality -> good RLE compression within a column
- stock price changes in increments -> good DELTA-based compression within a column

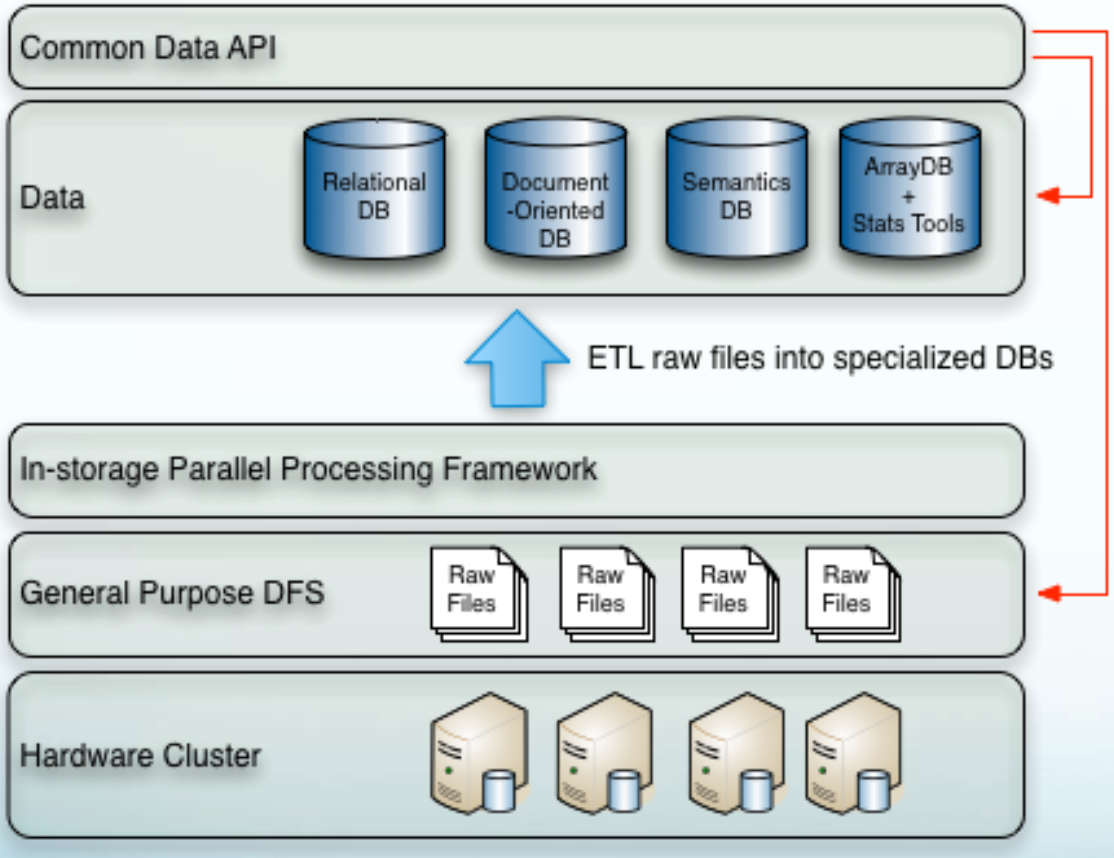
Challenges

- Tick Data seems a good fit for column-store or array DB, but…
  - DBs are slow for retrieving large subsets
  - Model development requires additional context -> a common language to access and blend data from relational, document-oriented or semantic DBs
  - DBs need better build-in time-series analytics -> specialized SQL language extensions
  - DBs need to integrate statistical tools supporting parallelism in complex (computationally extensive) analysis

Core Data System Zoomed-In: It's a very complex (and costly!) operational environment



Challenges: Market Data Platform



Provides access to raw files and heterogeneous DBs

MPP DBs serve as specialized "materialized views" of raw file data

Time-series friendly (TS file as a minimum processing unit?)

Provide file-level metadata and semantics for data navigation and quality control

A shared cluster hosting both raw files and DBs

Challenges: Bringing Data Together

The hard way:

```
SELECT Date, Exchange, Ticker, Price, Dividend
FROM tbl_ticks AS Ticks
JOIN (
        QUERY JSON:                                          //Query document-
                                                             // oriented DB
        SELECT db.dividends.find(
                { ticker: "MSFT" },                          //selection criteria
                {date:1, ticker:1, dividend:1}               //project document
                                                             //attributes as
                                                             columns
            ) AS Date, Ticker, Dividend

    ) AS Dividends ON Ticks.Date = Dividends.Date AND Ticks.Ticker = Dividend.Ticker
WHERE Ticks.Date = '6/25/13' AND Ticks.Exchange = 'NASDAQ' AND
Ticks.Ticker = 'MSFT'
```

The easy way:

```
analytics.correlate("SP500",'6/25/13',"1 second").top(10)"
```

Questions?

- Presented by Middle Lake Partners, LLC
- Boutique Big Data Technologies Advisory and Investment Firm
  - Enterprise Big Data Advisory Services:
    - Business Case Analysis
    - Strategy and roadmap
    - Architecture and design
    - Technology due diligence and selection
    - Implementation
  - Big Data Technology Investments

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