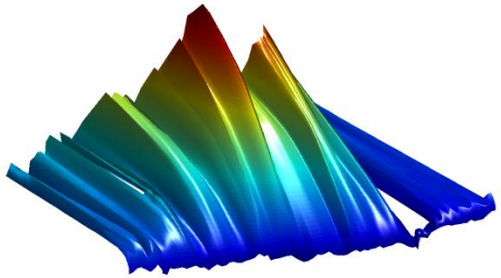
Delivering Financial Models from the Quantitative Analyst efficiently into a Financial Institutions Enterprise Applications/Systems



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Model Development Process Flow

1 Access and Explore Data

Files

Databases

Market Data

THOMSON REUTERS

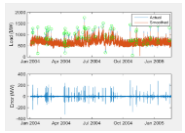
MONEY.NET

Bloomberg

Win.d

2 Preprocess Data

Working with Messy Data



Data Reduction/ Transformation

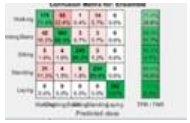
Feature Extraction

3 Develop Predictive Models

Model Creation e.g. Machine Learning

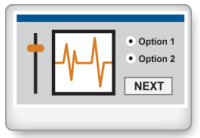
Parameter Optimization

Model Validation



4 Integrate with Production Systems

Desktop Apps



Enterprise Scale Systems

MATLAB Excel
.NET C/C++
.exe
Java .dll

Enterprise Systems

5 Visualize Results

3rd party dashboards

Spotfire® TIBCO Software

+ableau

Qlik

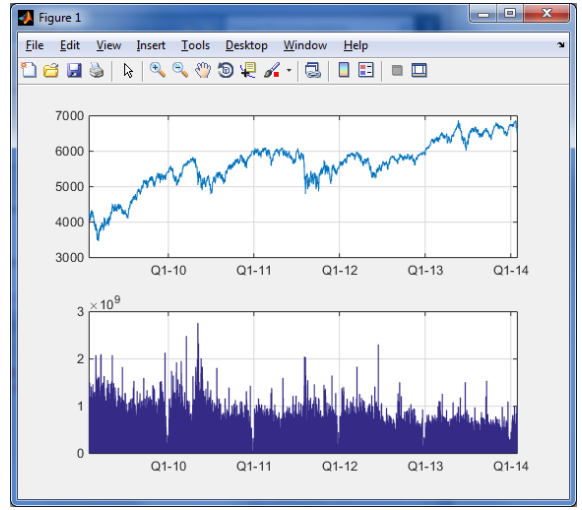
Power BI

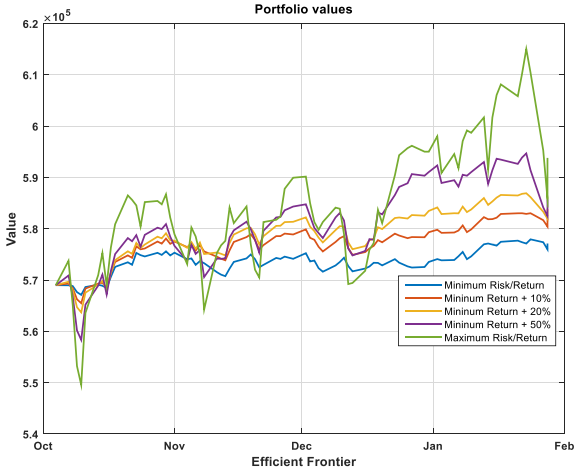
Web apps

Data connectivity (Datafeed and Trading)

R2015a - R2017b

- Interactive Brokers interface enhancements for custom event handlers and market depth, contract details, trade execution records, and portfolio data R2015a
- Bloomberg Data License support R2015a
- Ravenpack News Analytics Interface R2015b
- Bloomberg portfolio access R2015b
- FIX Flyer Integration R2015b
- FIX Data Support R2015b: Convert between structure arrays and tables to and from FIX messages
- Bloomberg multiple order routing functionality R2015b
- STATS.com R2016b
- money.net R2016b
- Transaction cost analysis R2016a, R2016b, R2017a
- Thomson Reuters Elektron R2017a
- Thomson Reuters Tick History/Datascope support R2018a
- Wind support R2018a





New Twitter API in Datafeed Toolbox

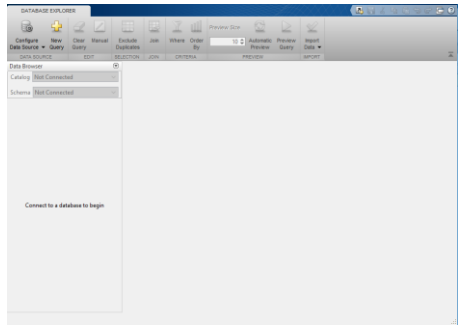
Historical Tweets and access to Twitter® REST API endpoints

- Search for Tweets by strings
- Retrieve historical Twitter data for sentiment analysis modeling
- Tweet programmatically

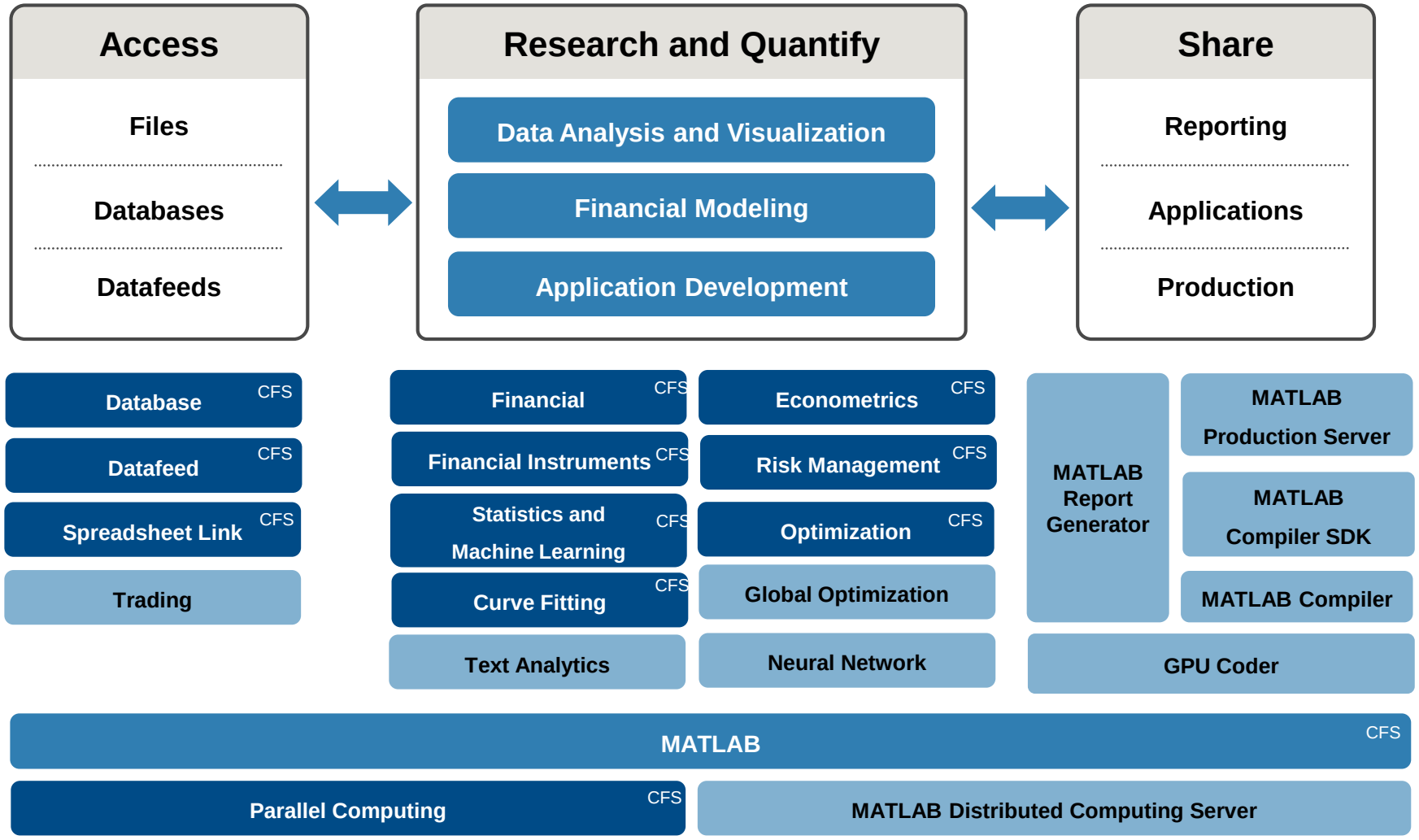
Database Toolbox R2016b - R2017b

Work easily with both structured and unstructured databases

- Retrieve graph data from Neo4j Graph Database R2016b
- Native-ODBC ready to replace JDBC-ODBC bridge R2017a
- MongoDB Support Package R2017b
- Redesigned Database Explorer App R2017b
- DatabaseDataStore & Tall Integration R2017b
- SQL Speaking methods R2018a
- Neo4j upgrade .. Write capability, support for multi-relational graphs R2018a



Develop MATLAB Algorithm/Model

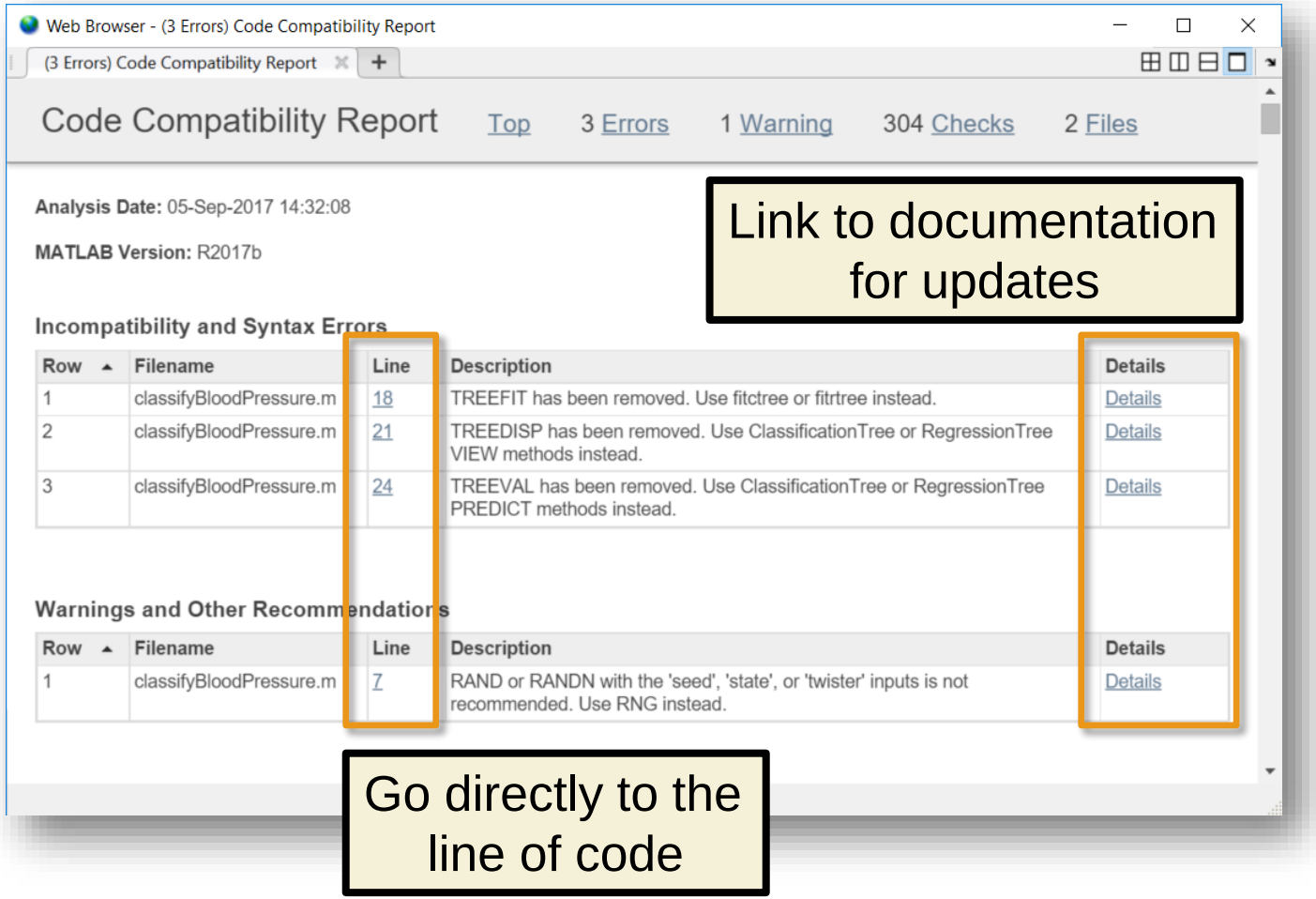


CFS = MATLAB Computational Finance Suite

Code Compatibility Report

R2017b

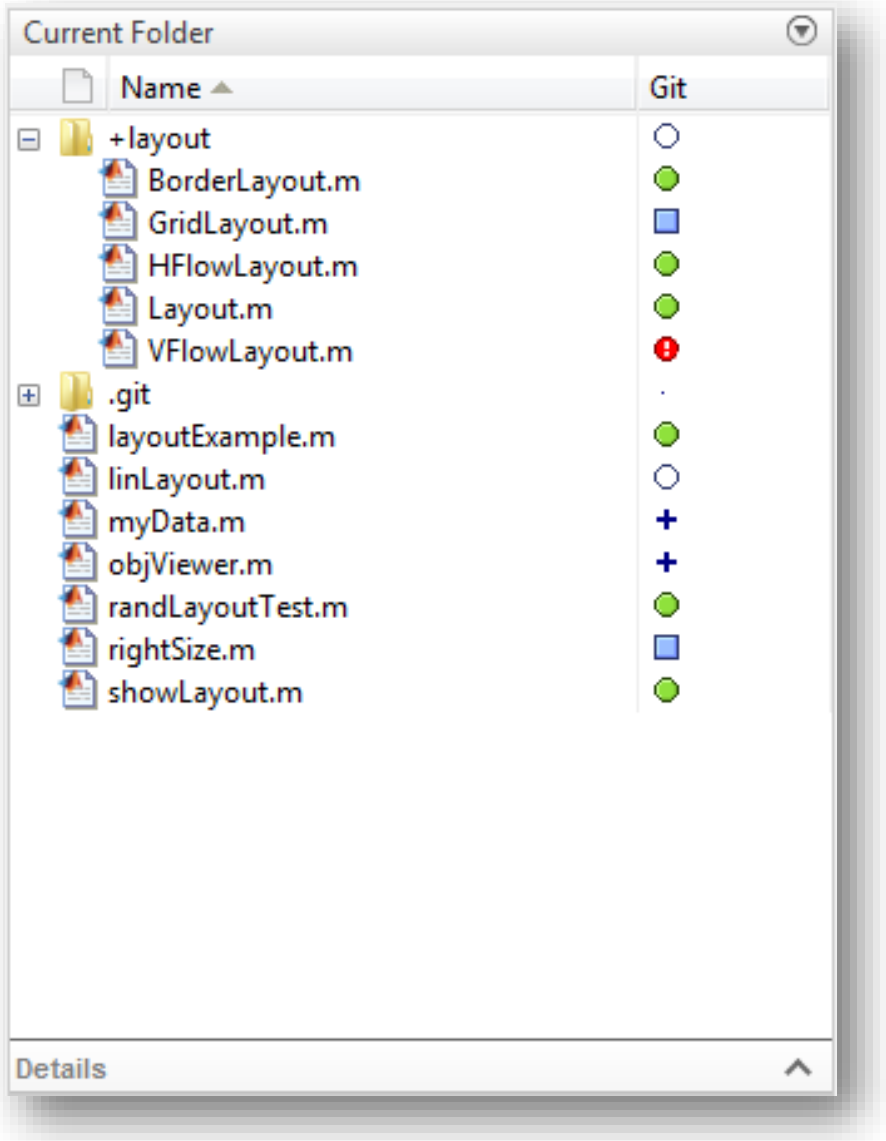
- Tool to help upgrade code to latest and greatest
- Identifies potential compatibility issues
- Hundreds of checks for incompatibilities, errors, and warnings
- More features coming!



Source Control Integration

R2014b

- Manage your code from within the MATLAB Desktop
- Leverage modern source control capabilities
  - GIT and Subversion integration in Current Folder browser
- Use Comparison Tool to view and merge changes between revisions

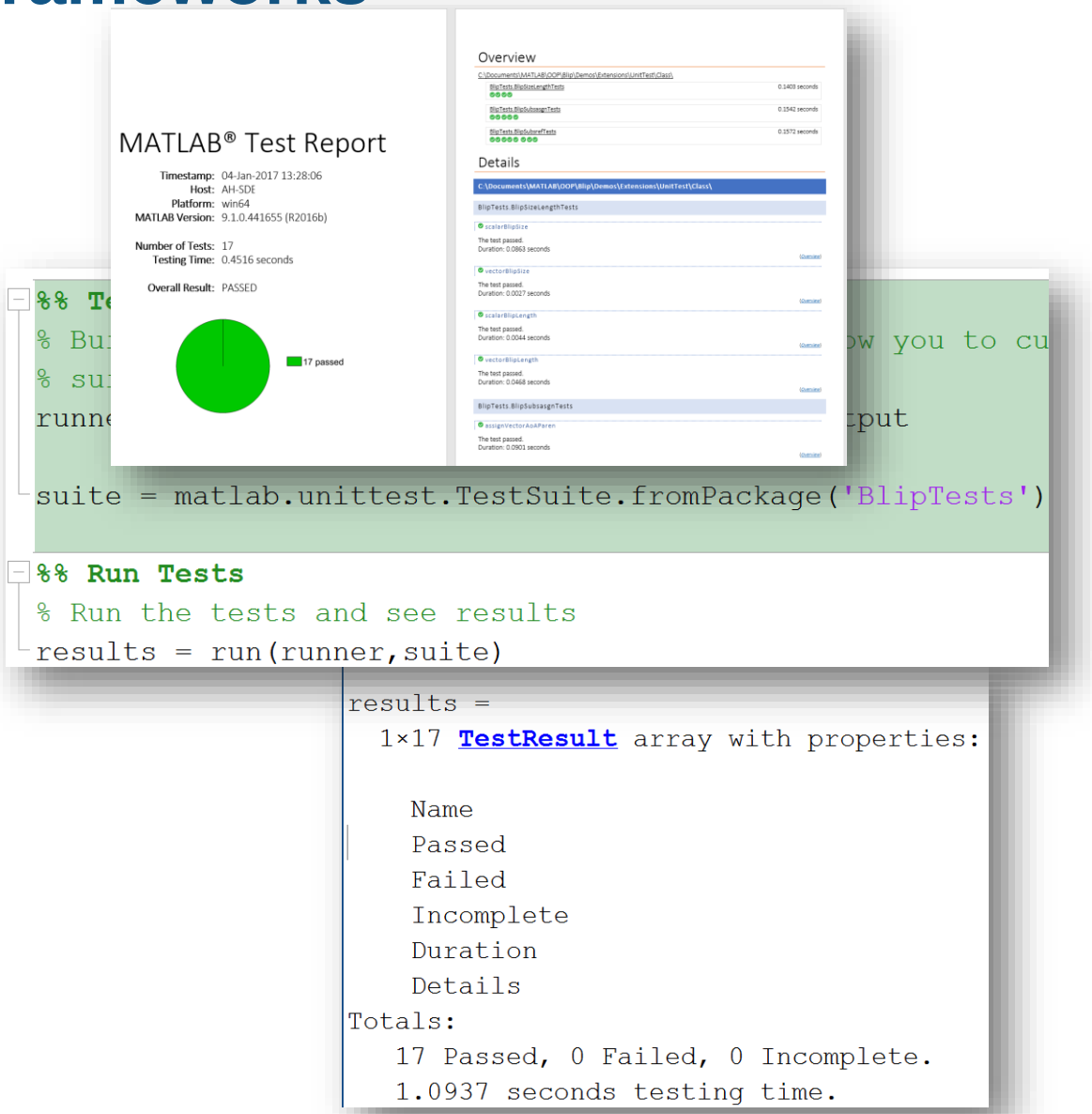


Test Frameworks

- MATLAB Unit Testing Framework
  - Test your code early and often
  - xUnit style framework
  - Script / function / class based testing
  - Works with continuous integration servers
  - Automatic reporting
  - Mocking framework
  - Capture screenshots

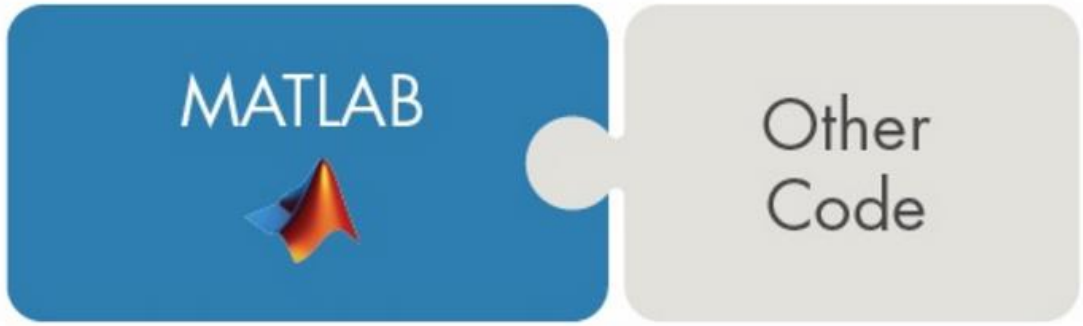
R2017a

- Performance Testing Framework
  - Time MATLAB code automatically
  - Track performance over time



External Interfaces

Calling Libraries Written in Another Language From MATLAB

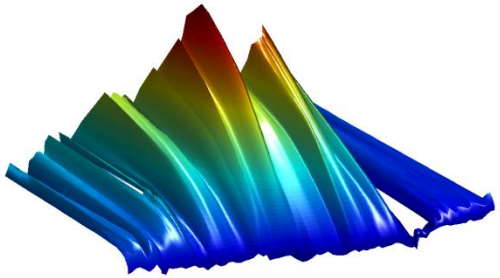


- Java
- Python R2014b
- C/C++
- Fortran
- COM components and ActiveX® controls
- RESTful, HTTP, and WSDL web services

Calling MATLAB from Another Language

- Java R2016b
- Python R2014b
- C/C++
  - Updated C++ API R2017b
- Fortran
- COM Automation server

Deployment of MATLAB Analytics/Models



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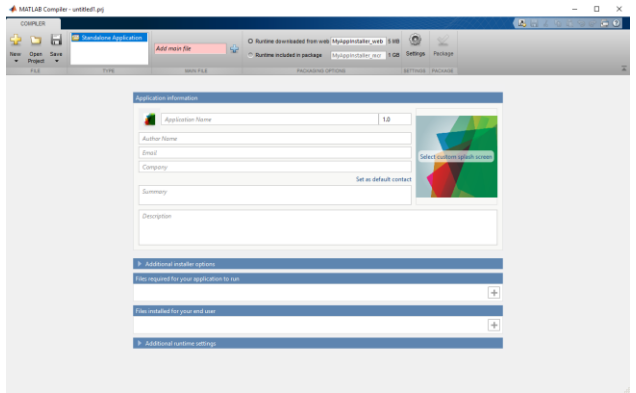
Application Deployment R2012b - R2017b

Strategic Direction --- ***MATLAB a Complete Development to Scalable Production Platform***

R2012b to R2014b



- Focus - Ease of deployment
  - Web Downloadable MCR's
  - New Deployment Project manager
    - Application Compiler
    - Library Compiler
    - MATLAB Production Server Components
- Hadoop support for deployed components
- New database driven depfun to deliver better compilation performance

R2015a

- New product packaging
- Compiler
- Compiler SDK

4 Integrate with Production Systems

Application Deployment R2012b - R2017b

- Strategic Direction --- ***MATLAB a Complete Development to Scalable Production Platform***

R2015b

- Python support
- MCR Numeric

R2016b

- Spark support for deployed components

- MATLAB Runtime installable through Big Data Automation Tools
  - Cloudera Manager R2017b
  - Apache Ambari R2018a
  - Azure HDInsight (Support package)

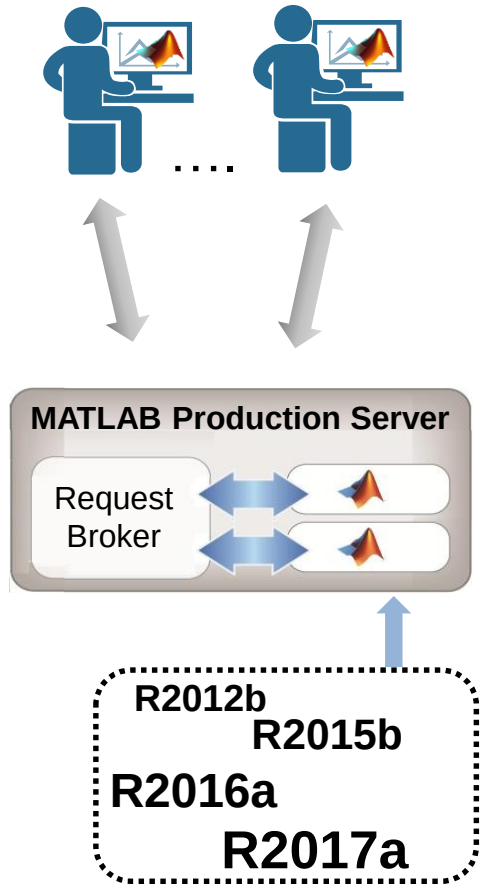
Application Deployment R2012b - R2017b

- Strategic **Direction --- *MATLAB a Complete Development to Scalable Production Platform***

- **R2012b** Release of MATLAB Production Server 1.0
  - JAVA and .NET Frameworks supported
  - Hosted compiled MATLAB components
  - MCR management for multiple releases from R2012b onwards
  - Scalable & Easy to configure and manage

- **R2013b** Release of Excel Builder incorporating server based xla's
  - Centrally managed MATLAB models
  - Lightweight Excel Add-in's
  - HTTPS support

- **R2014b**
  - Python Interface



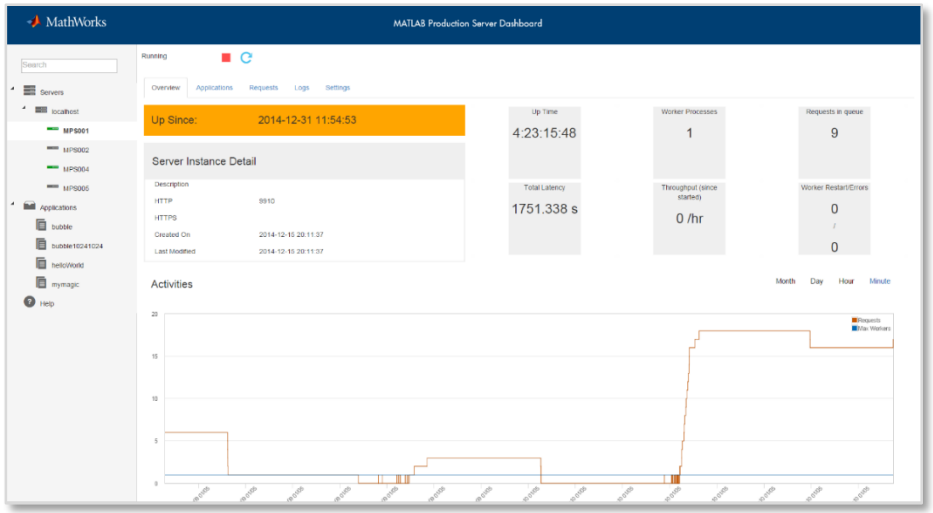
Application Deployment R2012b - R2017b

R2015a

- C client interface
- C++ client Interface
- Dev and Test support

R2016a

- JSON/Restful Interface
- Improved throughput and overall performance



R2016b

- Asynchronous JSON RESTful interface
- Static content and cross origin resource sharing (CORS)
- New simpler JSON representation of MATLAB Data
- Asynchronous Java client

R2017a

- MATLAB Production Server Management Dashboard

RESTful Discovery API R2018a

- Answers the question:
  - What functions are available and how do I call them?
- RESTful API for retrieving a list of archives & their functions
- HTTP GET operation returns a JSON object
  - http[s]://<host>:<port>/api/discovery
- Response contains function signatures for each discoverable function
  - Input & output parameter names
  - Type & size information
- Must opt-in
  - Discovery must be enabled in the server configuration
  - An archive must contain discovery information in order to be discoverable

R2018a MATLAB Production Server

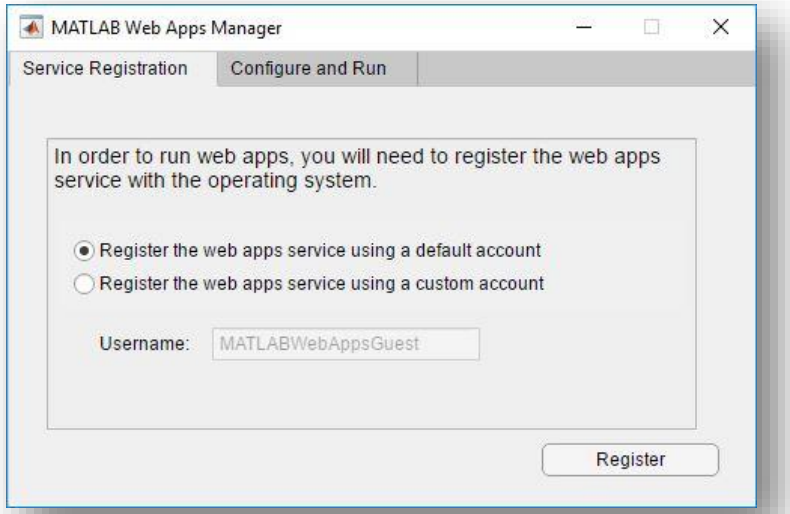
- RESTful API for service discovery
  - Using portion of functionSignatures.json schema
- mps.json.encode / mps.json.decode
  - Helper utilities for MPS's REST interface
- Java client side logging
  - Critical for debugging issues related to async interface

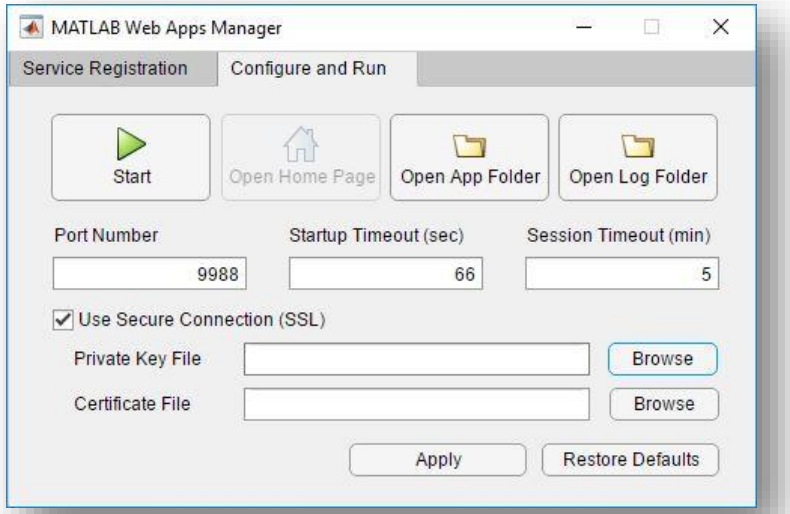
Application Deployment R2018a

- In R2018a, MATLAB Compiler will enable App Designer apps to be compiled into a MATLAB web app to be shared as a URL

- Involves 3 key pieces:
  1. MATLAB Web App Server
  2. Share and Package Workflow
  3. Discovery Page

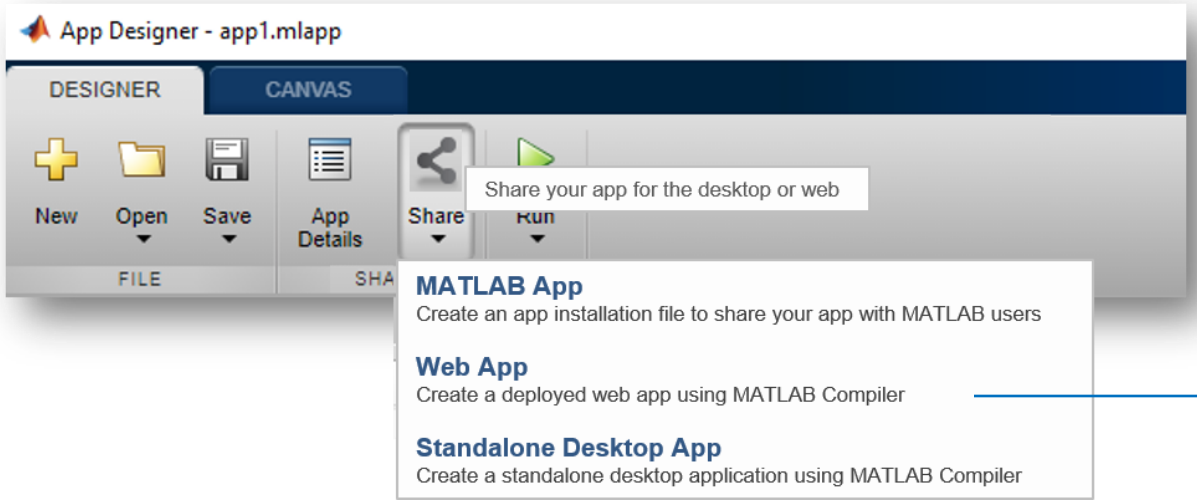
R2018a MATLAB Web Apps Server: IT Admin (or App Author)

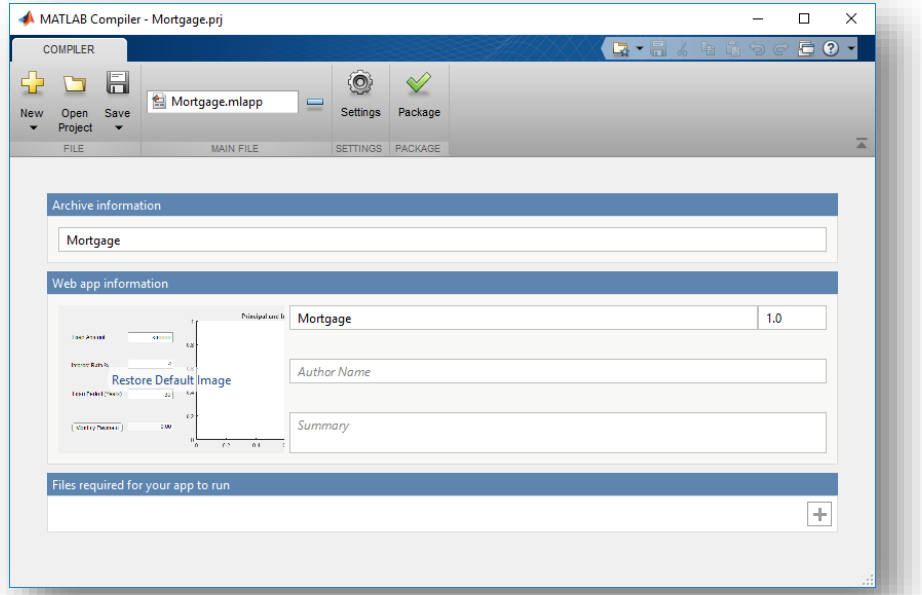




- EXE installer for a MATLAB Web App Server is provided as part of MATLAB Compiler
- UI provided to set up and configure the server on a machine of the user's choosing
  - May create and set up a new, low-privileged user account on the machine
  - Creates an **app folder** where deployed web app files will live
  - Creates a home **discovery web page** for end users to access available web apps

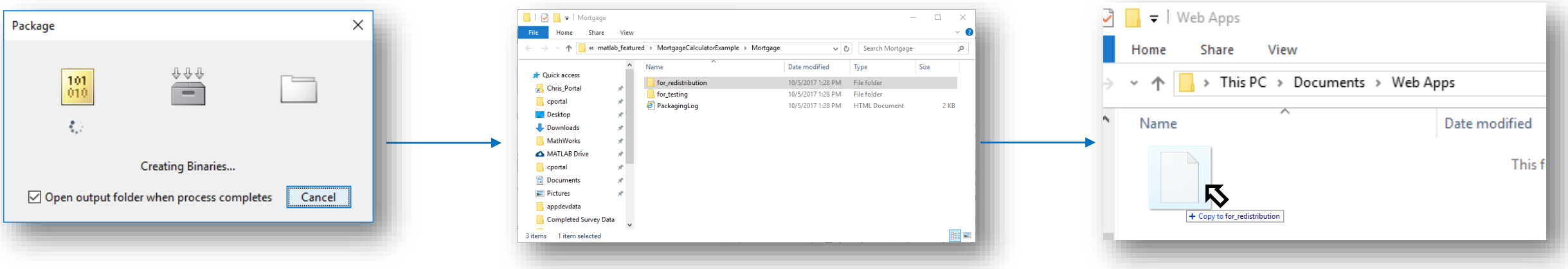
R2018a Share and Package Workflow: App Author





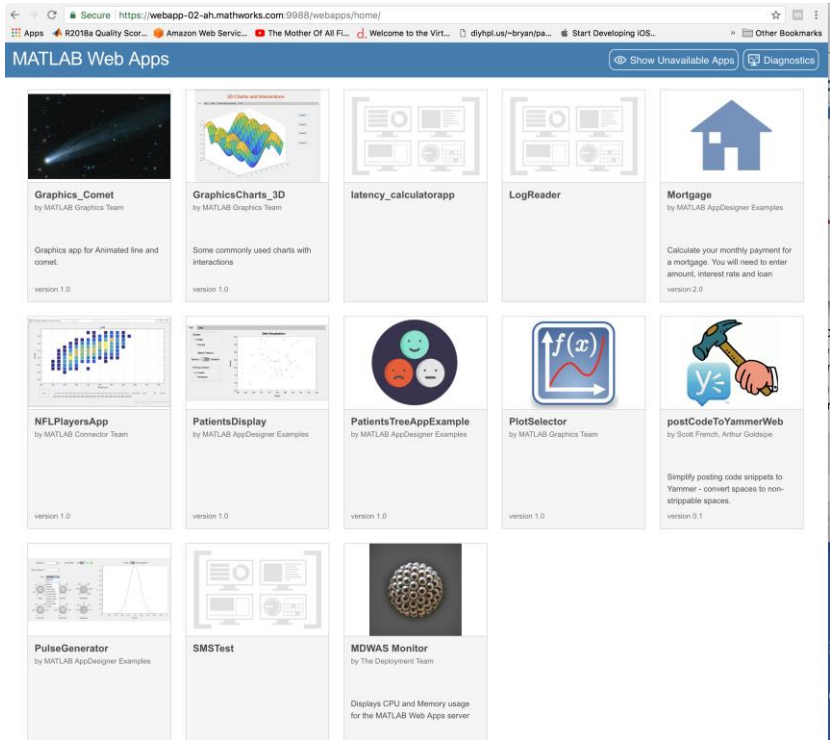
- App Designer desktop offers a Web App share option
  - Enabled if MATLAB Compiler is installed
- Option launches MATLAB Compiler's deploytool UI

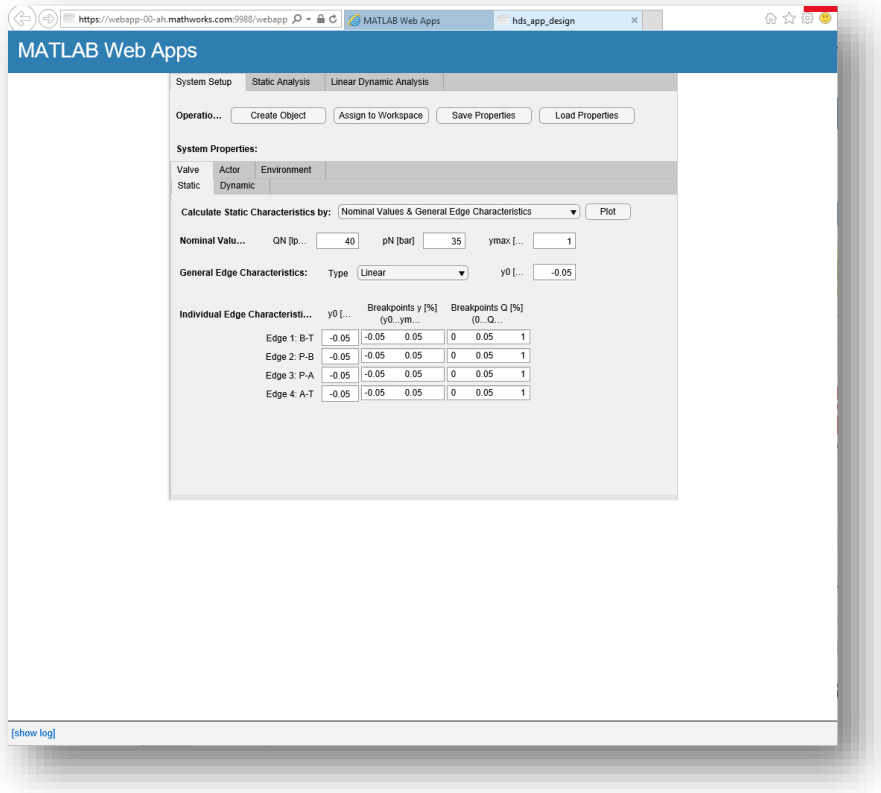
R2018a Share and Package Workflow: App Author



- Packaging step creates web app artifacts
- These need to be manually copied to the server's "app folder"

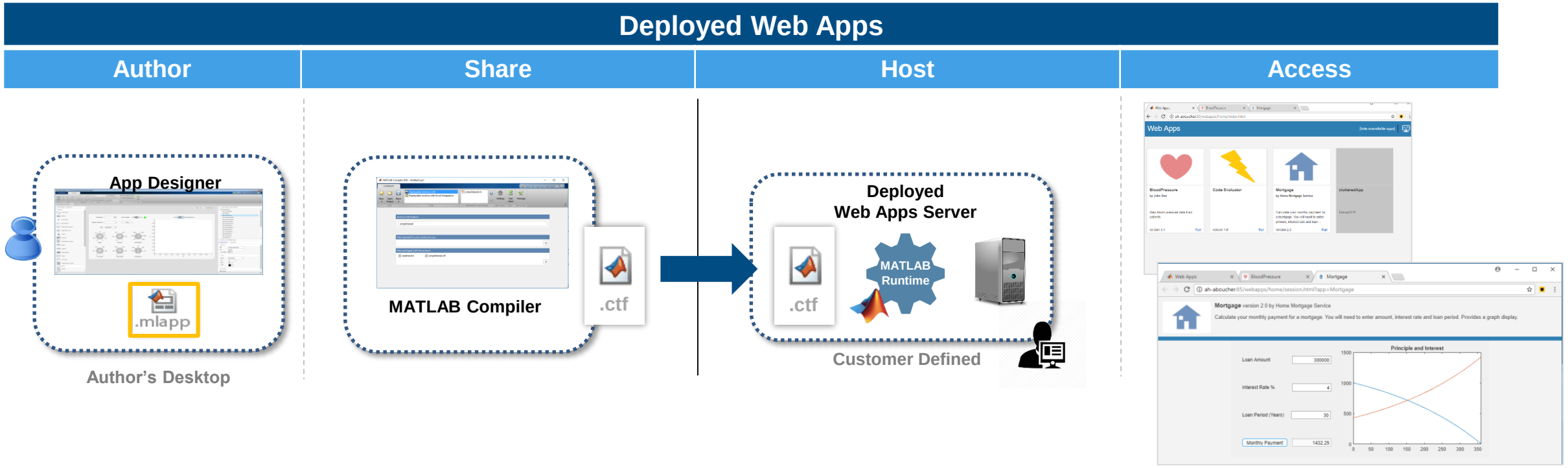
R2018a Discovery Page: App Consumer





- A web page used to discover and launch any available web app
  - The URL for this page is what would get shared with any app consumer
  - Accessible from any machine that is part of the same network the MATLAB web app server is on
- Apps are launched in a new browser tab
  - Each app tab represents a unique instance of the app

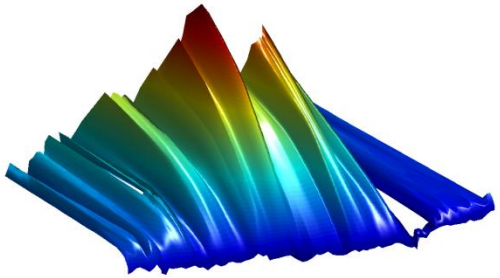
Small Scale Deployment of Web Apps



Deployed Web Apps

– Deploy App Designer-built Web Apps to a small workgroup on an internal intranet

Scaling into the Enterprise



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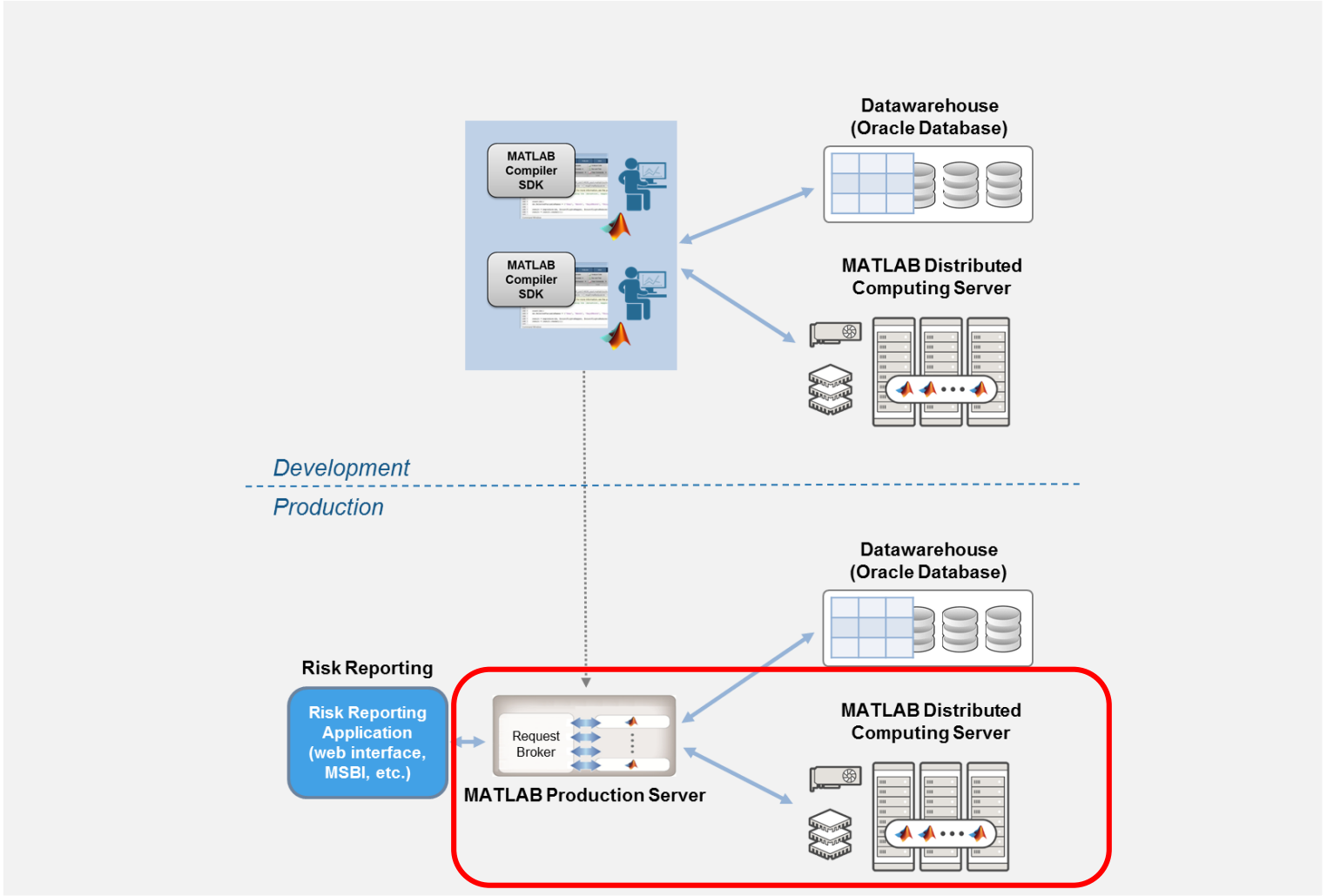
4

Integrate with Production Systems

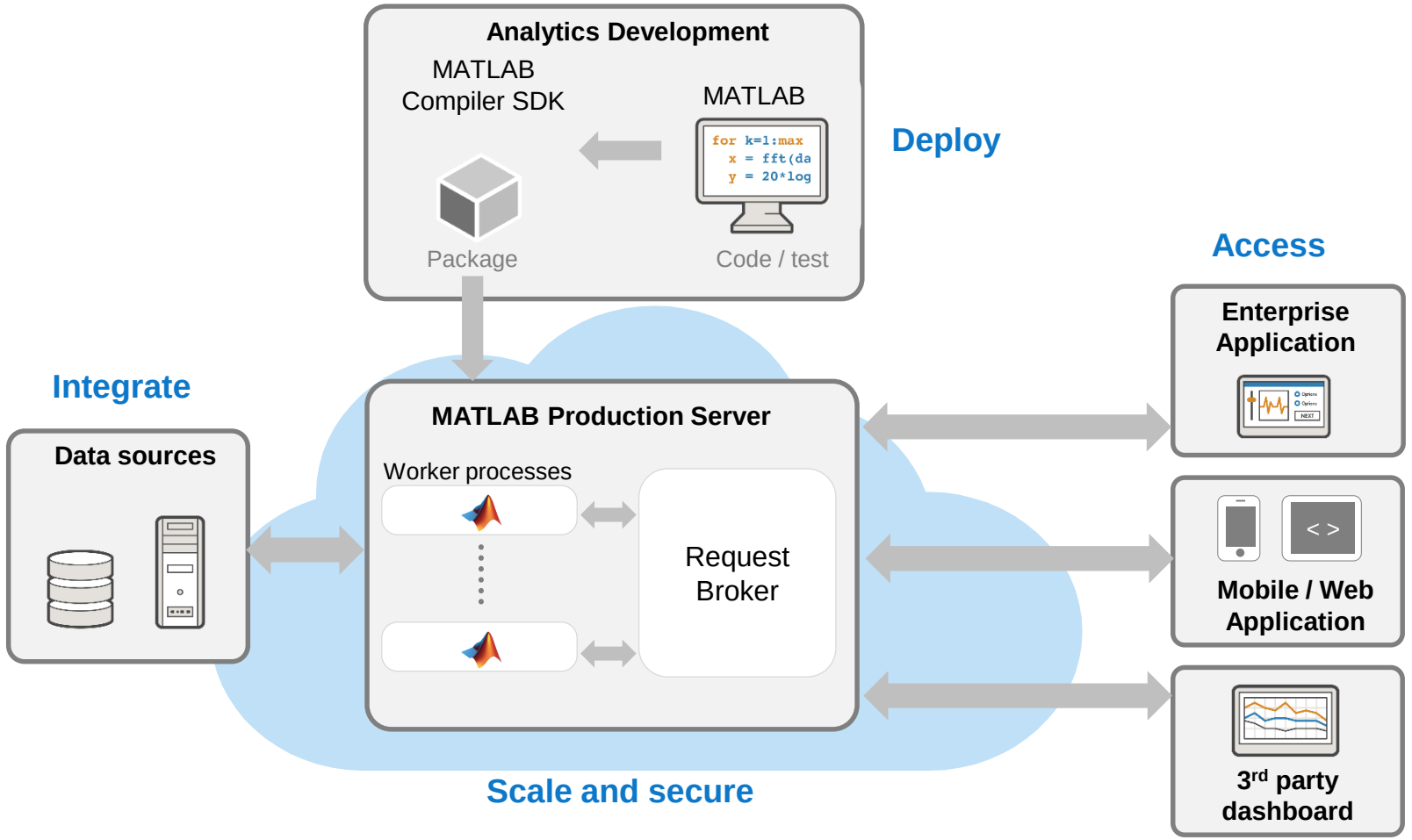
Production scaling with MATLAB Production Server and MDCS Technology Stack



4

Integrate with Production Systems

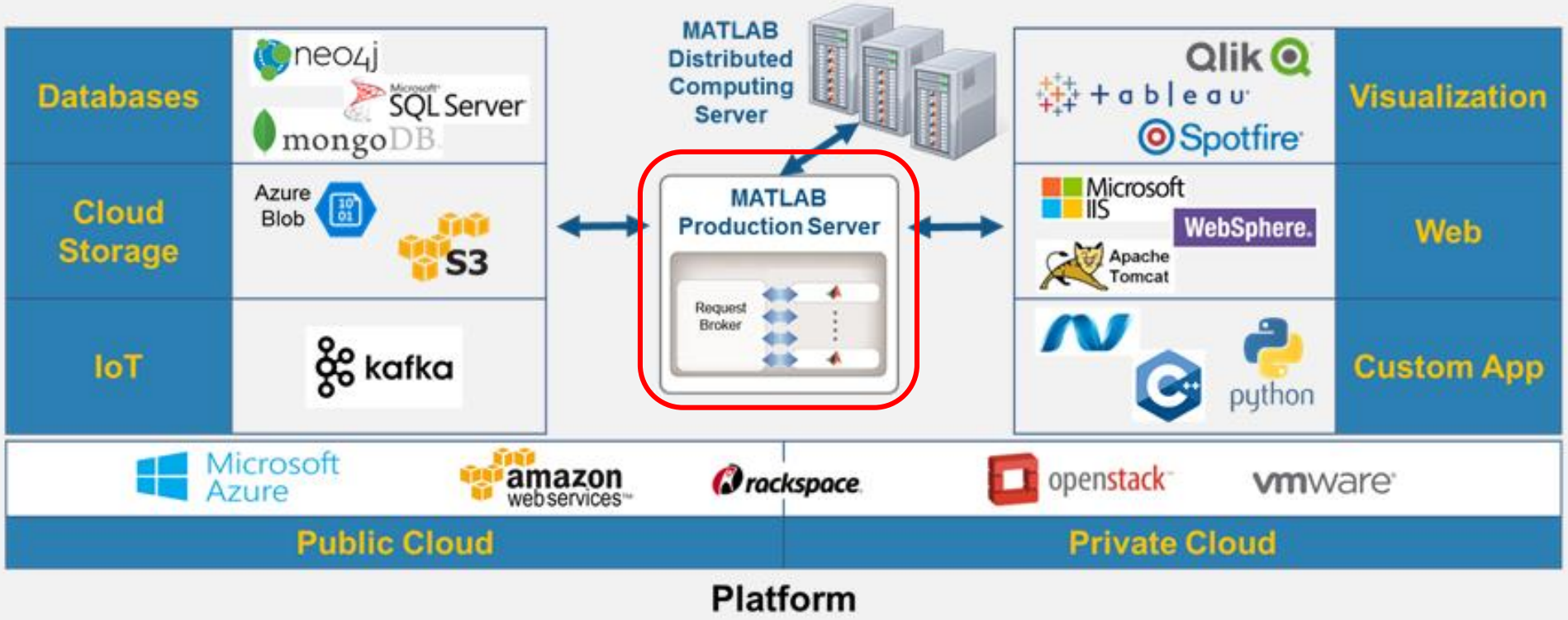
Deploy your MATLAB model as a reliable and scalable service with MATLAB Production Server



4 Integrate with Production Systems

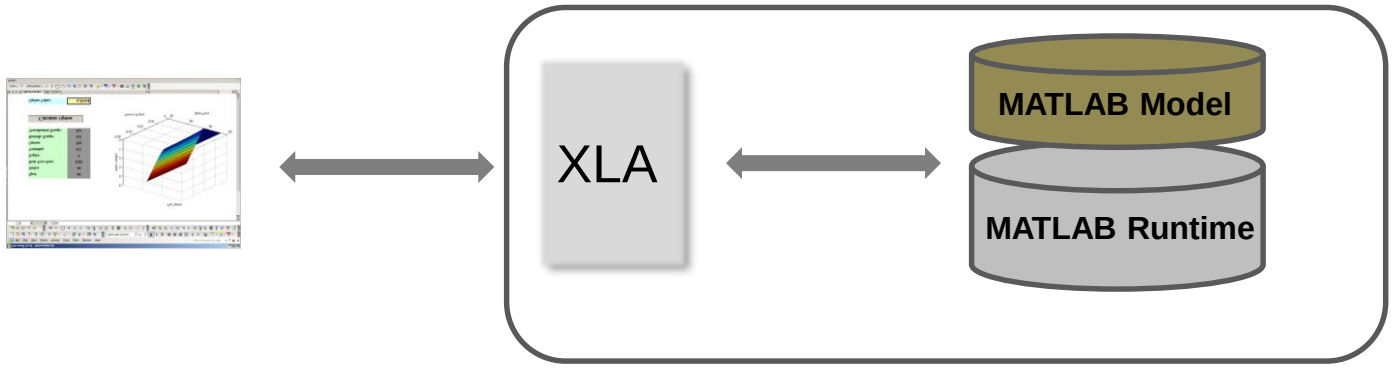
MATLAB Production Server Integrates With 3rd- Party Enterprise Systems

5 Visualize Results



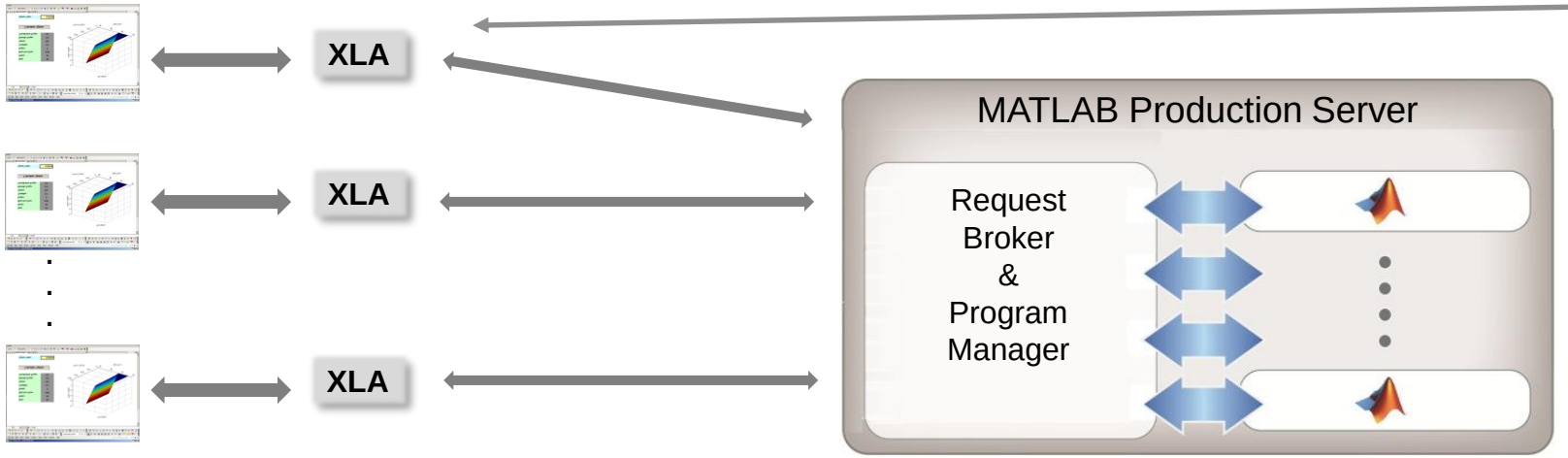
MATLAB Data Analytics embedded as Excel Add-ins

- Desktop Excel Add-ins with compiler



Generated by MATLAB Compiler

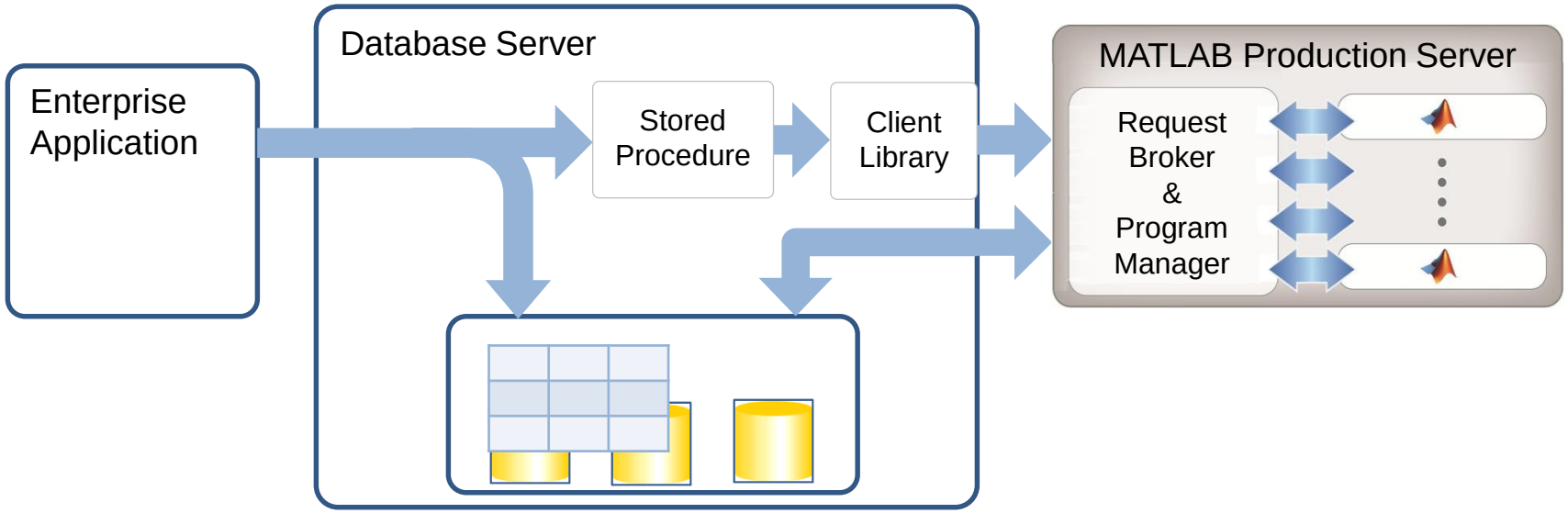
- Server based Excel Add-ins with Compiler SDK



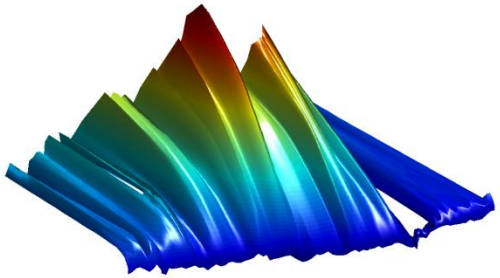
Generated by MATLAB Compiler SDK

Integration with Databases

- Optimize numerical processing within databases
  - Request MATLAB analytics directly from database servers(JSON/Restful)
  - Trigger requests based upon database transactions
- Minimize data handling using Database Toolbox



Customer Use Cases



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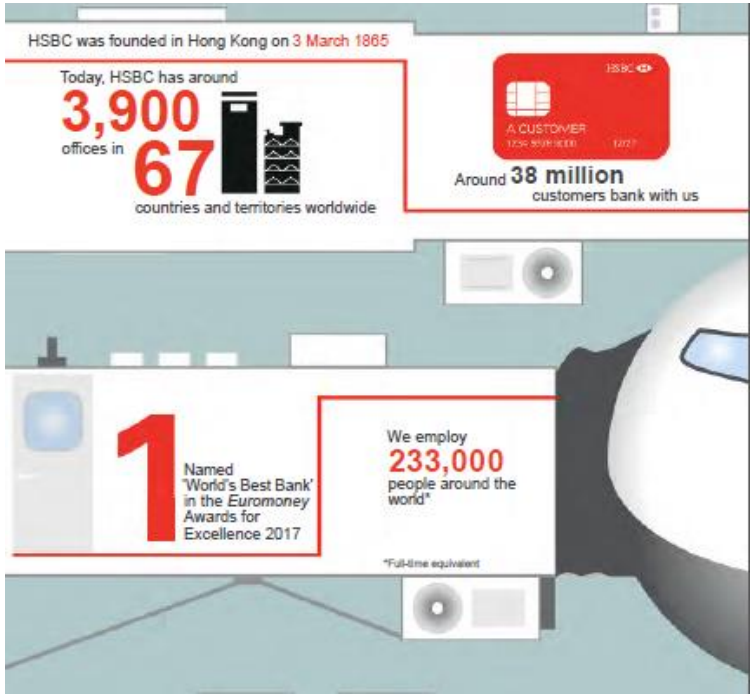
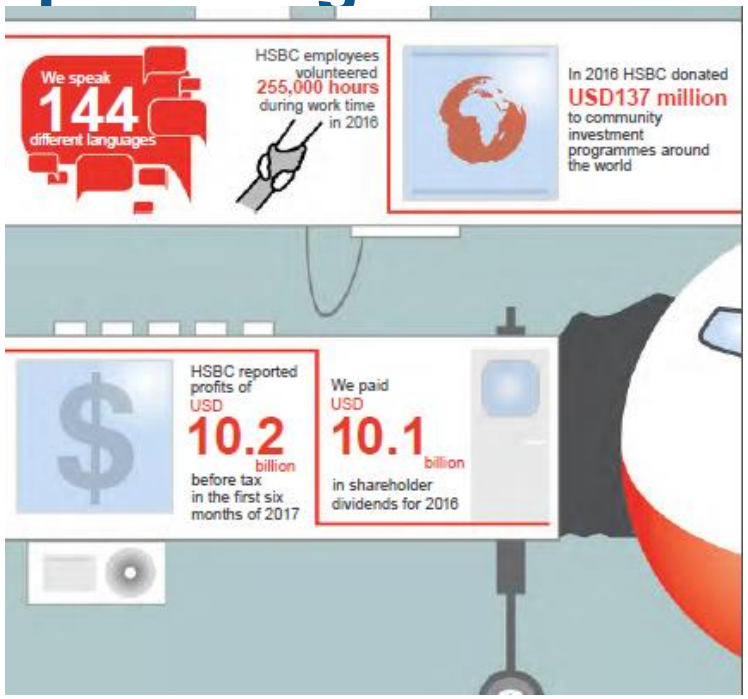
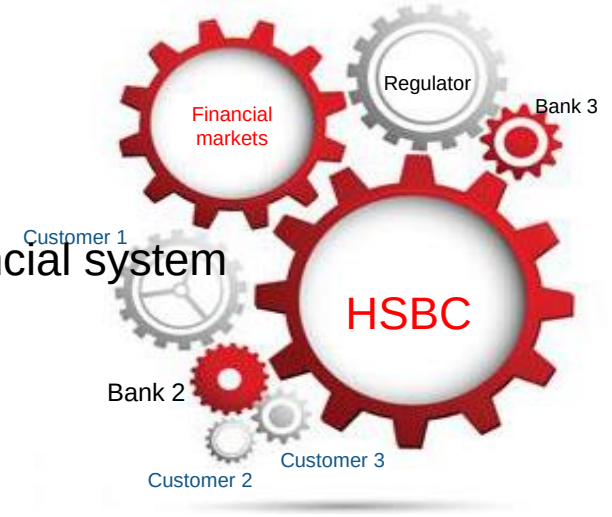
HSBC – today

One of the world's most important global financial





HSBC is a market participant within the wider financial system

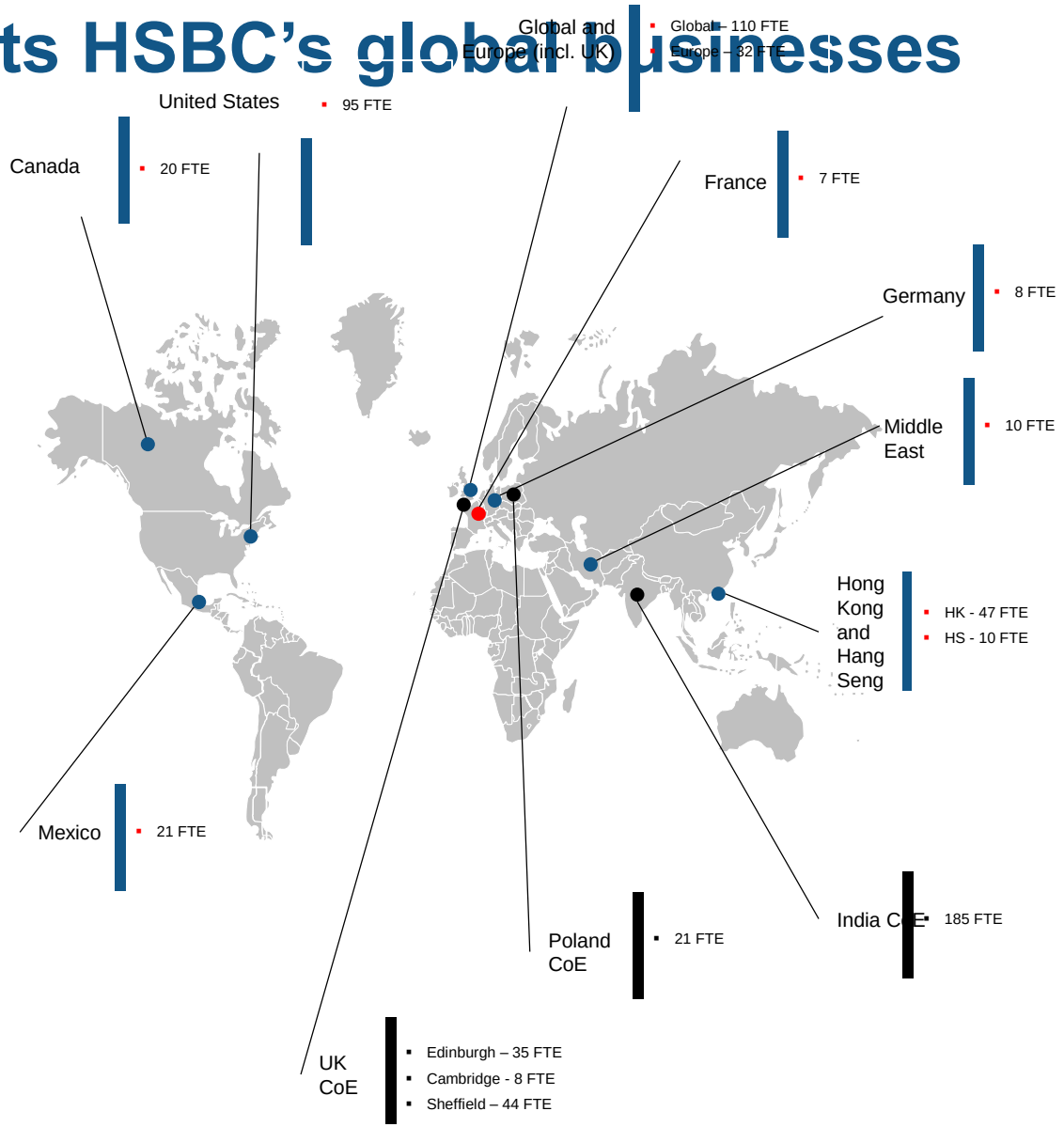


Global Risk Analytics

Our global function supports HSBC's global businesses

- Global team, with 650+ resources in 4 regions
- Global standards, driving consistency
- Strong incentive for staff mobility

Just as HSBC is a global business, GRA is a global function, with 650+ staff in offices across 17 cities in 10 countries. We provide support to all of the 67 countries and territories in which HSBC operates.



Global Risk Analytics

Sharing best practice and driving Risk Analytics innovation at HSBC

Risk exists in client relationships, our product offering, the markets we participate in and resulting transactions. These risks need to be identified, then measured, monitored and managed within the bank's appetite and tolerance.

What is our Purpose?

- Provide cutting-edge tools to help manage risk and ensure compliance with both our internal policies and the requirements of our regulators.

Our Objectives are simple

- We build and manage solutions (models) to meet business & client needs, and provide end-to-end management of the models' lifecycle, ensuring governance, control and appropriate usage.

Model Risk Management Framework

HSBC's Model Risk Management Framework underpins everything GRA do. It ensures appropriate model risk management policies and governance framework exist; that models are developed and implemented robustly and appropriately; and that those models undergo appropriate validation and independent reviews pre and post implementation.

Notes

1 - Understand the reasons behind the creation of a model and the expectations for how the model output will be used

2 - Model is logical, developed robustly and appropriately for its intended purpose and is consistent with global standards.

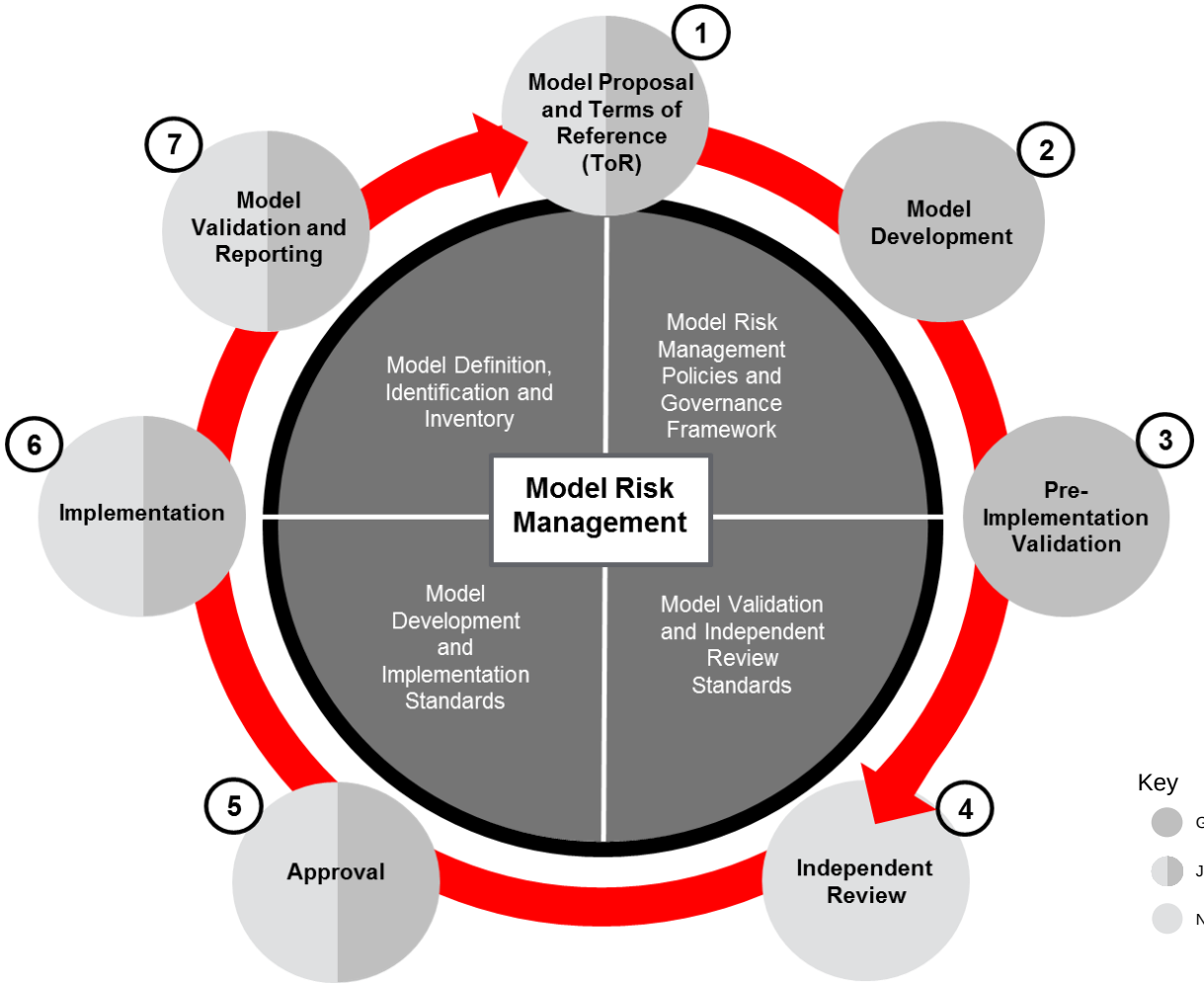
3 - FLOD control to ensure model is conceptually sound, data used is appropriate and results meet intended purpose

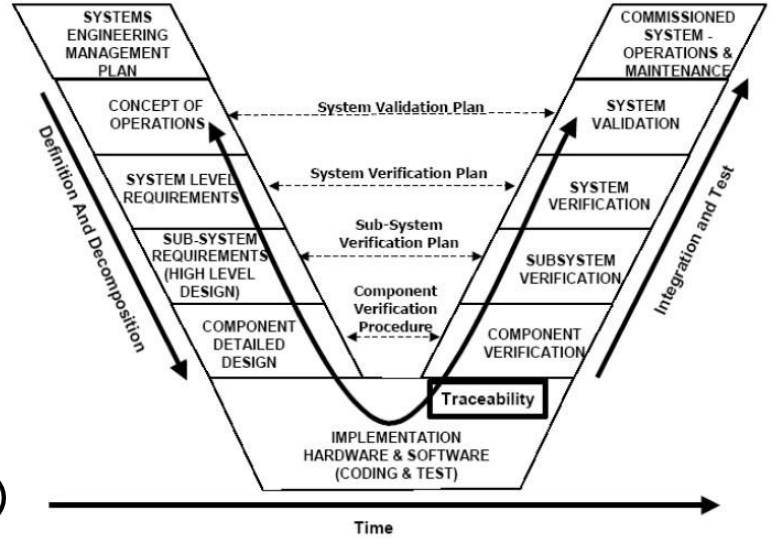
4 - SLOD control where key models undergo an independent review to provide credible challenge and additional assurance to management, helping to identify limitations prior to model's use.

5 - Model has received appropriate approval from the relevant authority or accountable individual(s) before use or implementation of the model

6 - Model has been implemented as per its original design and purpose and that appropriate testing have been performed before implementation

7 - Model is performing satisfactorily and being used as per its original design and purpose. This includes a number of activities including first line monitoring and validation, and independent validation and review



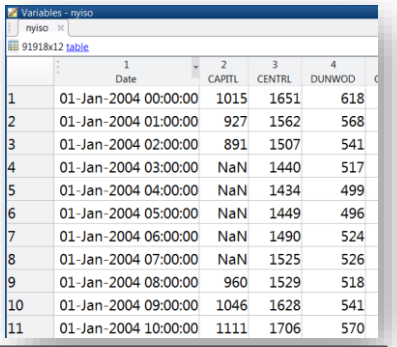


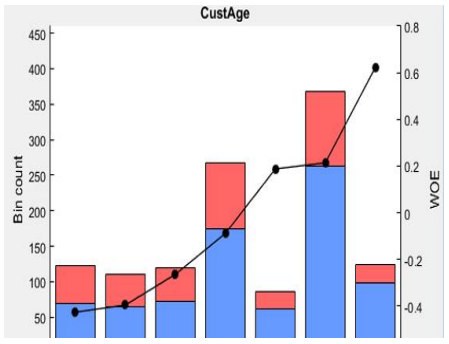
Compared to the Model Based Design V Diagram…

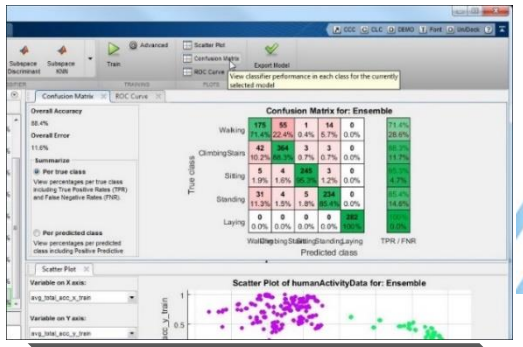
Key

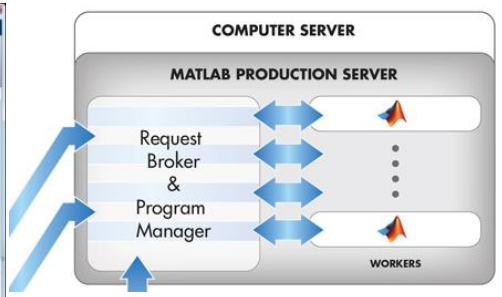
- GRA responsibility
- Joint GRA responsibility
- Non GRA responsibility

Model Development Workflow









Access and Explore Data → Process Data and Create Feature → Build and Validate Models → Deploy Model Review Model

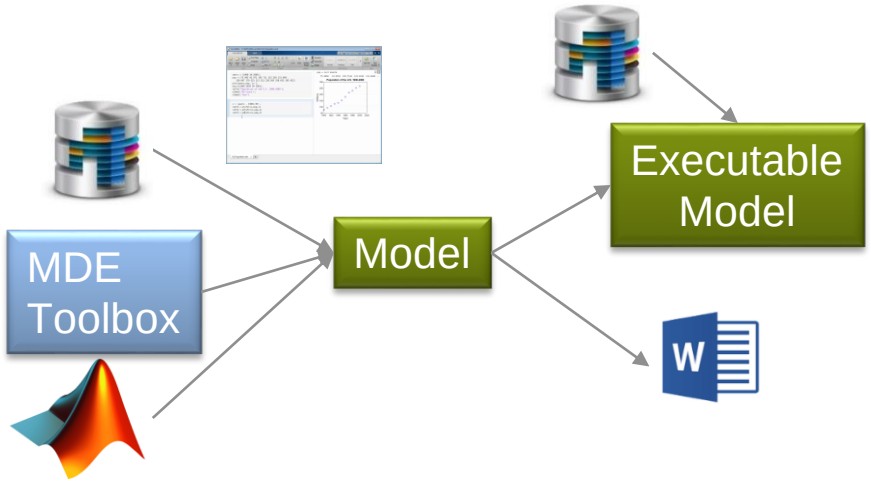
- Today, more time spent processing data than building models.
- Automation: finding data, generating reports, recoding models
- High cost of incorrect data assumptions causing models to be rejected by regulator.
- Need to iterate rapidly.

Model Development Environment (MDE)

Mission: *Improve the pace, transparency and reproducibility of the model development and review processes through user-friendly tools that encourage a consistent approach.*

What are the pain points?

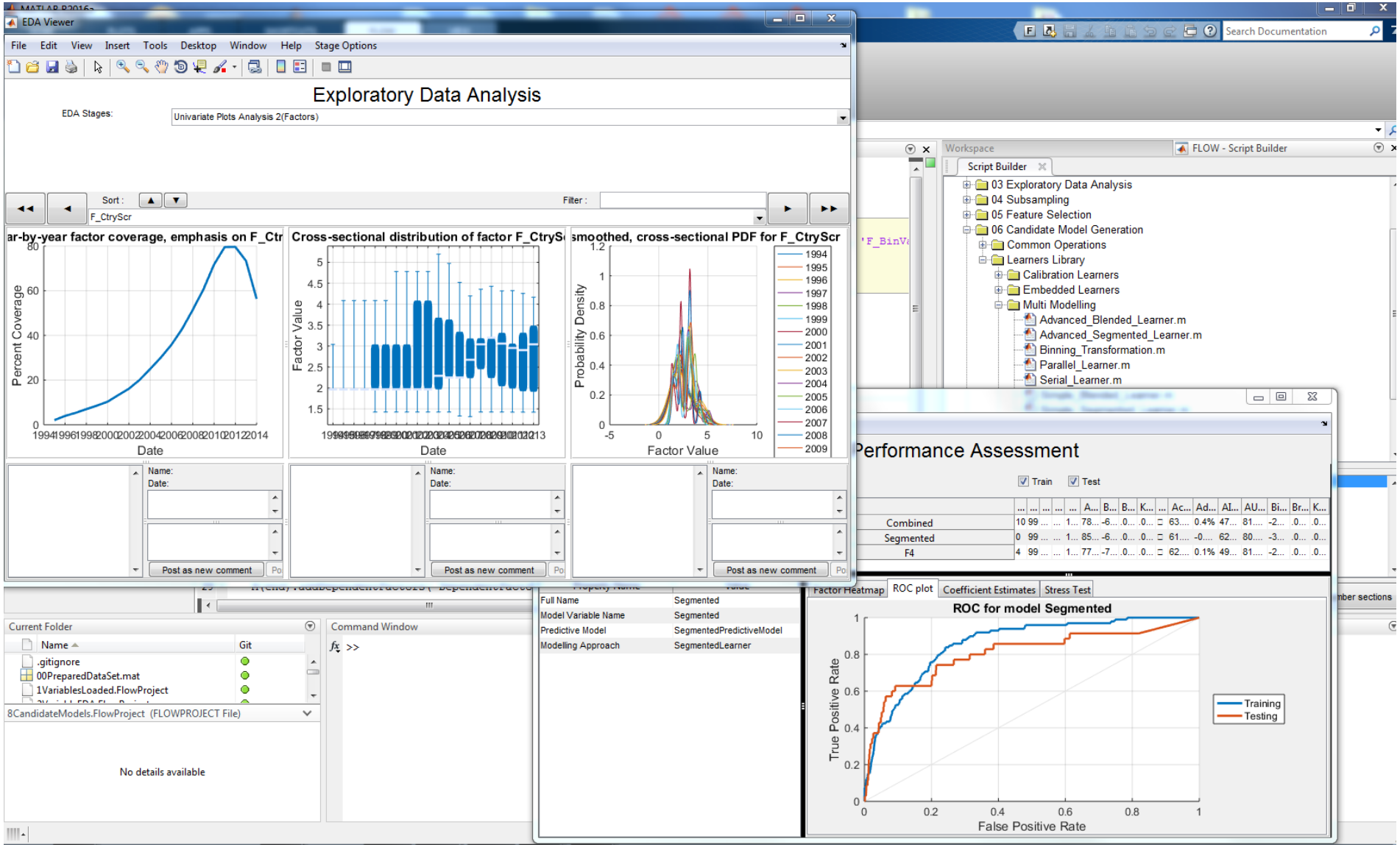
- Pace of building and reviewing models
- Ability to reproduce results
- Consistency of modeling approaches



What is the solution?

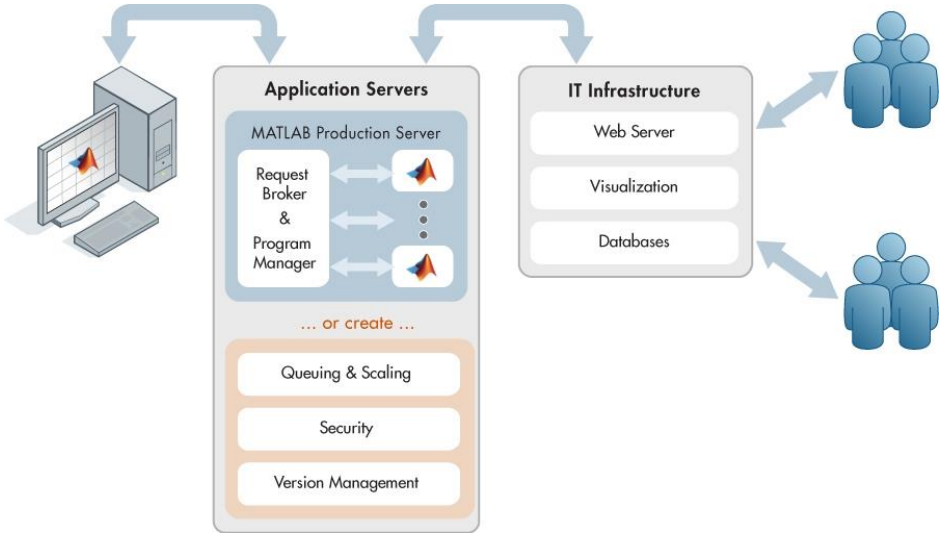
- MATLAB toolbox for risk modelling at HSBC
- Functions, apps, demos, and documentation
- Supports all stages of the workflow
- Leverages MATLAB toolboxes
- Target users: risk modellers and analysts
- Aims: improve pace, transparency, accuracy, reproducibility, consistency

Model Development Environment (MDE)

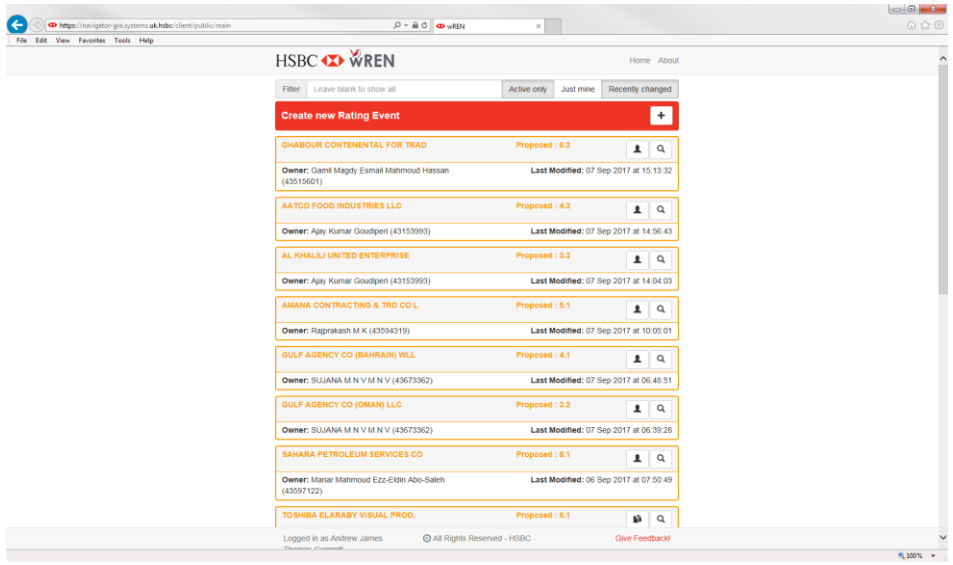


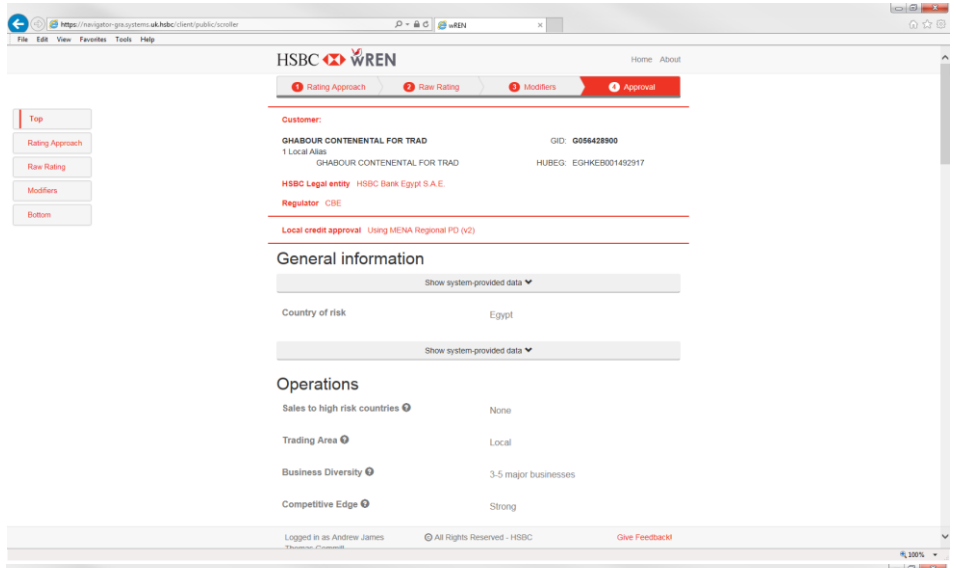
Model Execution Environment (MEE/wREN)

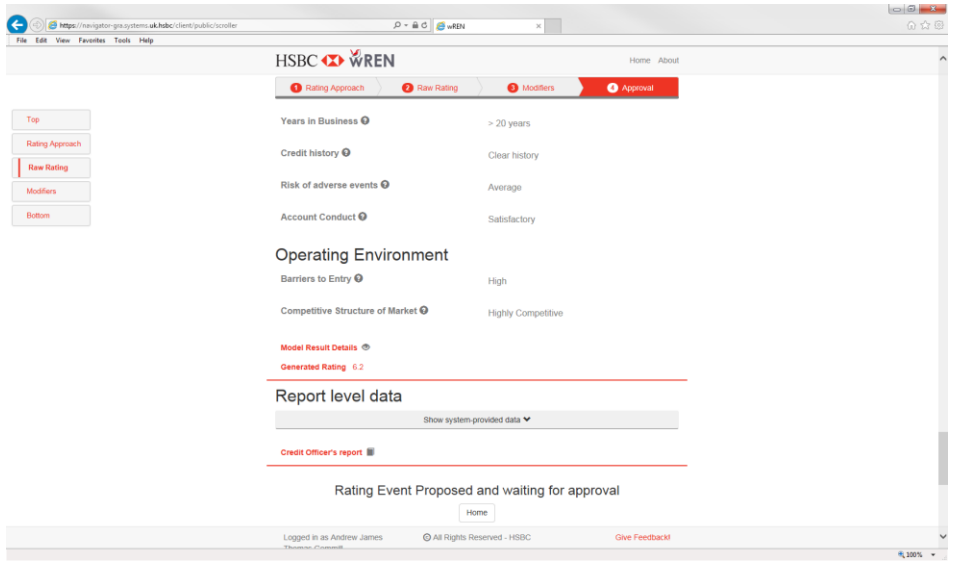
- Includes MATLAB Production Server in HSBC's production environment
- APIS and conventions for calling models
- Infrastructure to connect directly to production data sources
- Runs legacy models and models built using MDE

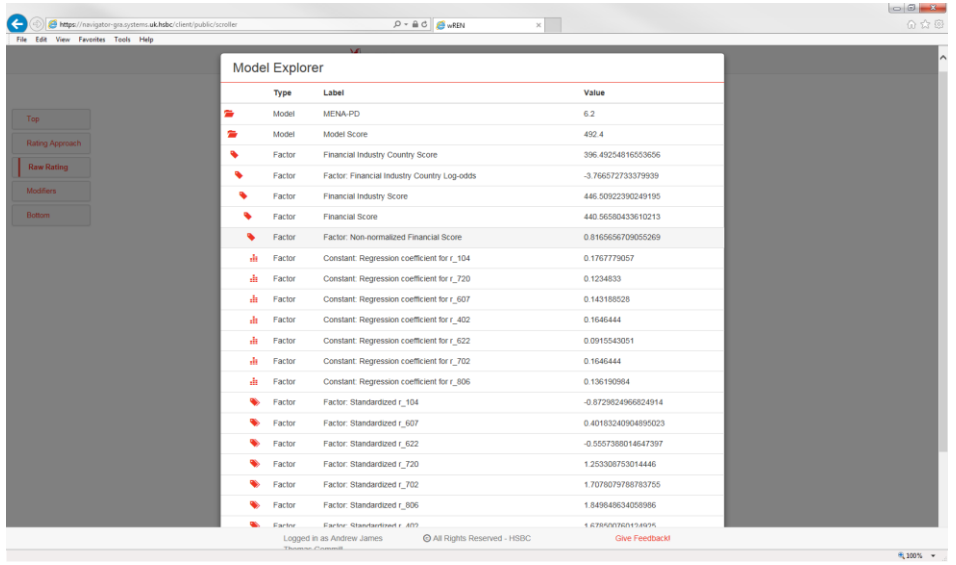


Model Execution Environment (MEE/wREN)







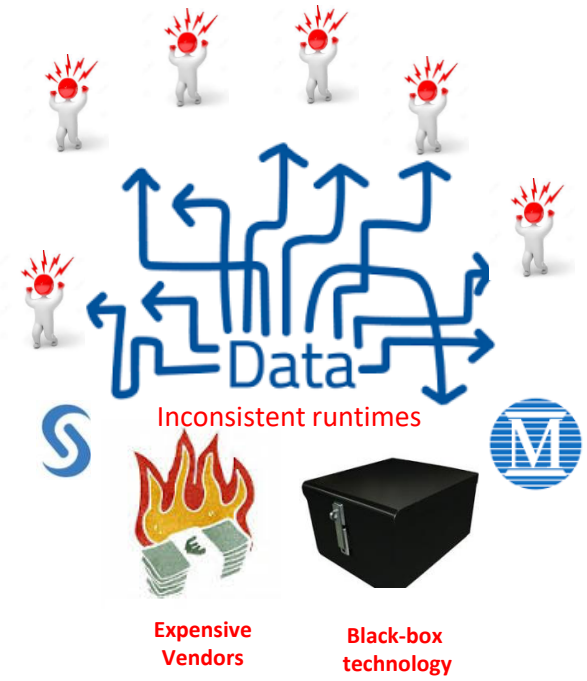


GRA in a SLIDE

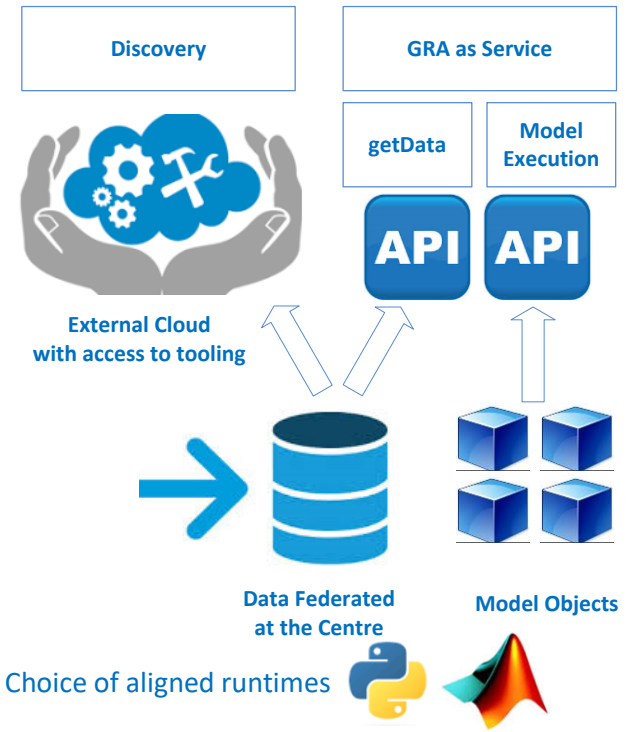
FROM THIS

TO THIS

Poor Quality Models
Regulatory Scrutiny
High Cost
Inconsistency
Frustrated Users



SDLC Vendor Driven



Reduced Cycle Time
Access to Tooling
Freedom to Analyse
Consistency
Lineage & Tractability
Low Cost

Agile/DevOps Focused

Rabobank Retail & Private Banking

- € 40 Billion Assets Under Management
- 3 Quantitative Researchers (CFA or PhD)
- Develops (quantitative) models to serve clients' needs
  - Forecasting models (Goal Monitor)
  - Risk models (Value-at-Risk)

Rabobank needs Goal Monitor to serve clients!

- Questions of clients arise, when they come for advice regarding their financial situation:
  - What can I expect after 20 years of investing?
  - What is the (downside) risk of my portfolio over time?
  - What is the chance that I support my children to university?

- As financial markets are unpredictable, Rabobank does need to provide insights though.
- We simulate the dynamics of the financial markets with Goal Monitor!

Observations & Questions…

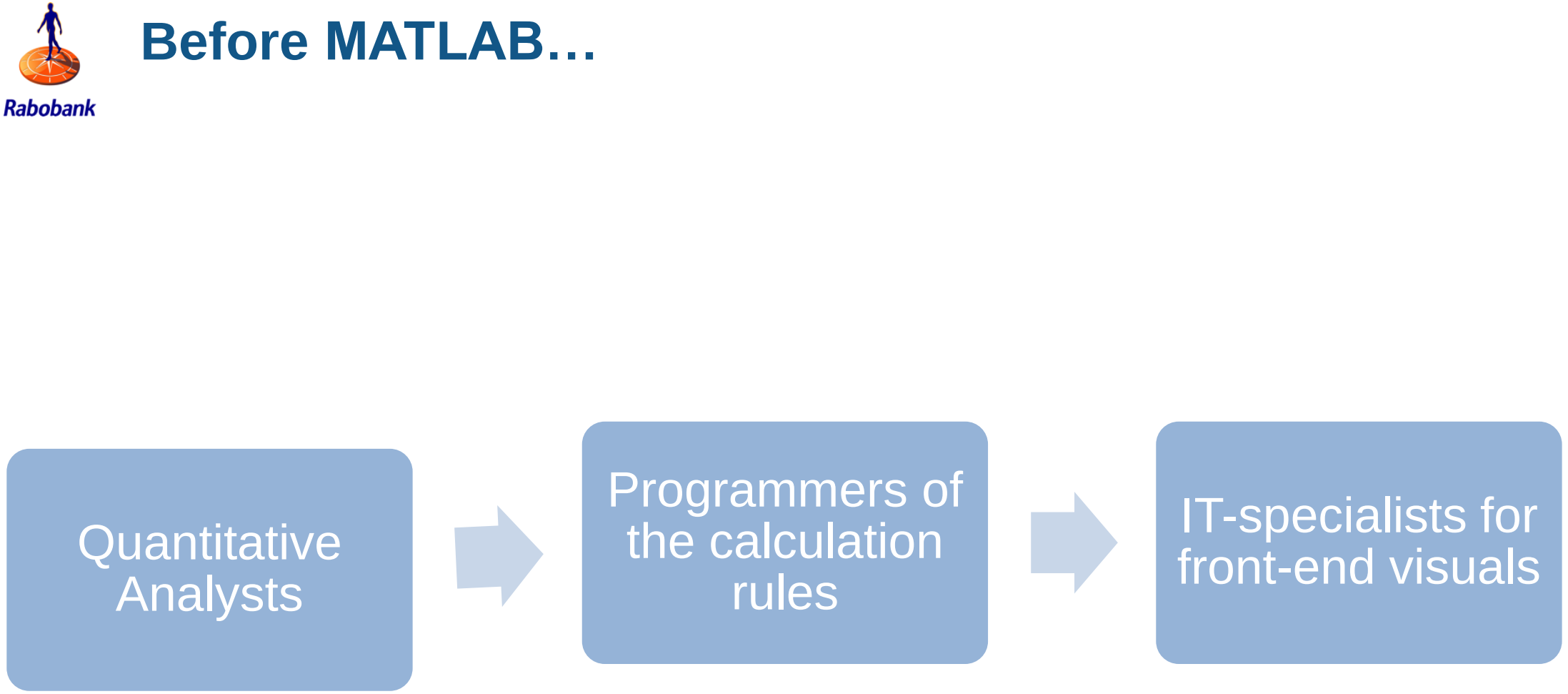
- **Yearly € 2 million** for an external system
- But…other parties also buy the same system for their clients
- But…we don't have any suitable software

- Is it really that hard to build internally??!!
- Do we have the expertise to build internally though?
- Which software would be the best for Rabobank?

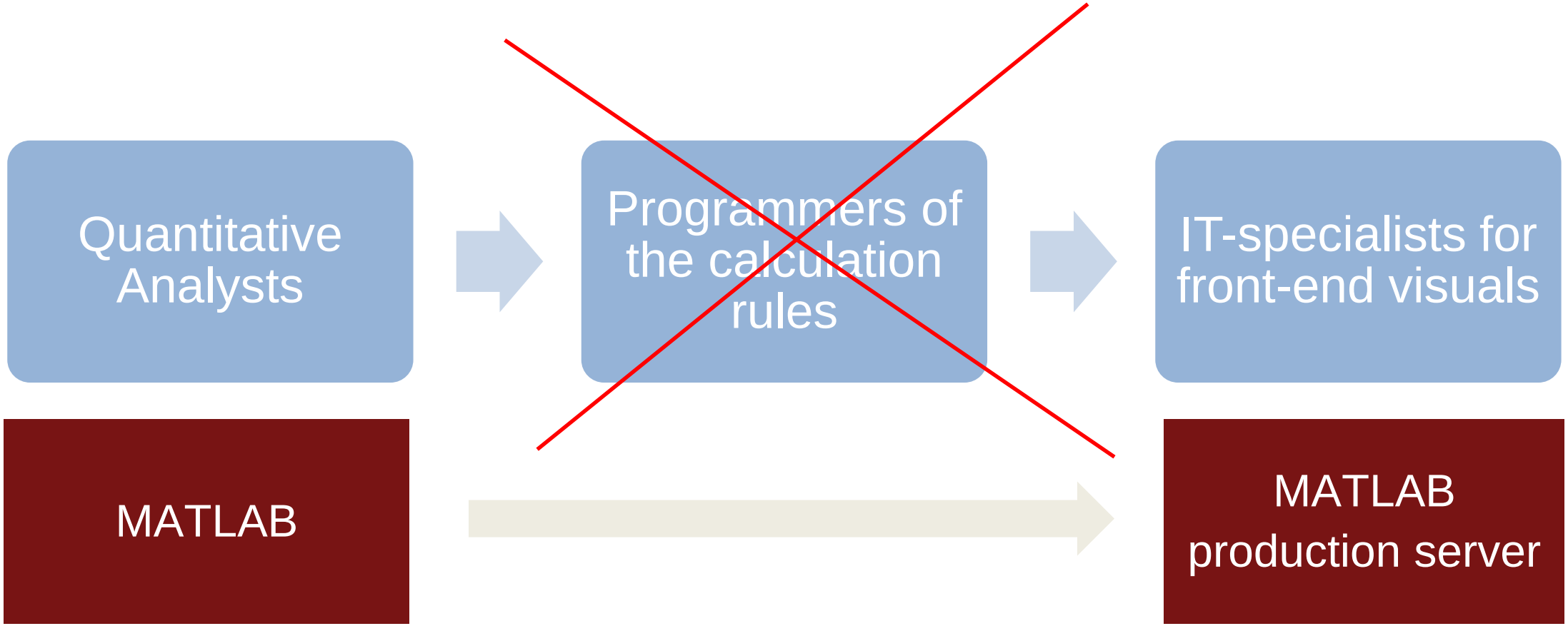
Why MATLAB…?

- Many universities use MATLAB as education software for students
- MATLAB is extremely fast with matrix multiplications
- In-house experience and knowledge with MATLAB

Before MATLAB…



…after MATLAB



Rabobank

Another saving! $ € £

- **Time = Money!**
- Much quicker implementation of adjustments in source code by the quantitative analysts
- ~~Verification of the programmer's code needed by the quantitative analysts~~

Rabobank

Wijzig beleggingsdoel

Toon suggesties

Hoe wilt u uw doel bereiken?

Huidige portefeuillewaarde € 4.466.971

Doelbedrag € 31.755.000

Looptijd 37 jaar

Einddatum 01 01 2054

Extra inleggen

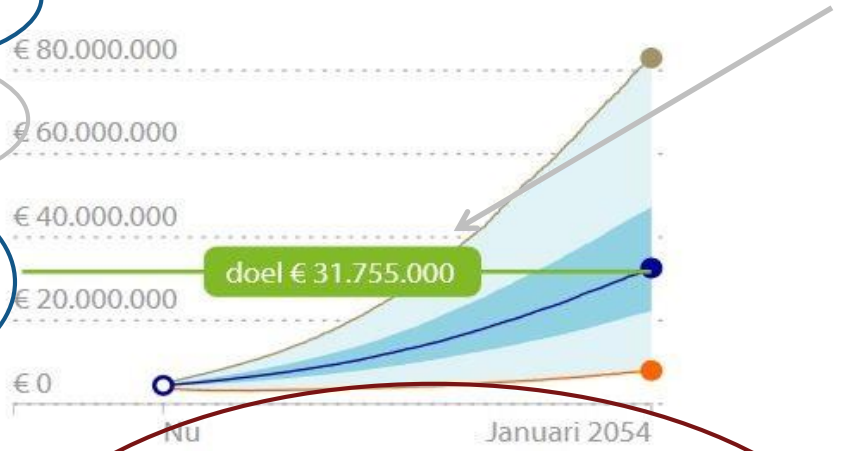
Eenmalige inleg € 0

Periodiek inleggen € 1.000

Met welke frequentie wilt u inleggen?

Per Maand

Verwachting



Portefeuillewaarde	€ 4.467.971
Goede markt	€ 83.001.128
Normale markt	€ 32.623.814
Zeer slechte markt	€ 8.024.866

MathWorks

Aspen

- Founded in 2002
- NYSE: AHL
- $13bn of assets at the end of 2017
- Offices in 9 countries
- Specialise in complex risks and reinsurance
- $3.1 bn gross written premium

Reinsurance pricing AIMS

- Profitability of contract & economic values
- VaR calculations
- Volatility
- Capital requirements for the contract

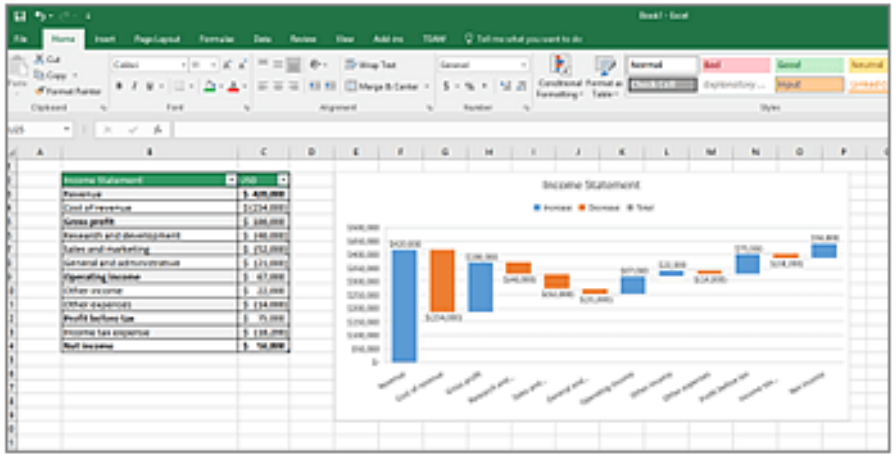
EXCEL and vba based models

- Helpful for initial prototypes
- Slow for simulation based calculations
- 100,000 years of simulation took minutes to complete and some calculations had to be turned off altogether
- Difficult to distribute and control version across the company

MATLAB Production Server

- Huge toolkit of standard functions which are well optimized
- Unit-testing framework included
- Handling of queues of jobs
- Enterprise grade
- Calculation time now around 5 to 15 seconds for typical cases with more calculations than the VBA version

MATLAB Production Server



Excel Spreadsheet

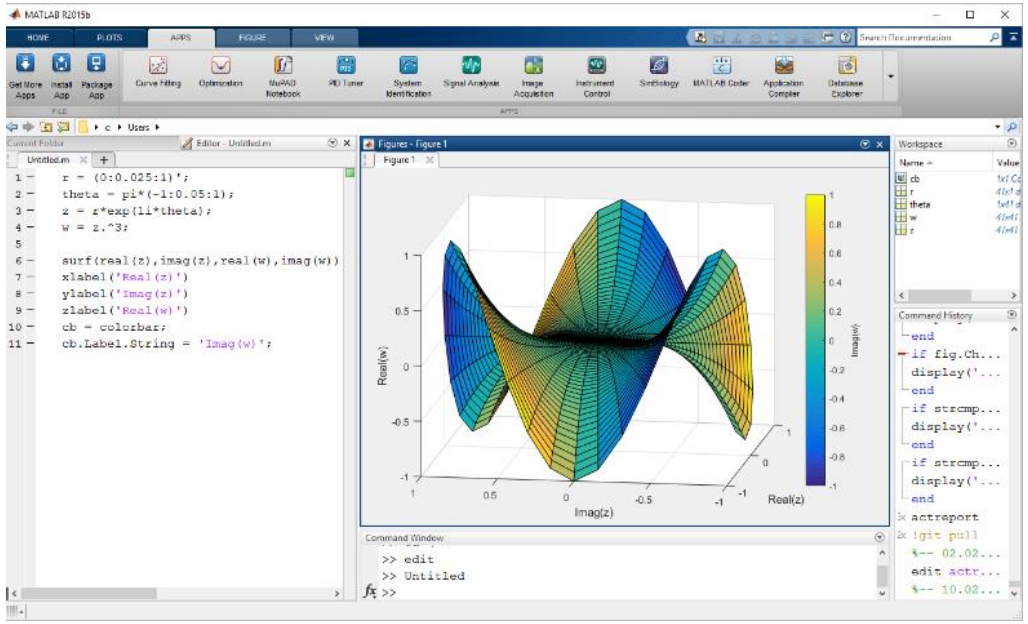
- User puts parameters into spreadsheet interface
- Excel calls the Matlab Production Server sending parameters to it
- Calculation outputs received and presented to user
- Distributed globally using Citrix

Matlab Production Server

- 24 workers ready
- Full disaster recovery on second site
- Available to all global offices as a service

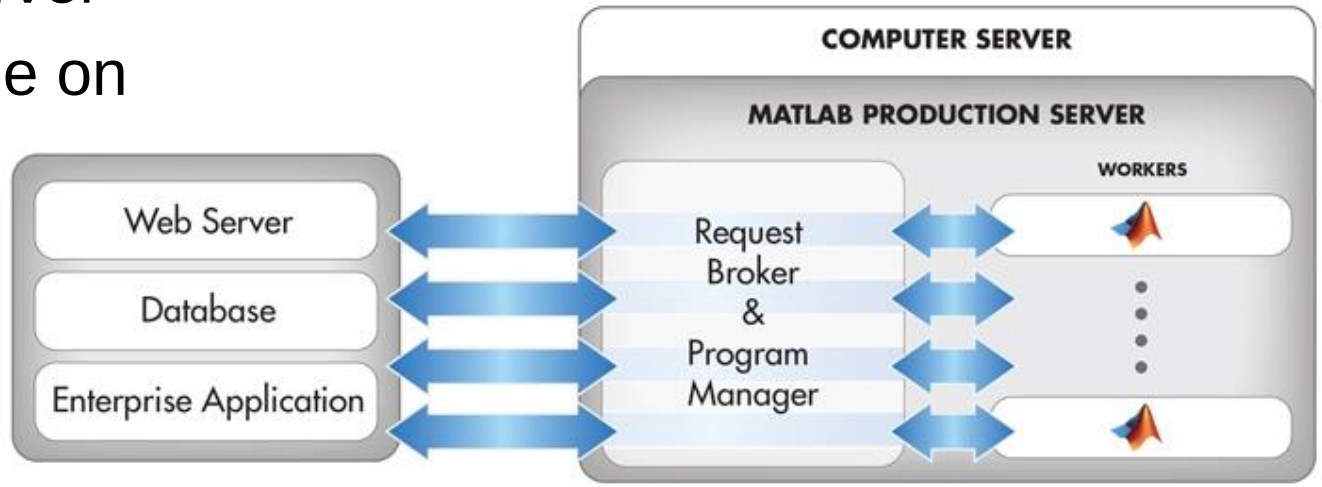
Development & deployment (1)

- Develop the code using standard MATLAB desktop environment
- Can debug efficiently
- Understand and verify calculations using plots etc. that would not be used in production
- Testing scripts
  - Automatically run 10s of thousands of real deals through the engine



Development & deployment (2)

- Compile code using Matlab compiler
- Publish to UAT environment for users to test
- Publish to MATLAB Production Server
- Can keep previous archives of code on server



Advantage in market

- Able to price complex deals which are not analytical evaluable
- Quickly prototype and deploy new features
- Instead of inaccurate estimations due to lack of computational power, we can simulate and get a good estimate of the profitability