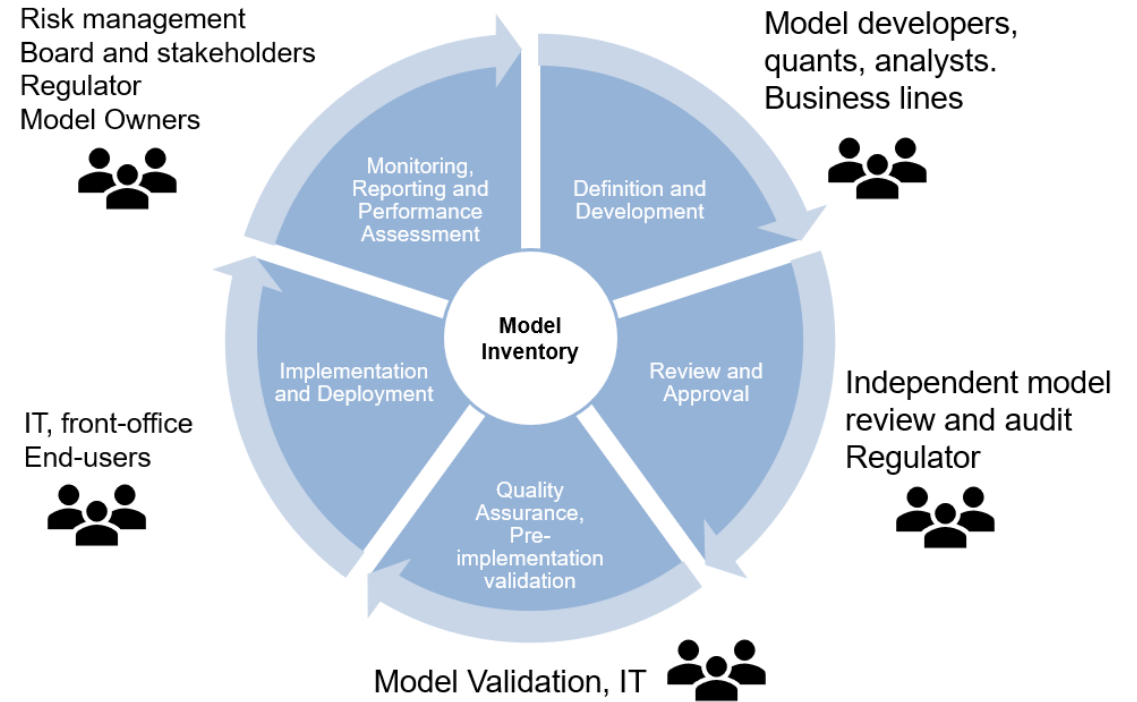


# Risk Management Model Management Model Governance

MATLAB Computational Finance Conference  
Paul Peeling, MathWorks



# Agenda

- Guidance from the Regulators
- Realising Model Risk Management with MATLAB
  - Model Inventory
  - Model Development
  - Model Documentation and Review
  - Model Monitoring
- Interpretability of Machine Learning Models

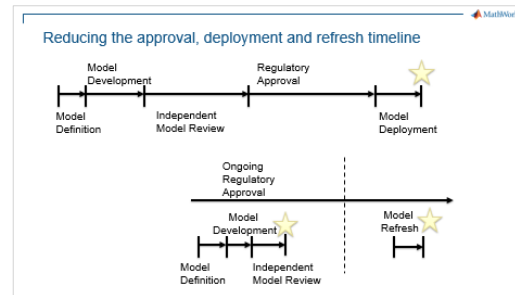
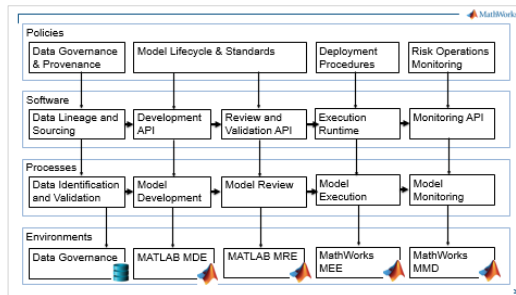
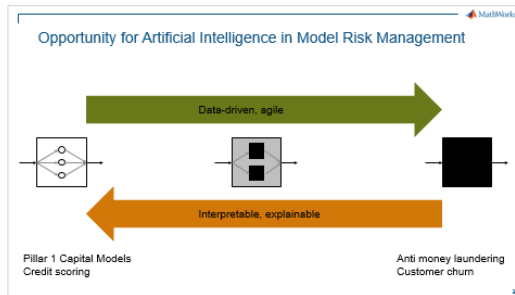
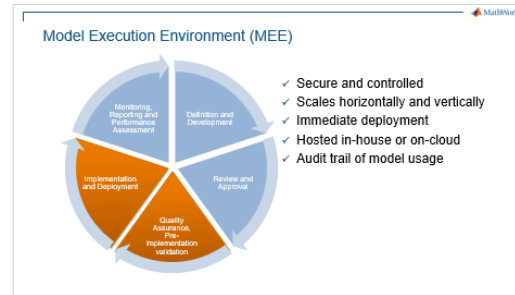
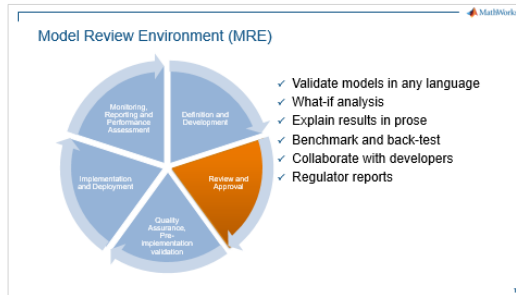
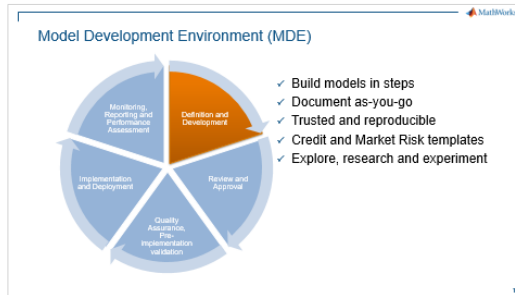
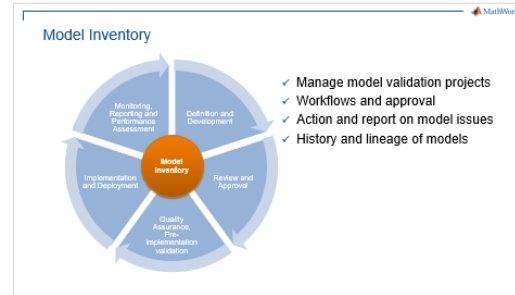
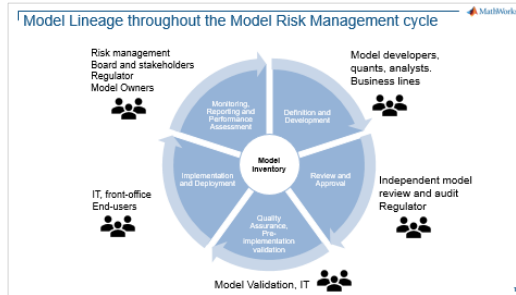
# Model Risk Management with MATLAB

### Model Risk Guidance 2018

European Central Bank  
Model risk management principles for stress testing activities

ECB guide to internal models

BANKING SUPERVISION



# Model Risk Guidance 2018



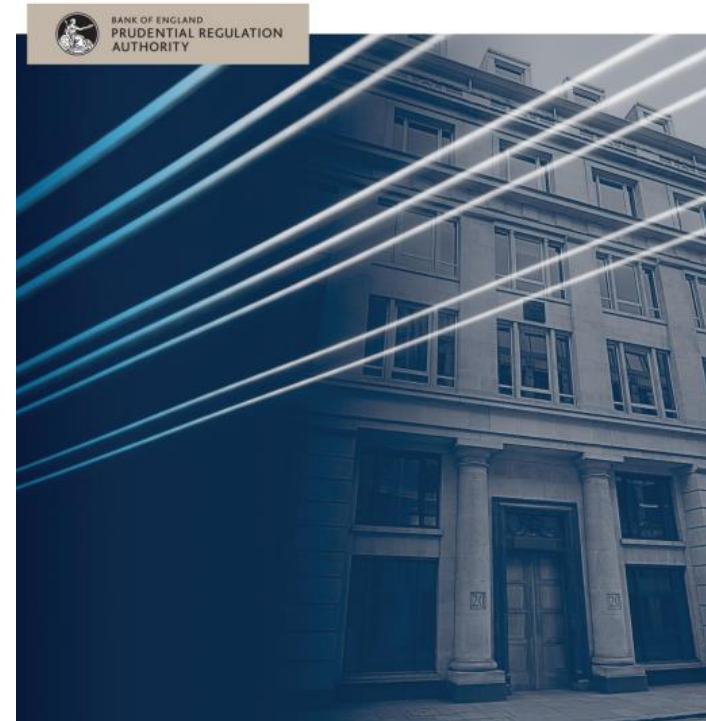
## ECB guide to internal models

General topics chapter



## Supervisory Statement | SS3/18 Model risk management principles for stress testing

April 2018



## Mitigating Model Risk (ECB guide to internal models)

- Unified inventory (“registry”) of models
- Consistency of modelling approaches
- Documentation standards – such that a 3<sup>rd</sup> party can implement
- Usage of models monitored on an ongoing basis

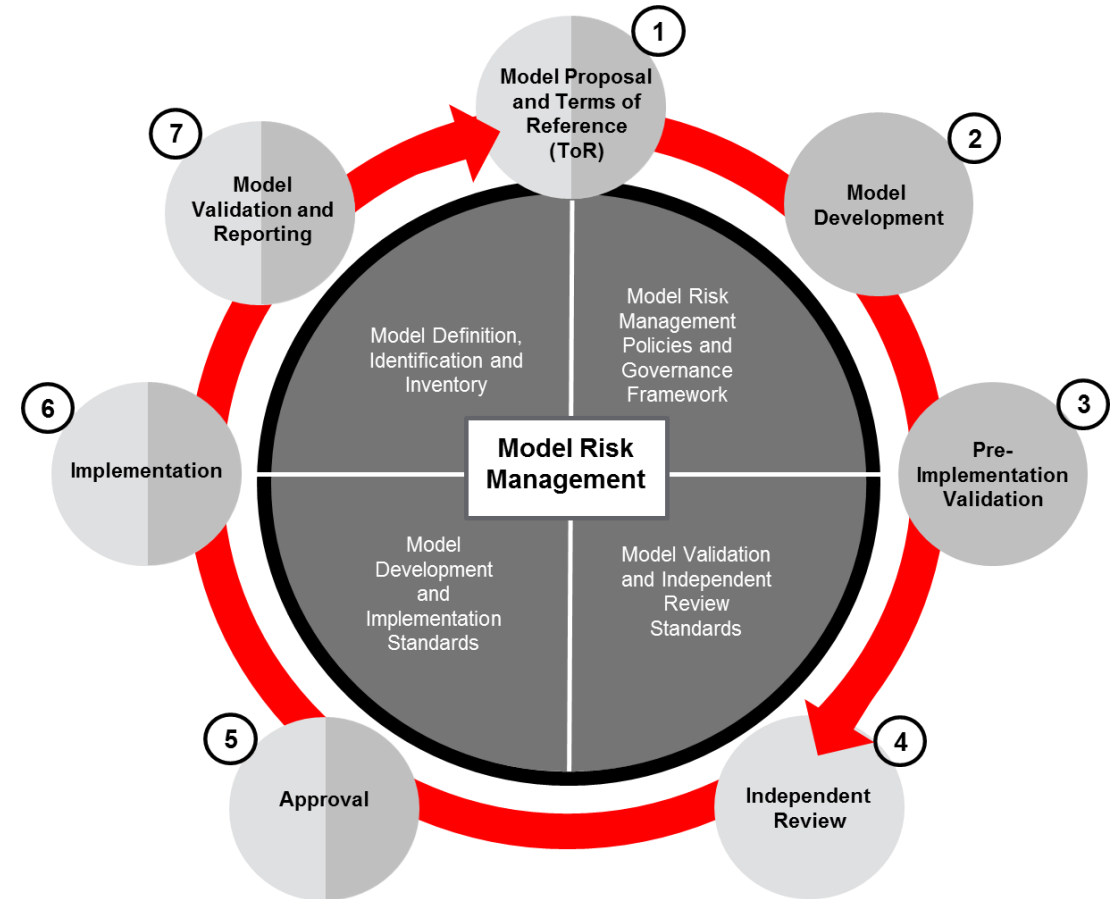
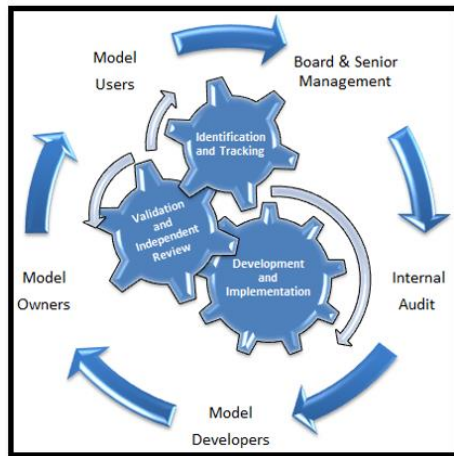
## Model Risk Management Principles (SS 3/18)

1. Banks have an established definition of a model and maintain a **model inventory**
2. Banks have implemented an effective **governance framework**, policies, procedures and controls to manage their model risk.
3. Banks have implemented a robust **model development and implementation** process, and ensure appropriate use of models.
4. Banks undertake appropriate **model validation and independent review** activities to ensure sound model performance and greater understanding of model uncertainties.

# Model Risk Management Frameworks

## Concluding remarks

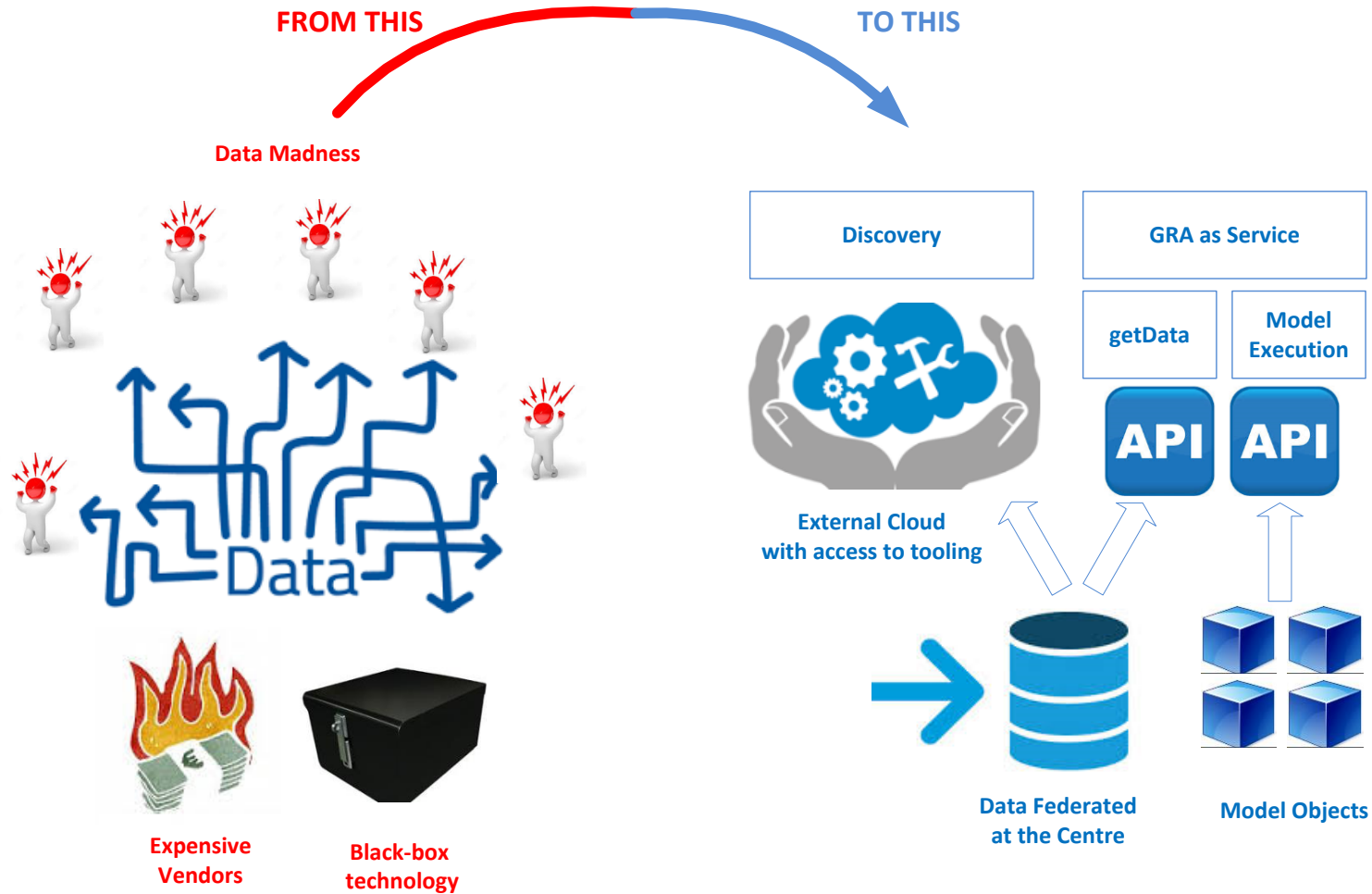
An effective model risk management framework is ...  
*an integrated and iterative process supported by a strong governance culture*



# Reality and Vision

Poor Quality Models  
Regulatory Scrutiny  
High Cost  
Inconsistency  
Frustrated Users

SDLC Vendor  
Driven

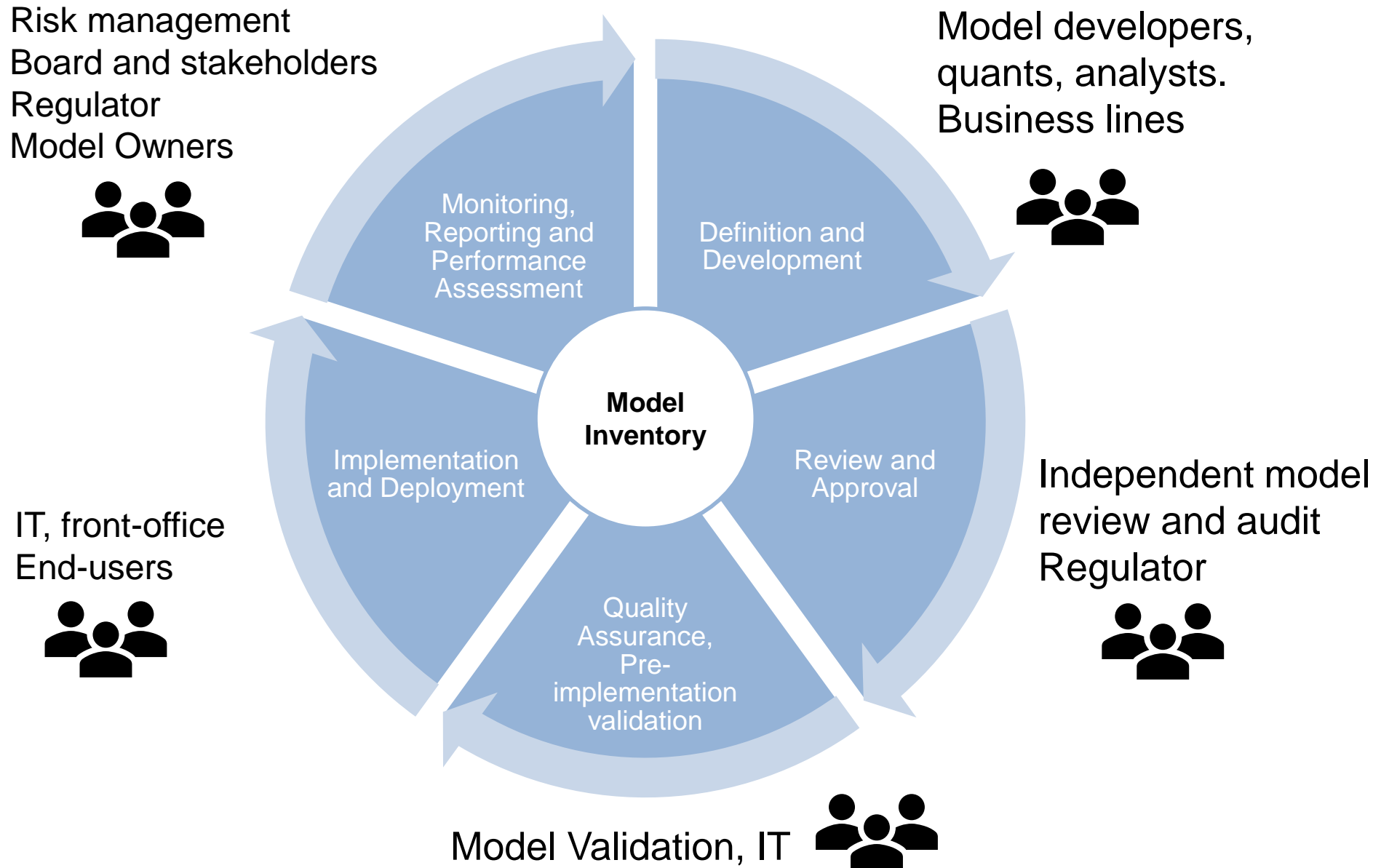


Reduced Cycle Time  
Access to Tooling  
Freedom to Analyse  
Consistency  
Lineage & Tractability  
Low Cost

Agile/DevOps  
Focused

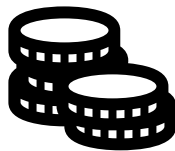


# Model Lineage throughout the Model Risk Management cycle



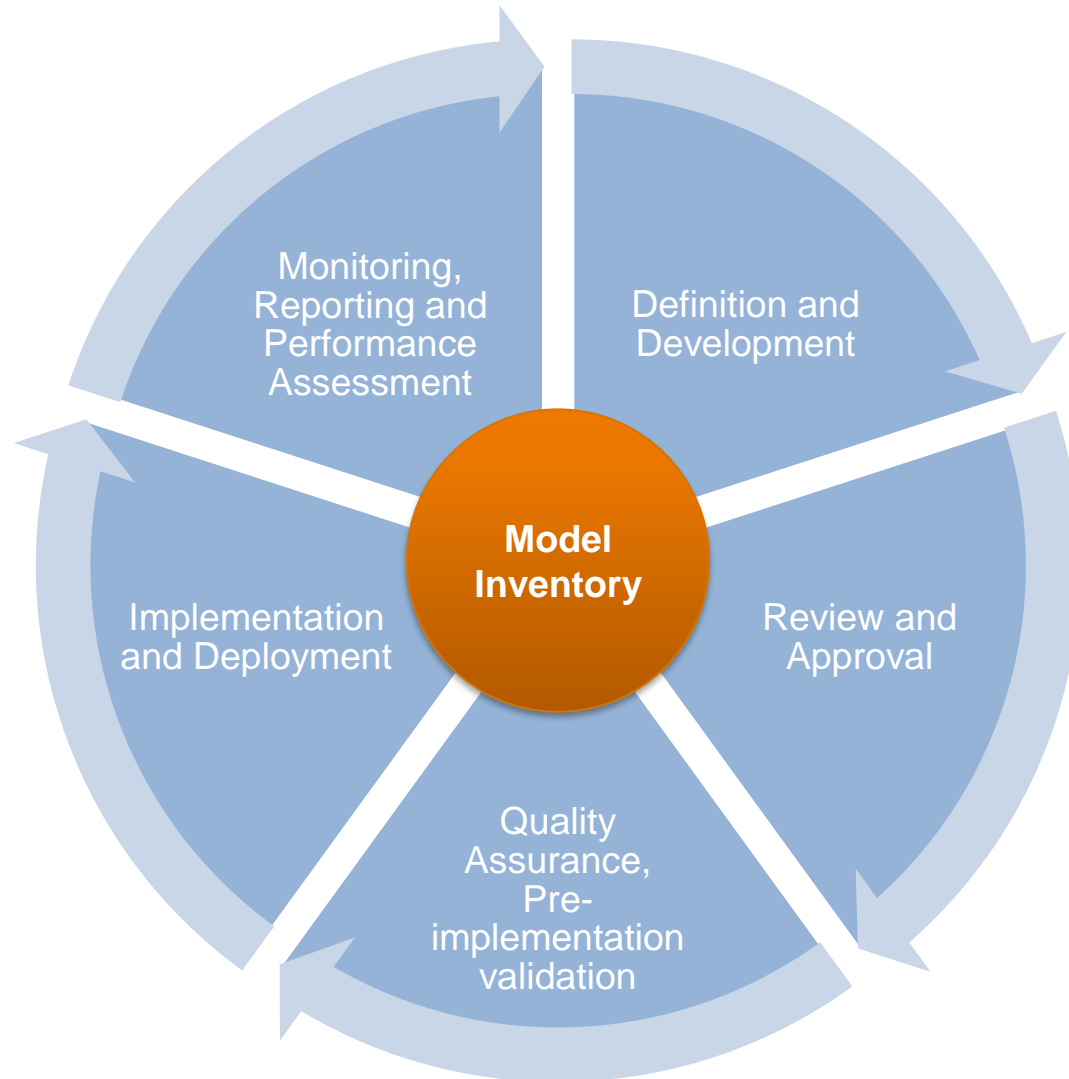
# Opportunity for Cost Savings with Model Risk Management

- Banks have 1,000s of models used in decision making
  - One FTE can manage approximately 10 models
  - One model per month can be validated
  - Number of models increasing by 10-25% annually
  - Model risk management can reduce costs by 30%
- 
- 20% of institutions have fully adopted model risk management



Source: McKinsey 2017  
Evolution of Model Risk  
Management

# Model Inventory



- ✓ Manage model validation projects
- ✓ Workflows and approval
- ✓ Action and report on model issues
- ✓ History and lineage of models

# Data Governance

Sourcing data from multiple platforms and processes

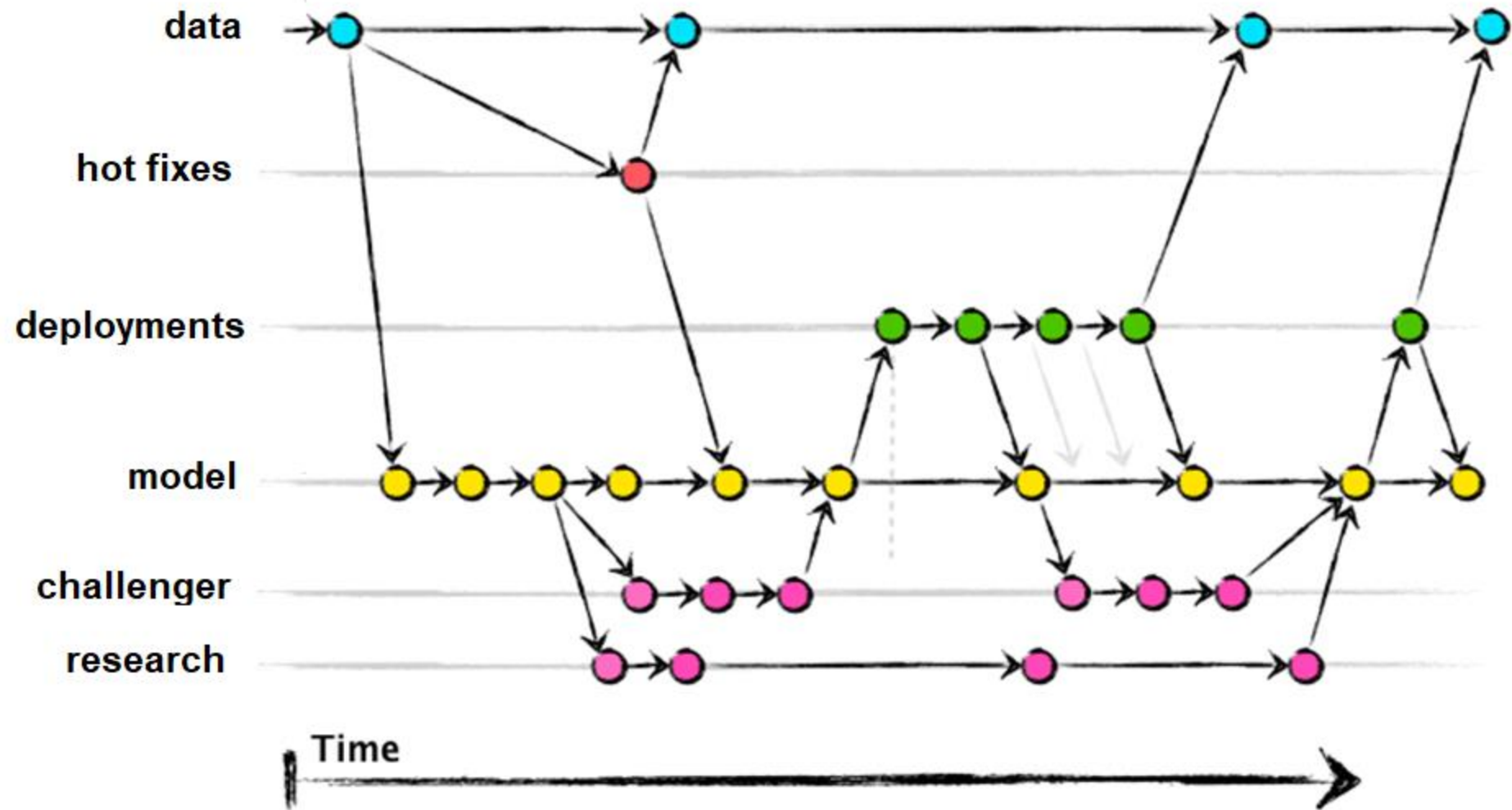
Vetting data quality

No unified data model or interpretation

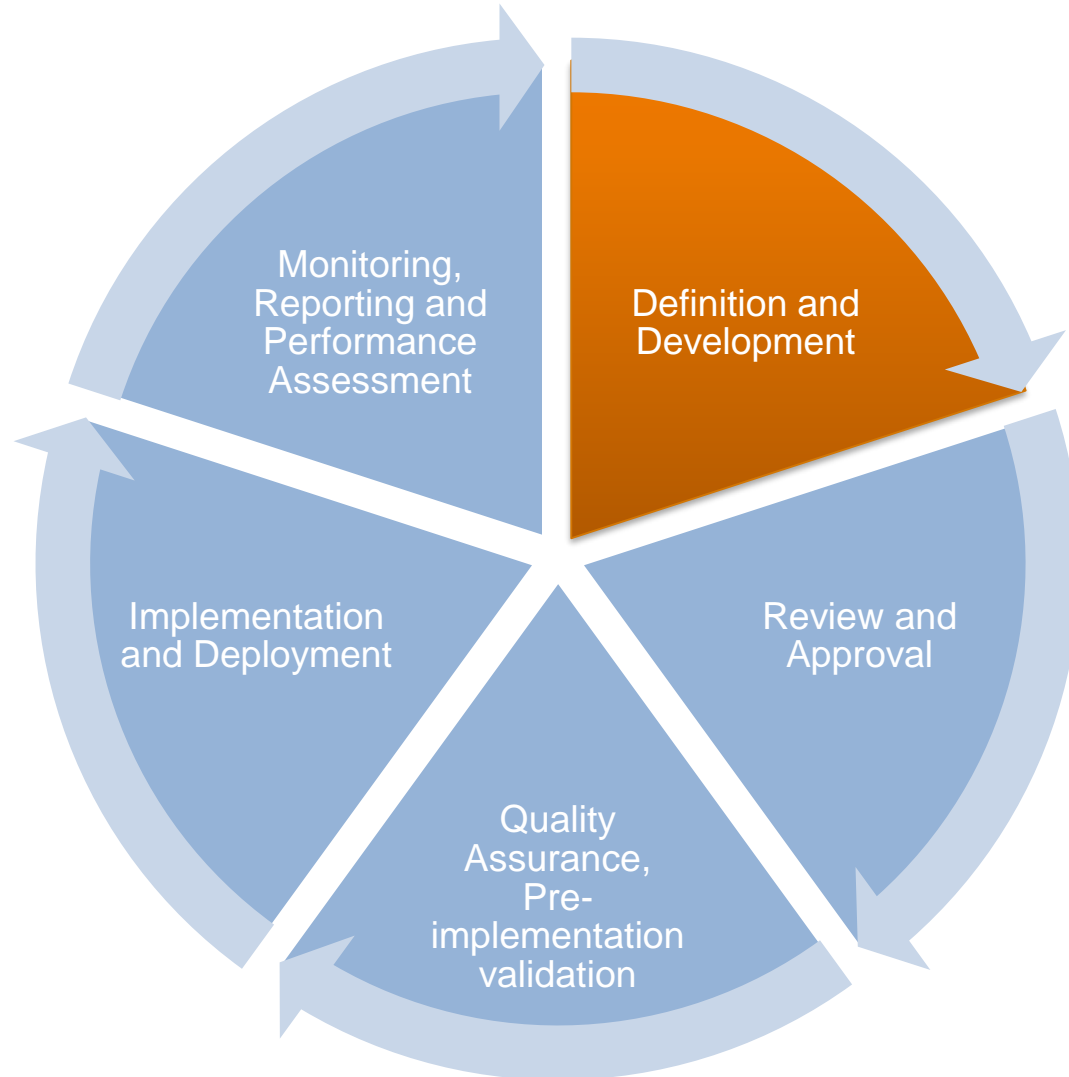
Inconsistent handling of data by location and over time

Historical data cannot be reproduced

Author: Vincent Driessen  
 Original blog post: <http://nvie.com/archives/323>  
 License: Creative Commons



# Model Development Environment (MDE)



- ✓ Build models in steps
- ✓ Document as-you-go
- ✓ Trusted and reproducible
- ✓ Credit and Market Risk templates
- ✓ Explore, research and experiment

## Model Development Environment (MDE)

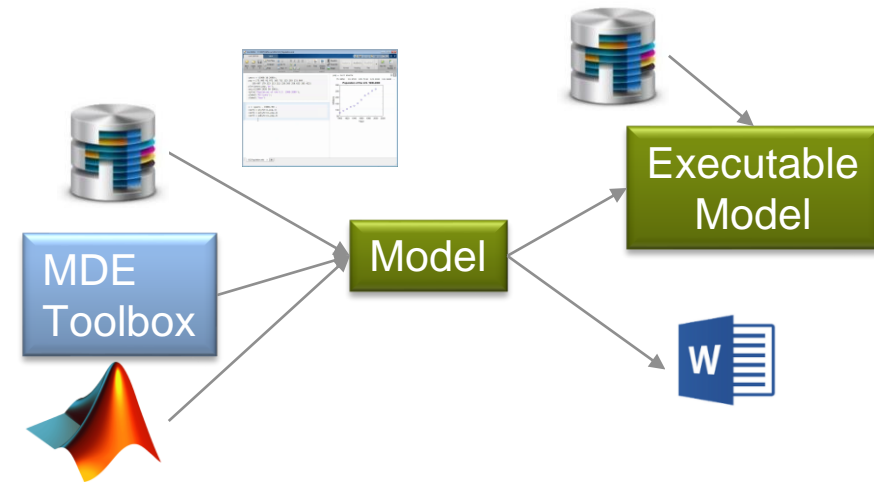
Mission: ***Improve the pace, transparency and reproducibility of the model development and review processes through user-friendly tools that encourage a consistent approach.***

### 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

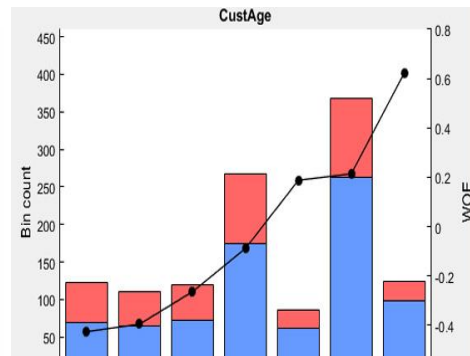


# Building Models as a Sequence of Steps

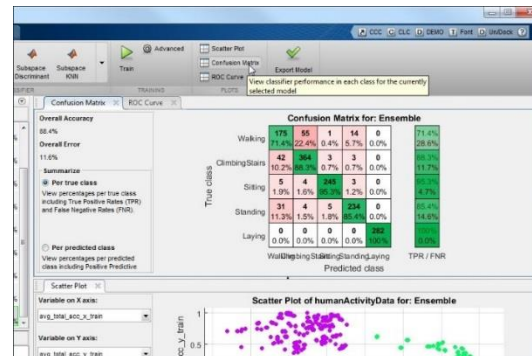
1. Data loading and pre-processing
2. Exploratory Data Analysis
3. Sampling and Segmentation
4. Feature Engineering
5. Train Models
6. Model Validation
7. Documentation
8. Deployment

	1	2	3	4
	Date	CAPITL	CENTRL	DUNWOD
1	01-Jan-2004 00:00:00	1015	1651	618
2	01-Jan-2004 01:00:00	927	1562	568
3	01-Jan-2004 02:00:00	891	1507	541
4	01-Jan-2004 03:00:00	NaN	1440	517
5	01-Jan-2004 04:00:00	NaN	1434	499
6	01-Jan-2004 05:00:00	NaN	1449	496
7	01-Jan-2004 06:00:00	NaN	1490	524
8	01-Jan-2004 07:00:00	NaN	1525	526
9	01-Jan-2004 08:00:00	960	1529	518
10	01-Jan-2004 09:00:00	1046	1628	541
11	01-Jan-2004 10:00:00	1111	1706	570

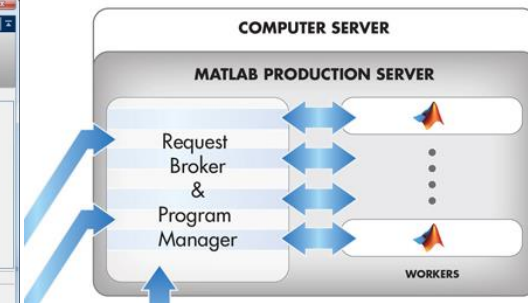
Access and Explore Data



Process Data and Create Feature

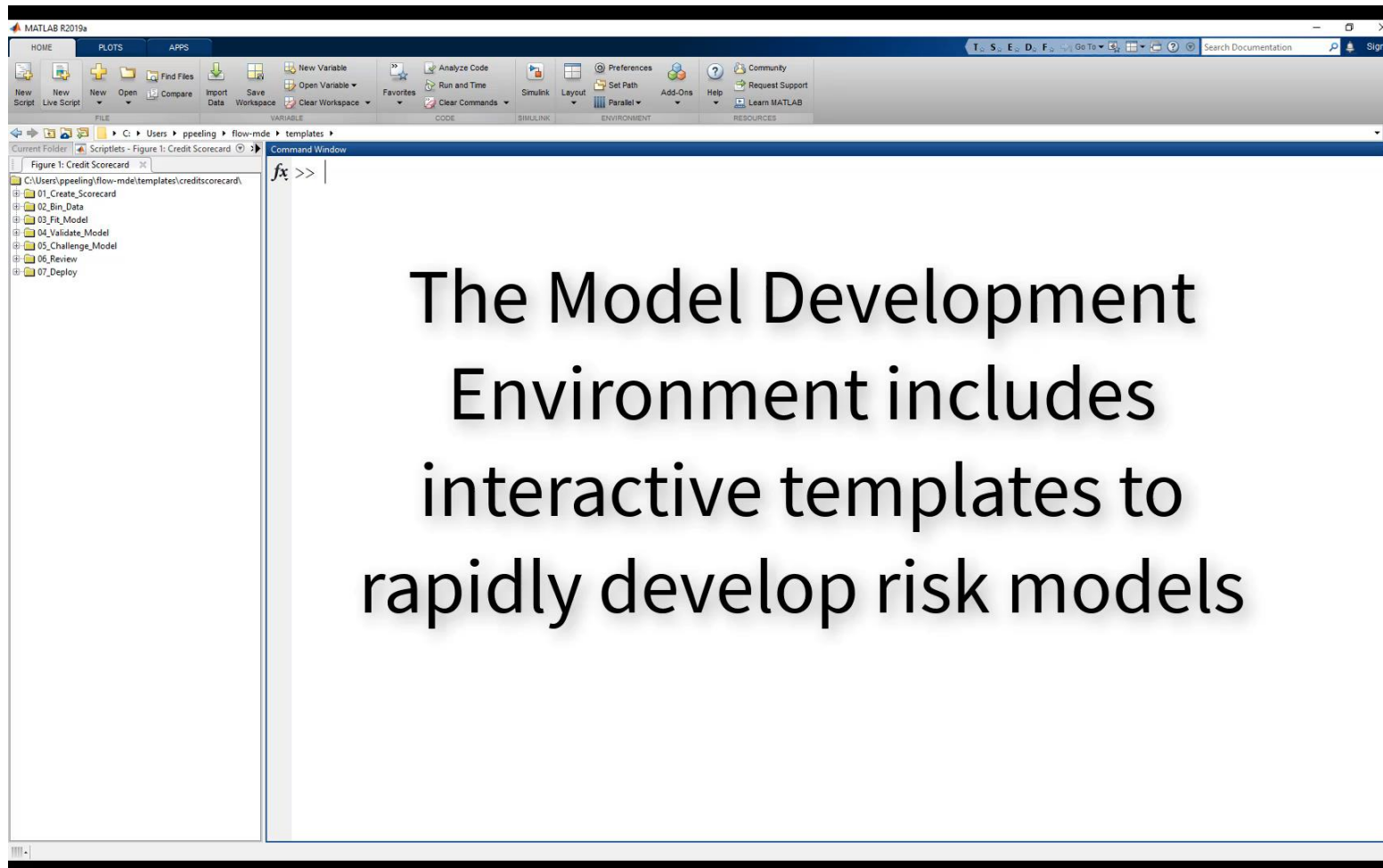


Build and Validate Models



Deploy Model  
Review Model

# Building a credit scorecard



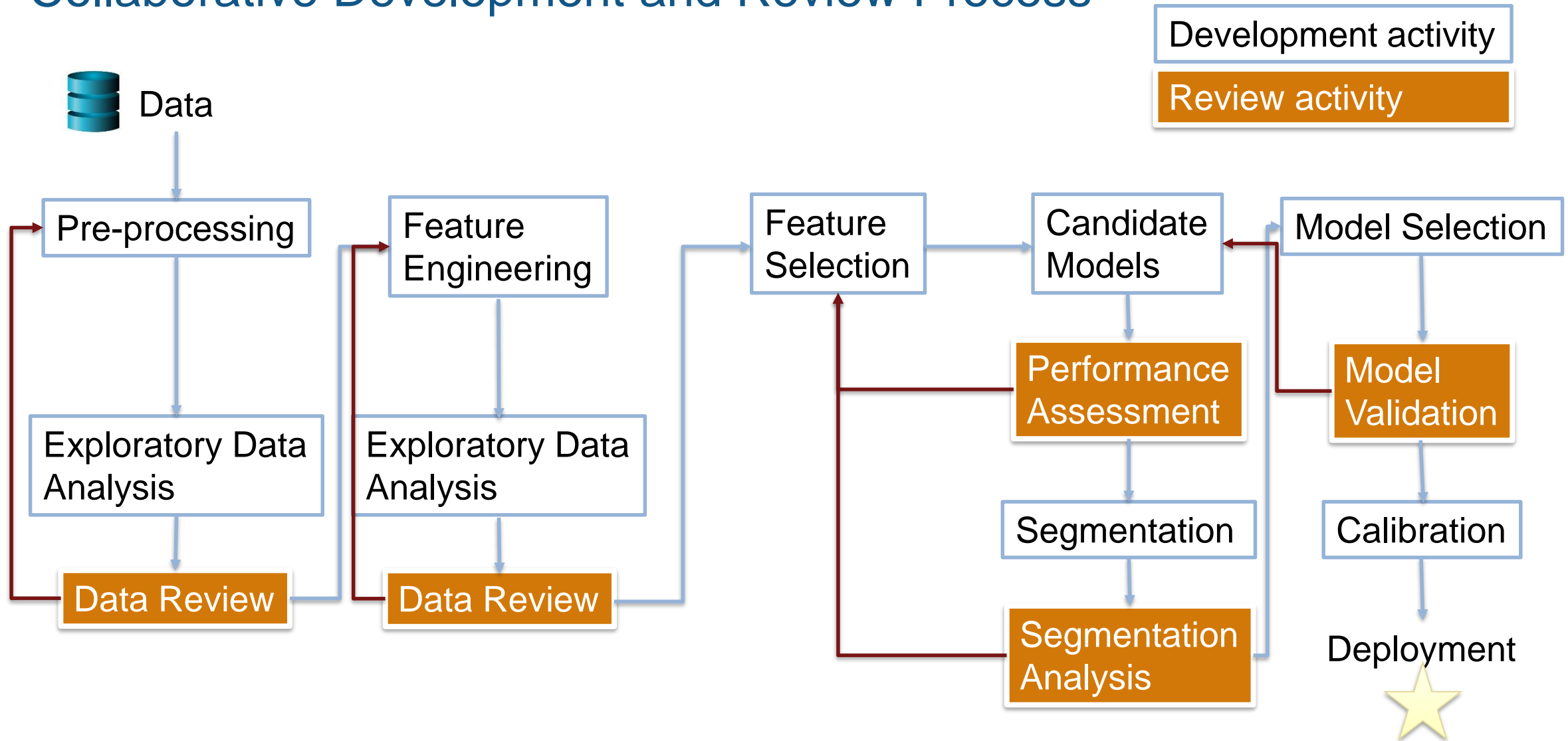


# Model Review Environment (MRE)



- ✓ Validate models in any language
- ✓ What-if analysis
- ✓ Explain results in prose
- ✓ Benchmark and back-test
- ✓ Collaborate with developers
- ✓ Regulator reports

# Collaborative Development and Review Process



# Regulatory Documentation Authoring

Automatic generation of supporting analysis relieves the burden on model development and validation teams, by:

- Keeping visualizations and tables in sync with model developments (no copy-and-paste)
- Adhering to corporate styles, templates and quality output

A model development document typically ranges between 200 and 500 pages, and consumes 30% of the effort.

Our approach allows developers and reviews to focus effort on insight, assumptions and limitations.

Example: [IRB Application](#) Modules

1. Scoping
2. **Technical model reviews**
3. IT and Data
4. **Use test and experience test**
5. Permanent partial use and roll out plans
6. **Financial reporting and stress testing**
7. **Internal audit and independent validation**
8. Governance

Authoring of highlighted modules are supported by the Model Review environment.

# Documentation Authoring Workflow

The screenshot shows a Microsoft Word document titled 'creditscorecardMDD.dotx'. The document is split into two panes. The left pane contains a large text area with the following content:

[Title]  
 Model Development Document

**Document Owner:** Click or tap here to enter text.  
**Document Approver/s:**

The right pane contains a 'Document Management Control' form with the following sections and tables:

**Document content details**

Author's job title	Author's name	Content development date

**Document details and status**

Document title	[Title]/ Model Development Document
Document status	Draft <input checked="" type="checkbox"/> Proposed <input type="checkbox"/> Approved <input type="checkbox"/> Obsolete <input type="checkbox"/>

**Revisions**

Version number	Issue date	Modifications
1.0		

**Document approval**

Document control role	Job title or name	Date approved	Next review date
Document Owner	Click or tap here to enter text.		
Document Approver/s			
Document Approver Deputy/ies (approves document in the absence of the Approver)			

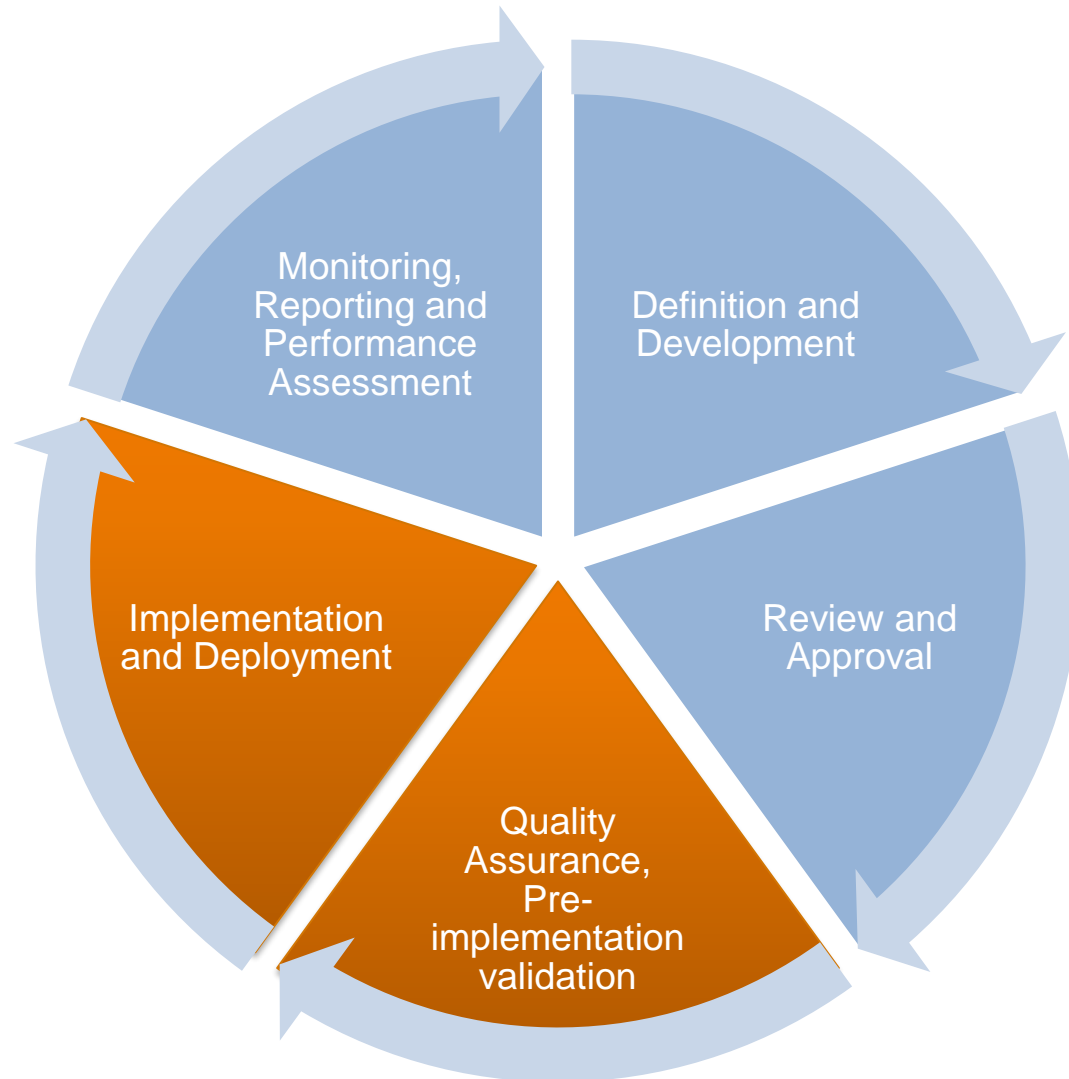
**Document issue details**

Document controller /issuer name	Job title	Date issued to document sharing platform	Stakeholder distribution list	Communicated to Stakeholders date

**Record control**

Record classification	Master record location	Record retention period	Primary retention driver	Historical interest Y/N	Record disposal requirement

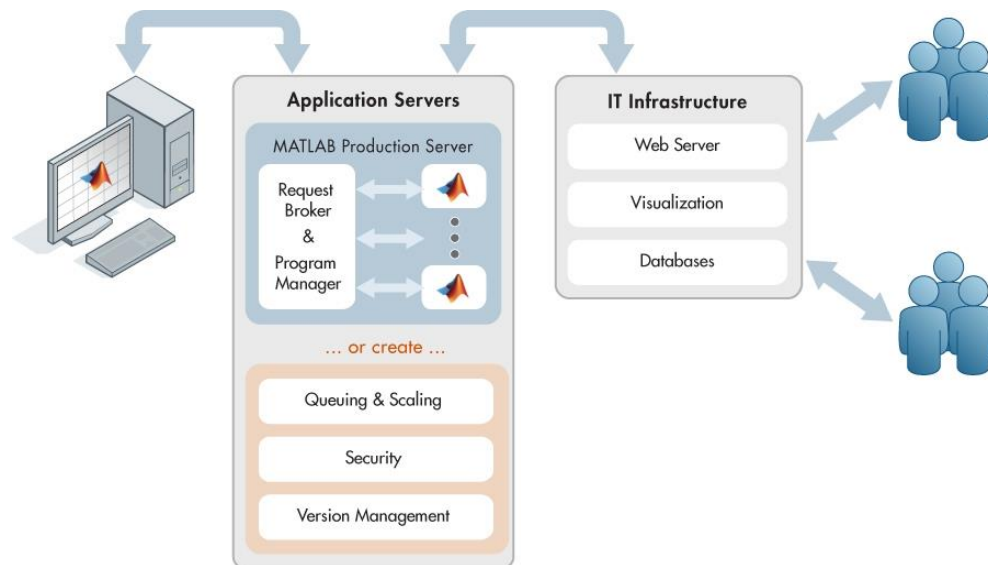
# Model Execution Environment (MEE)



- ✓ Secure and controlled
- ✓ Scales horizontally and vertically
- ✓ Immediate deployment
- ✓ Hosted in-house or on-cloud
- ✓ Audit trail of model usage

# Packaging, Production Deployment and Monitoring of Models

- Automated deployment of models into production without translation
- Integrate with existing front-end and back-end tech, or self-service platforms
- Performance of models monitored for operational and regulatory requirements



The screenshot shows the **HSBC WREN** web application interface. At the top, there are navigation links for **Home** and **About**. Below the header, there is a search filter section with options: **Filter** (Leave blank to show all), **Active only**, **Just mine**, and **Recently changed**. A prominent red button says **Create new Rating Event** with a plus icon. Below this, two event cards are visible:

- GHABOUR CONTENENTAL FOR TRAD**: Proposed : 6.2, Owner: Gamil Magdy Esmail Mahmoud Hassan (43515601), Last Modified: 07 Sep 2017 at 15:13:32
- AATCO FOOD INDUSTRIES LLC**: Proposed : 4.3, Owner: Ajay Kumar Goudiperi (43153993), Last Modified: 07 Sep 2017 at 14:56:43

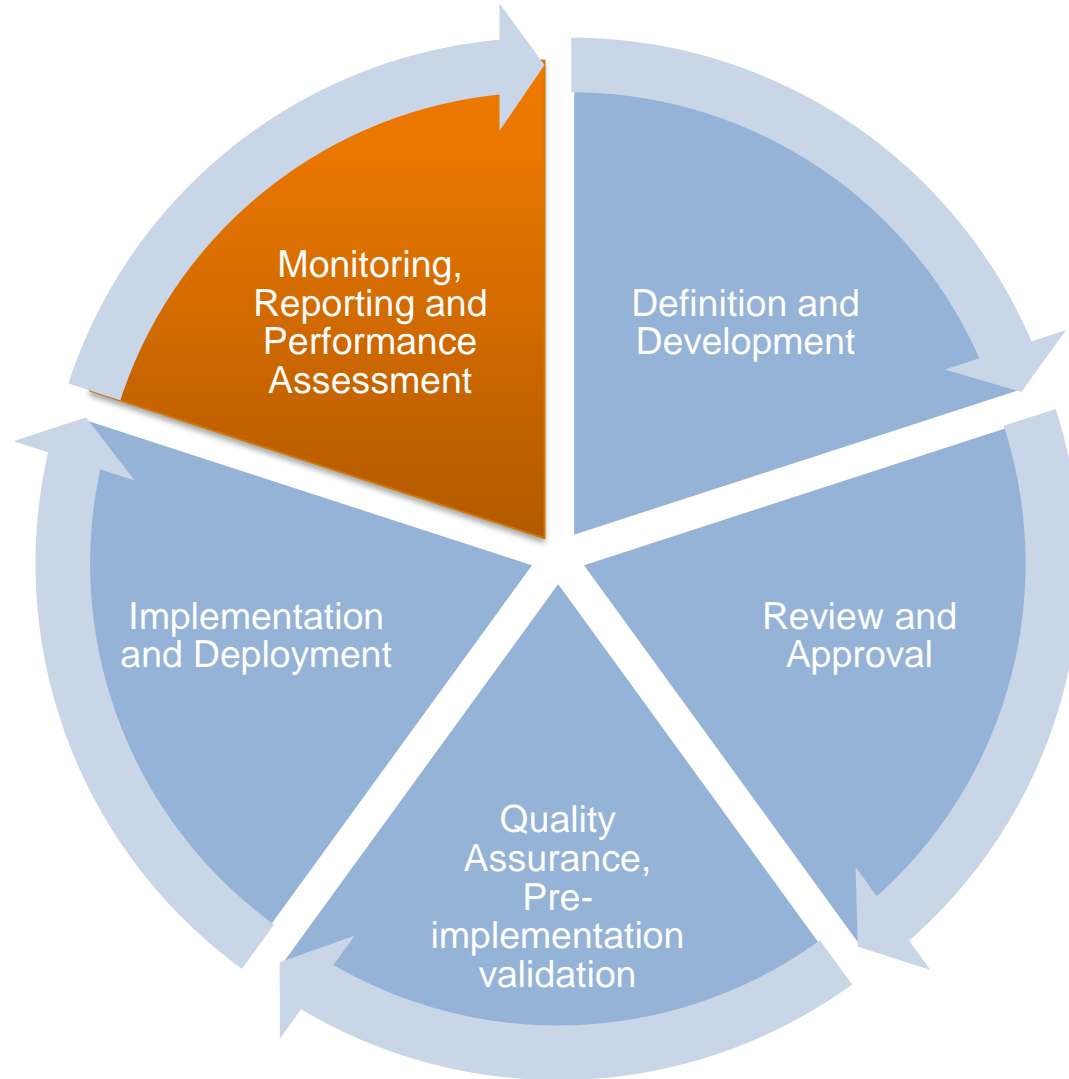
Below the event cards is a progress bar with four steps: **1 Rating Approach**, **2 Raw Rating**, **3 Modifiers**, and **4 Approval** (highlighted in red). Under the **Approval** step, several criteria are listed with their values:

- Years in Business**: > 20 years
- Credit history**: Clear history
- Risk of adverse events**: Average
- Account Conduct**: Satisfactory

Below this is a section titled **Operating Environment** with two items:

- Barriers to Entry**: High
- Competitive Structure of Market**: Highly Competitive

# Model Monitoring Dashboard (MMD)



- ✓ Visuals and metrics
- ✓ Multiple views
- ✓ Real-time monitoring
- ✓ Configurable alerts
- ✓ Configurable layout

# Model Monitoring Workflow

MDE



Publish

MEE

App Designer

Analyse

Monitor

MMD

Deploy



# Model Monitoring

pppeeling logout about support

Model Health Credit Scorecard Monitoring VaR Monitoring

## Model Health Dashboard

Executor Status

Executors

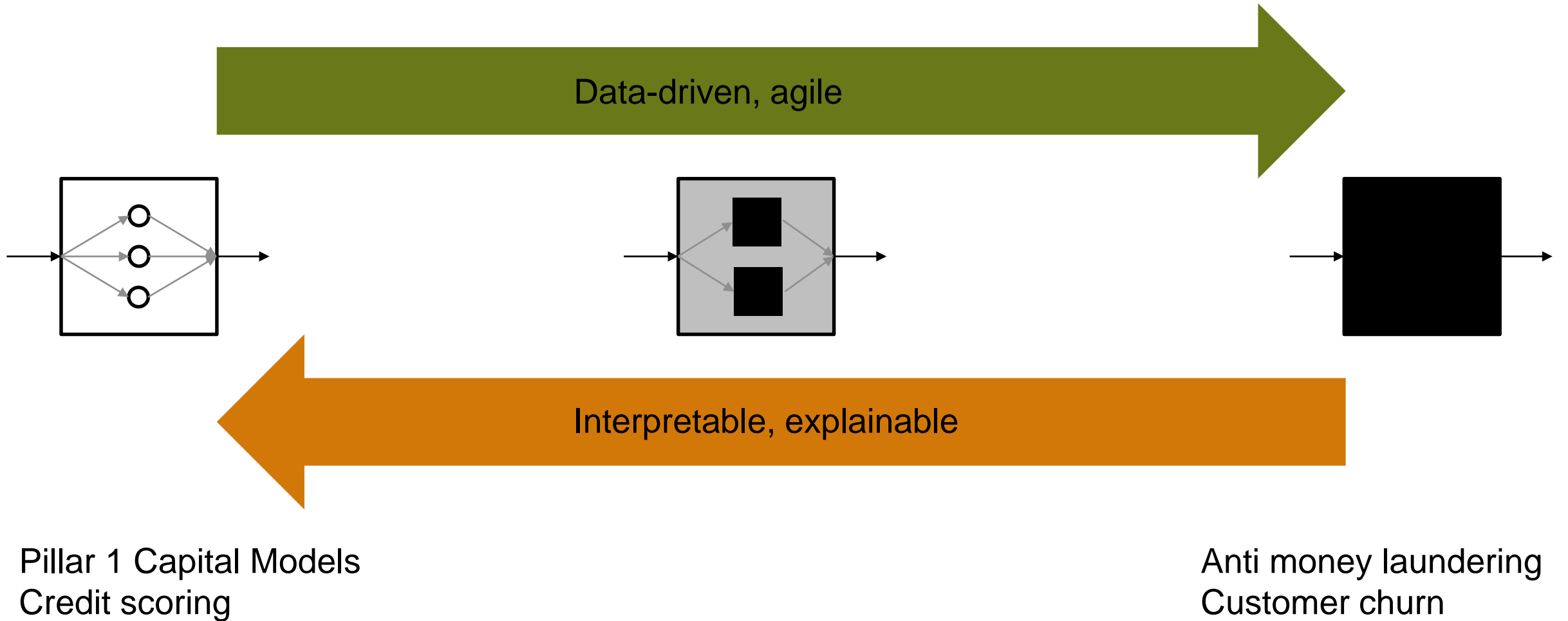
Pipeline

No models in pipeline

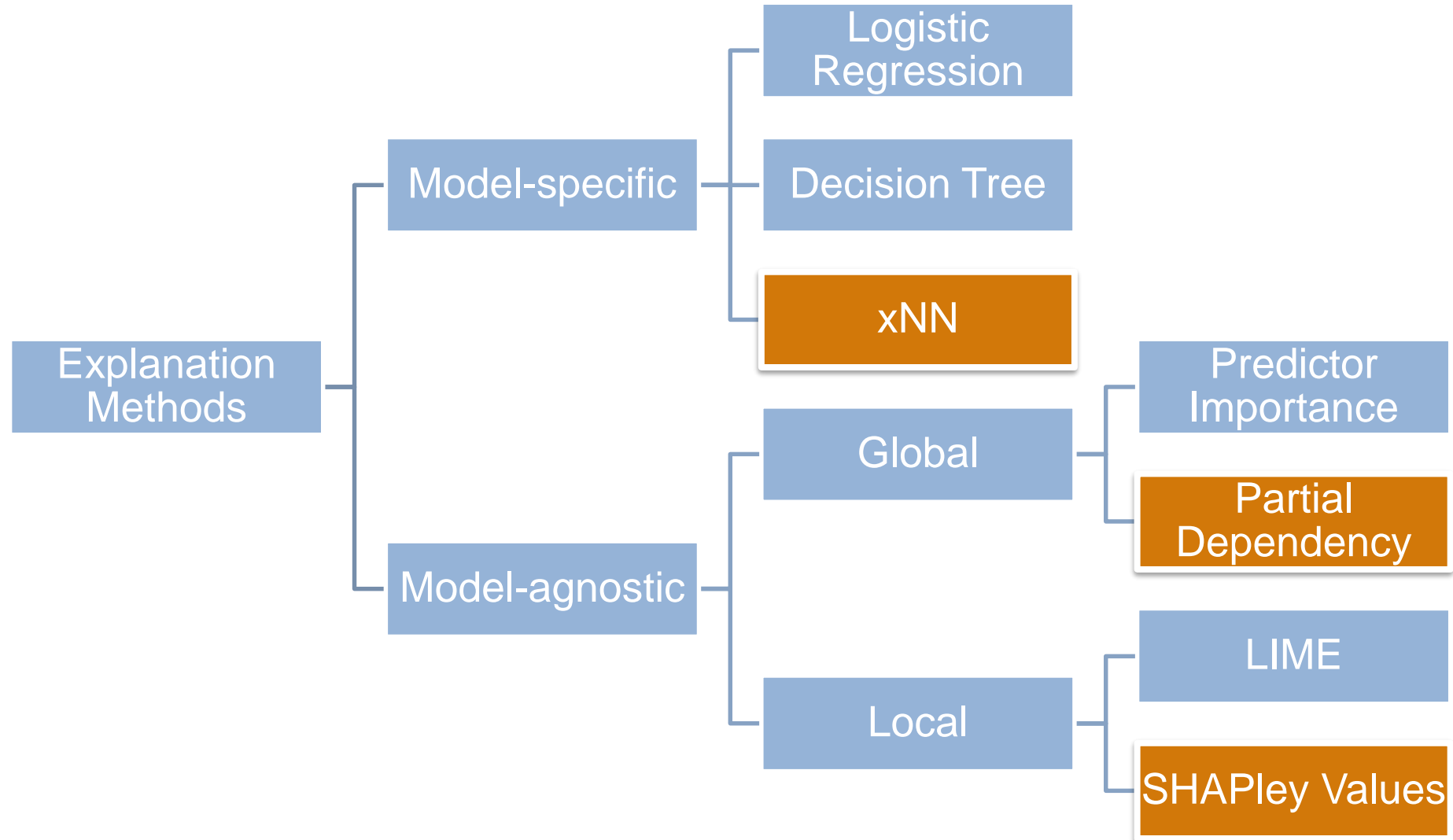
All Credit Market Liquidity

W	Status	Name	Uptime	Last Failure	Last Duration
*	1	initialScorecard1/sc	01:18.994	00:00.000	00:00.085
*	1	initialScorecard2/sc	01:11.227	00:00.000	00:00.073
*	1	initialVaR/EWMA	01:20.701	00:00.000	00:00.000
*	1	initialVaR/Historical	01:20.707	00:00.000	00:00.000
*	1	initialVaR/Normal	01:20.711	00:00.000	00:00.000

# Opportunity for Artificial Intelligence in Model Risk Management



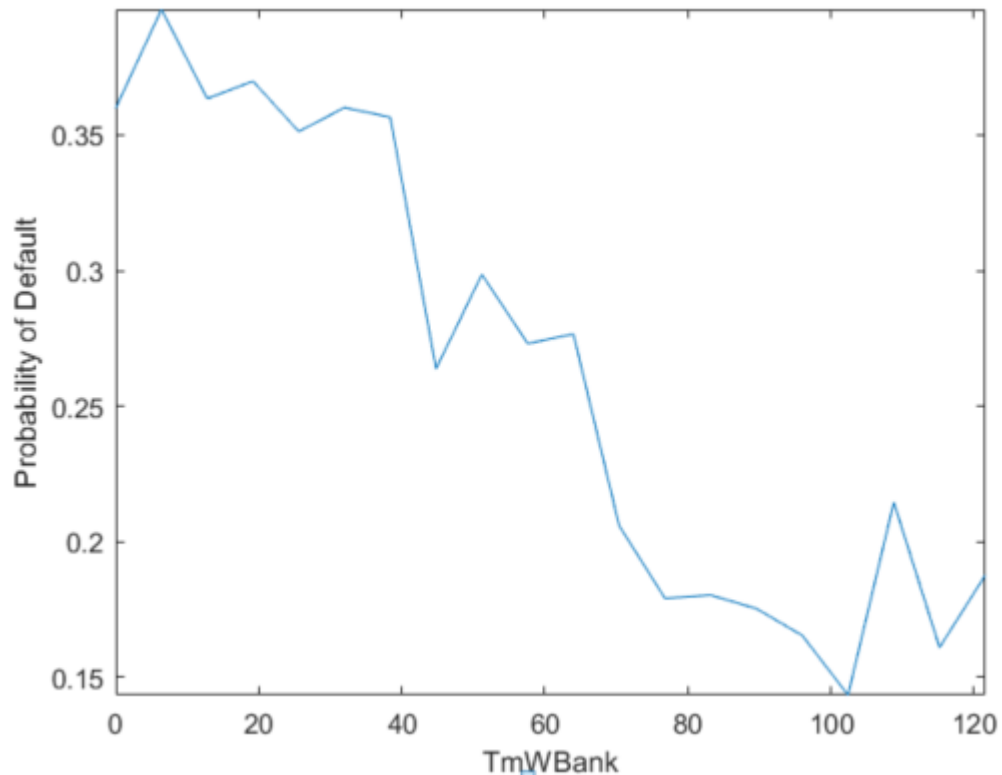
# Explaining Machine Learning



# Explaining Machine Learning

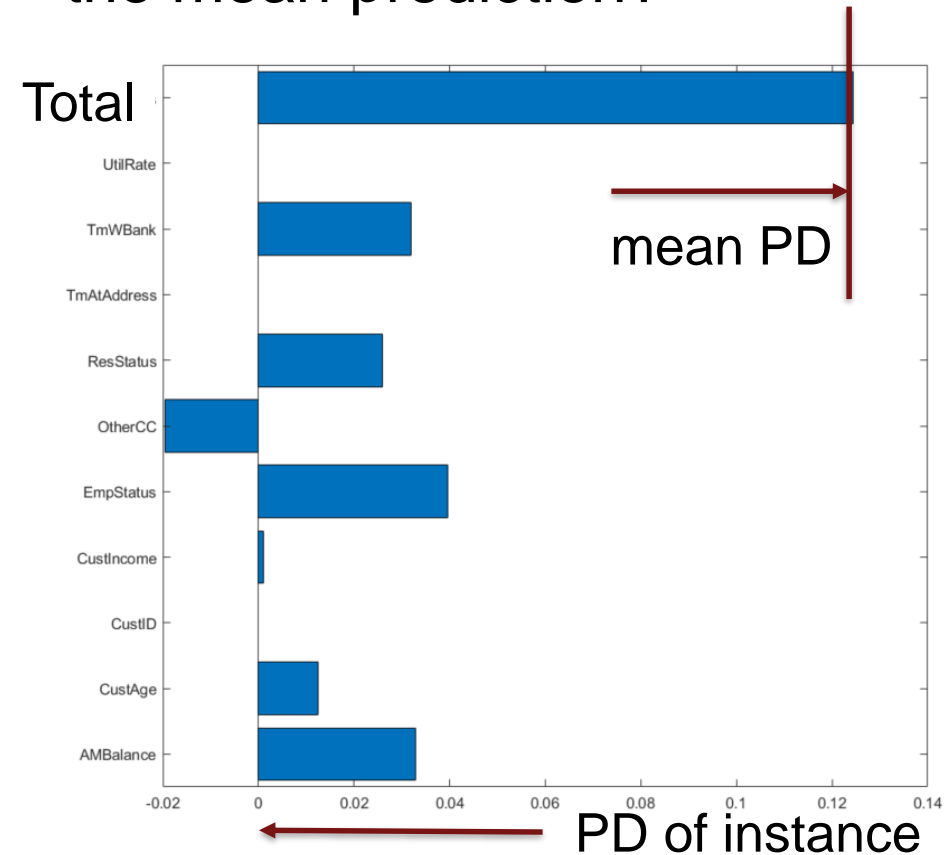
## Partial Dependency Plots

Marginal effect of a feature on the prediction

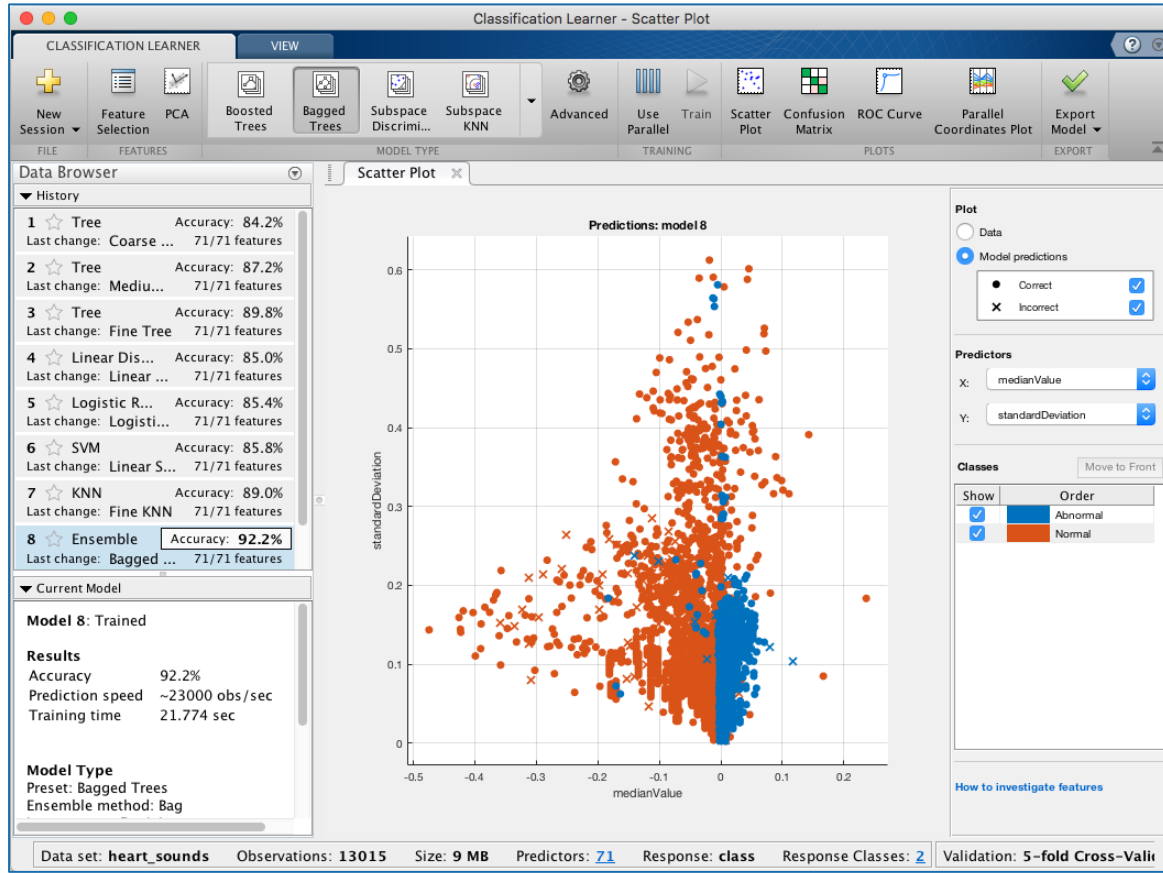


## SHAPley Values

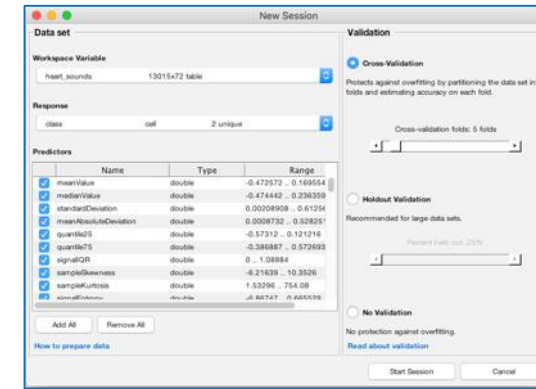
How far is the instance away from the mean prediction?



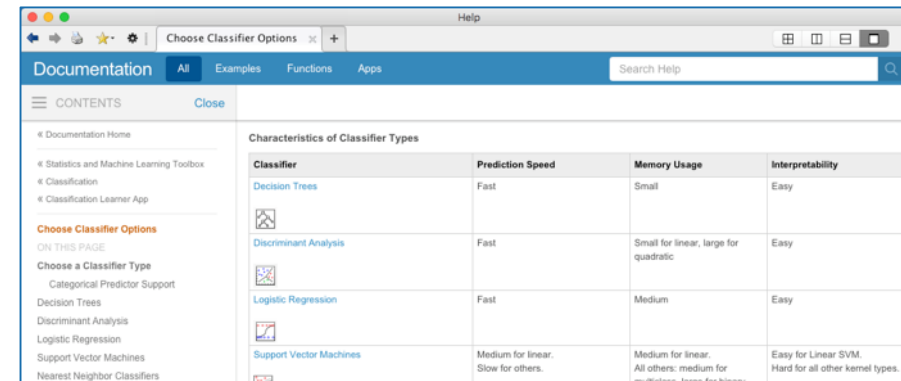
# Machine Learning **Ease-of-Use**



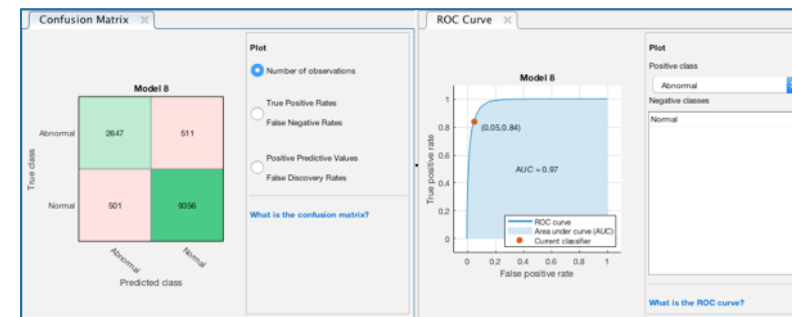
Classification Learner app



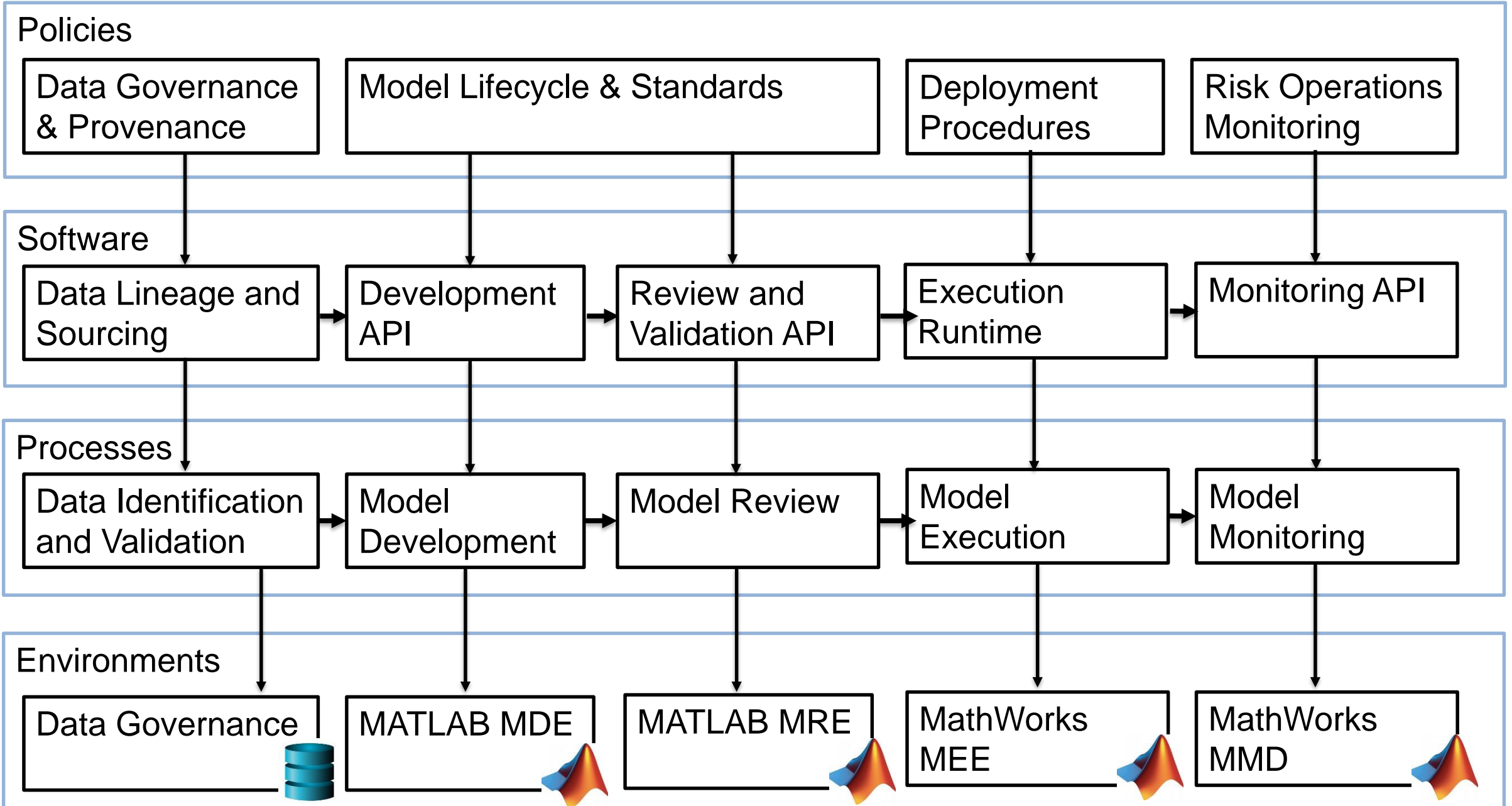
Protect Against Overfitting



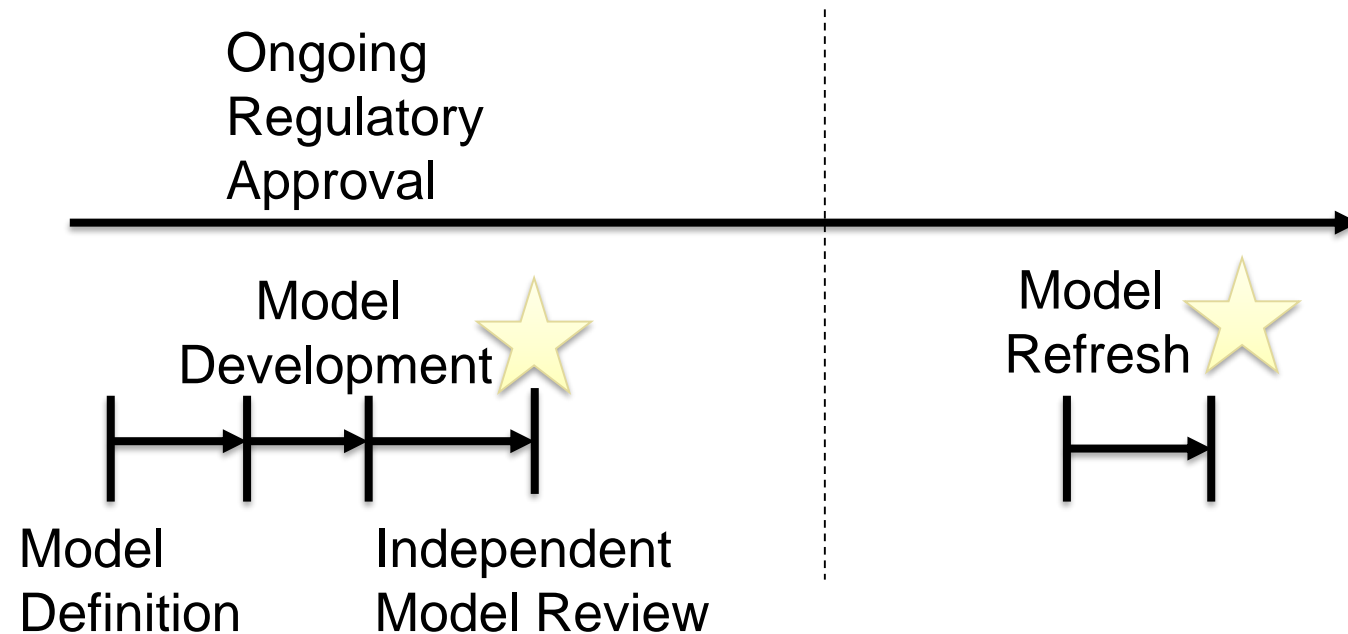
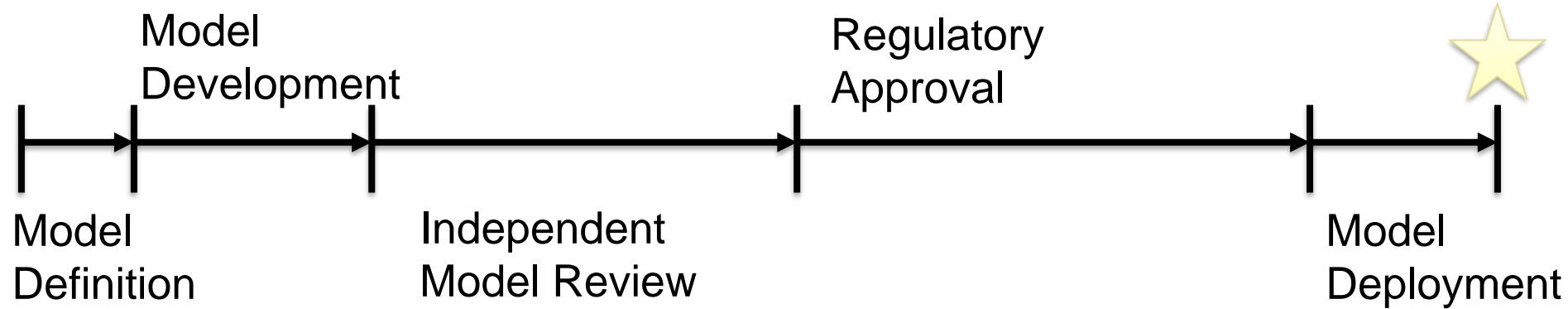
Learn About Model Types



Compare Models with a Variety of Evaluation Metrics

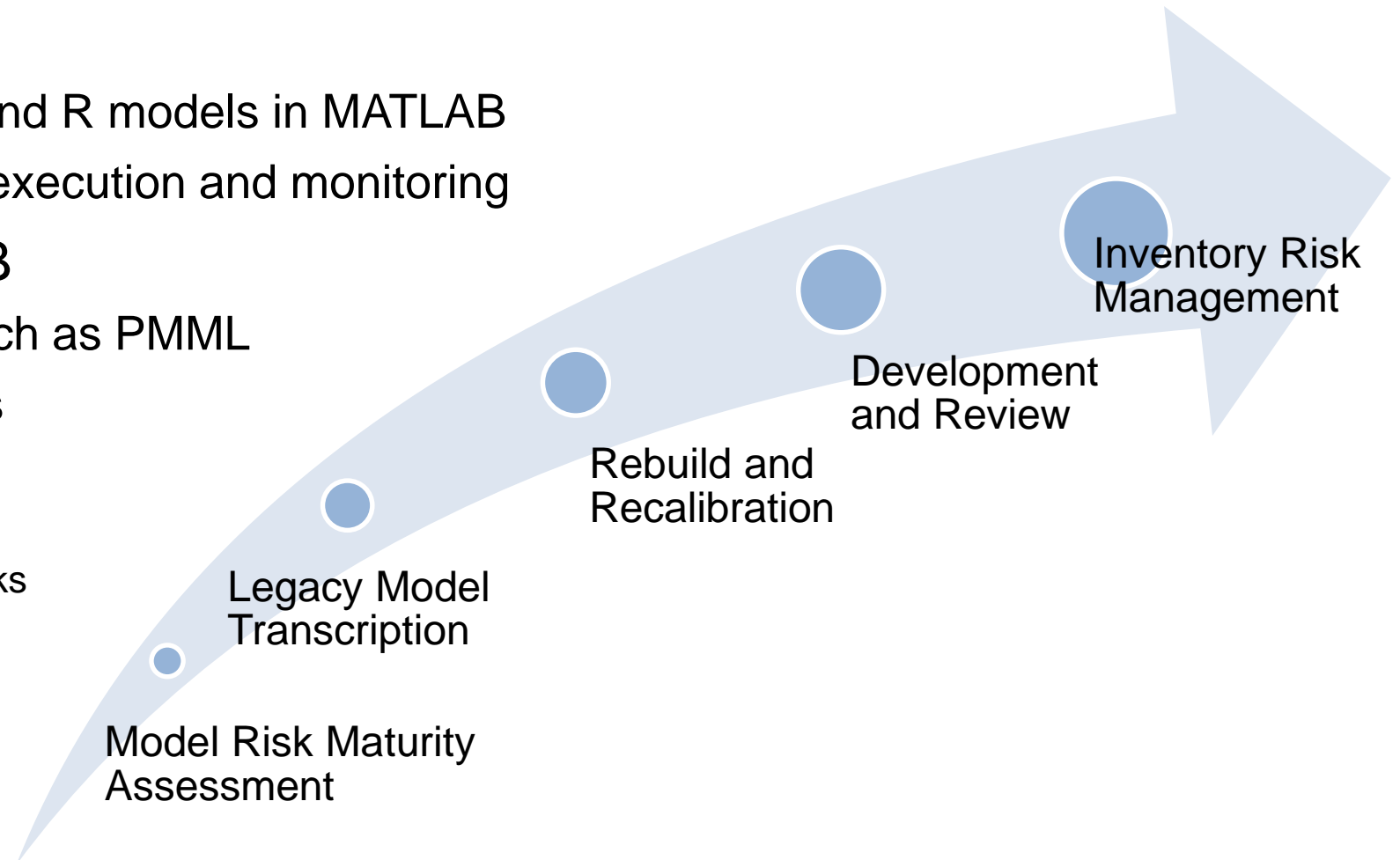


# Reducing the approval, deployment and refresh timeline



# Implementation Options for Existing Models

- Co-execution
  - Directly execute Python and R models in MATLAB
  - Supported for validation, execution and monitoring
- Transcription to MATLAB
  - Automated for formats such as PMML
  - Guidance for SAS models
    - Videos
    - Cheat-sheets
    - 1-1 sessions with MathWorks





# Implementation Challenges and Data Considerations

- Best-in-class tools embrace an Agile/DevOps approach
  - Version and configuration control is mandatory for traceability
  - Reviews, workflow, project management for complex software
- Support innovation in modelling
  - Reproducibility and performance across different platforms
  - Permit scrutiny and independent implementation
  - Reusing innovations in modelling and methodology in different tools
- Data considerations
  - Cleansing not always possible in source systems
  - Data modelling is not independent of risk modelling