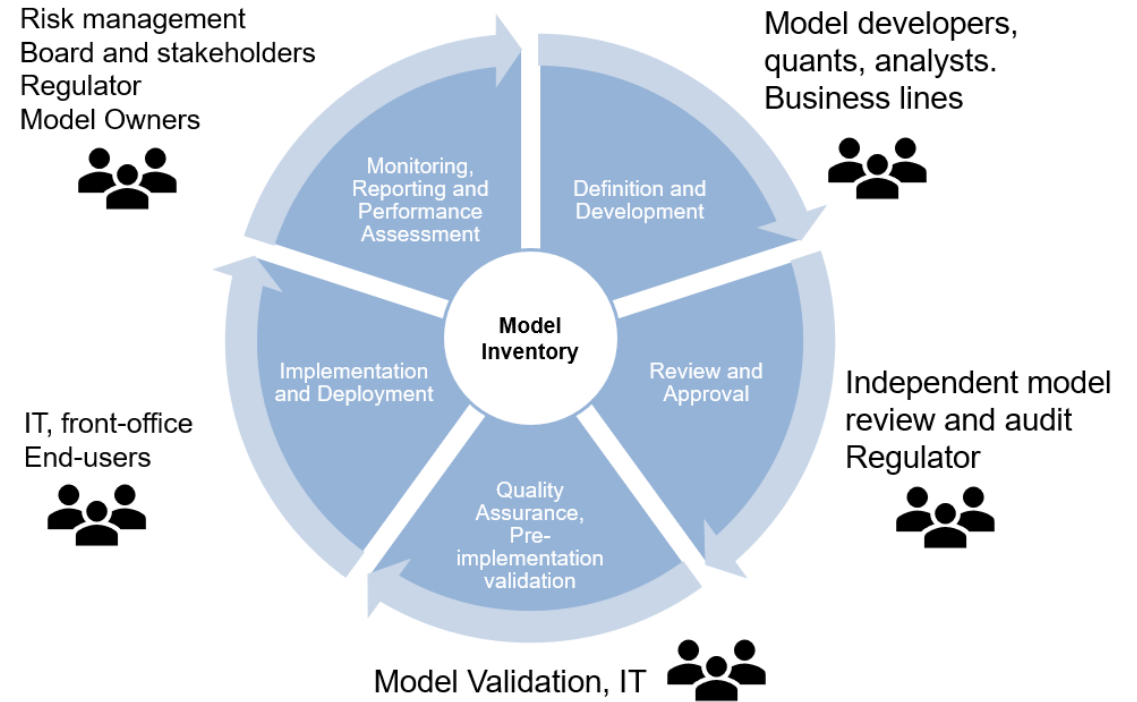


Risk Management Model Management Model Governance

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

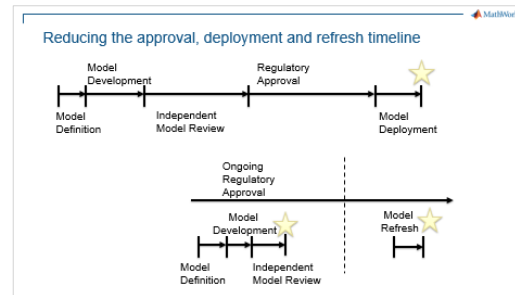
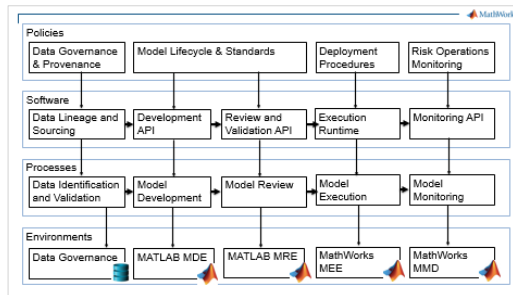
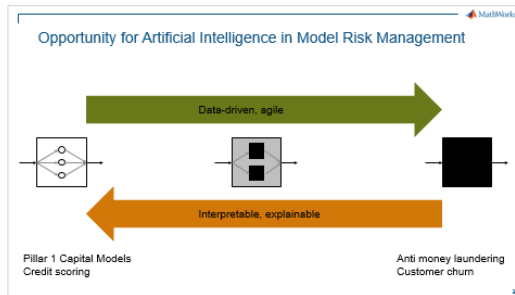
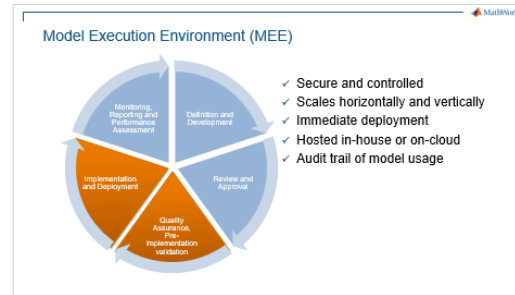
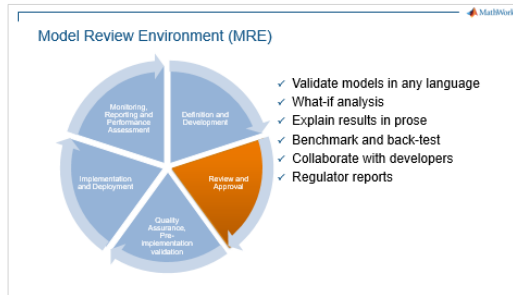
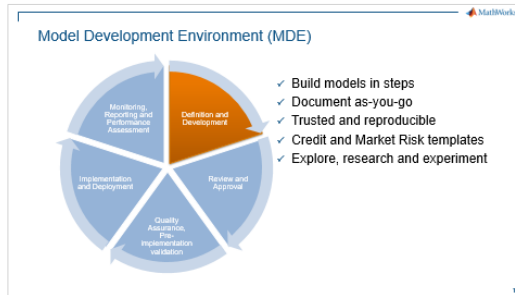
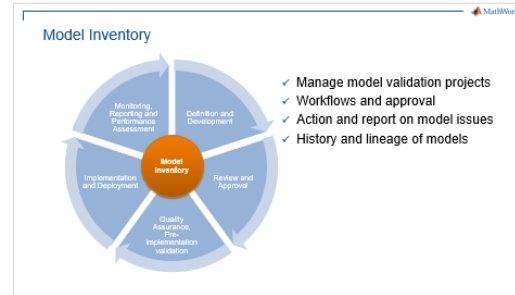
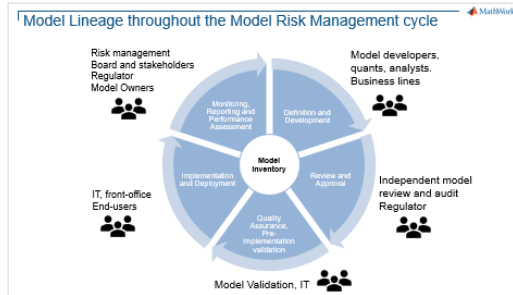
Model Risk Management with MATLAB

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



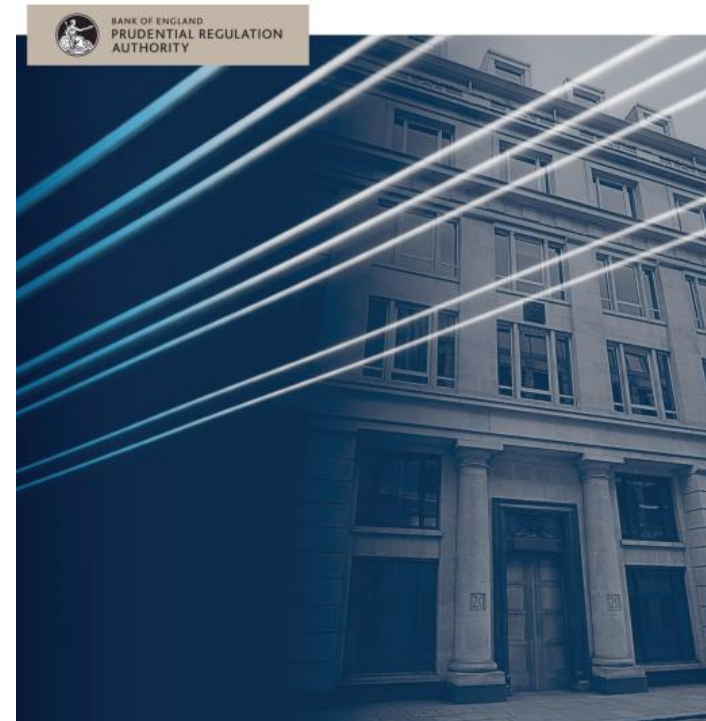
ECB guide to internal models

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 3rd party can implement
- Usage of models monitored on an ongoing basis

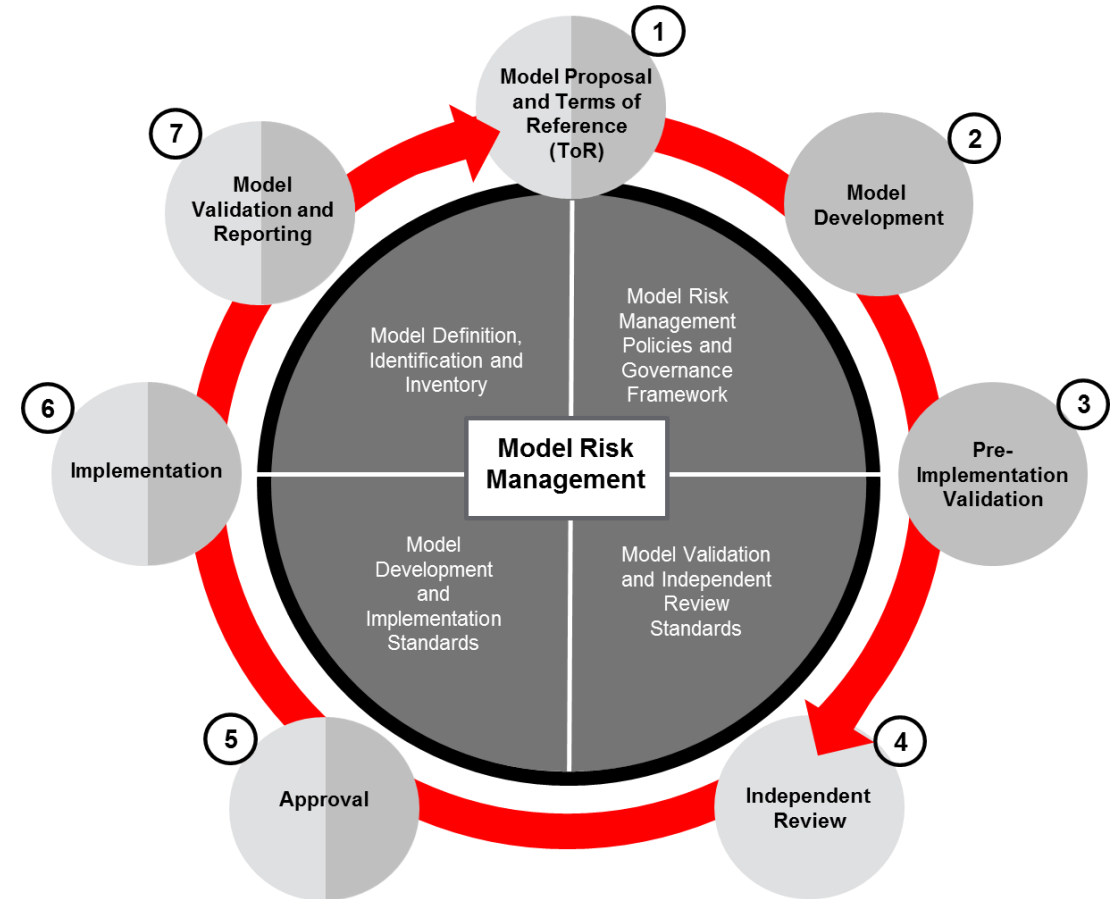
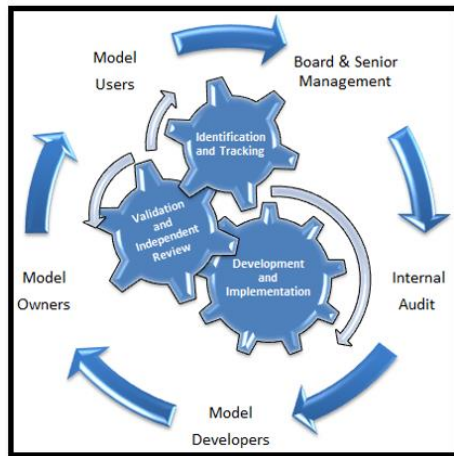
Model Risk Management Principles (SS 3/18)

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

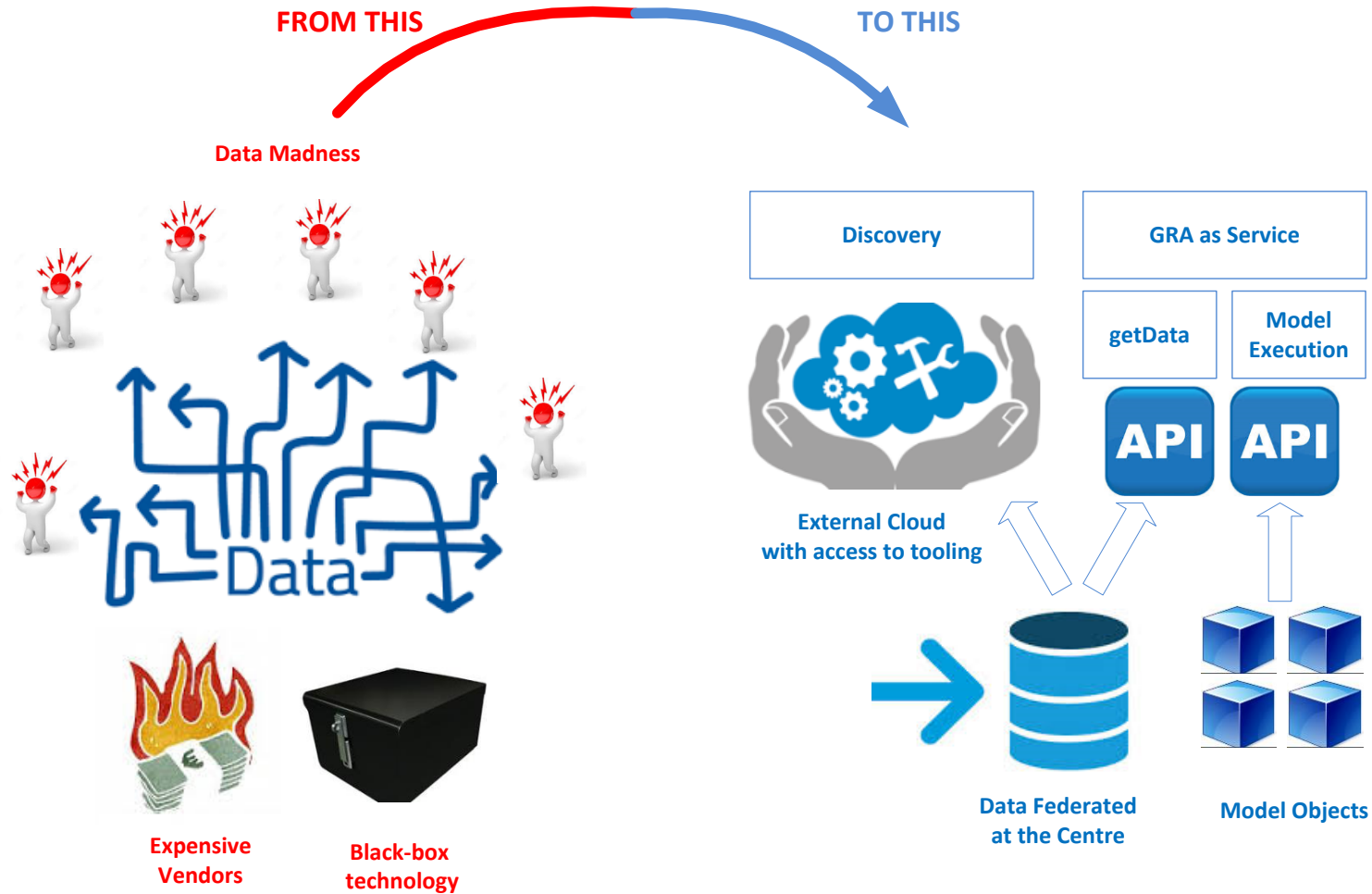
An effective model risk management framework is ...
an integrated and iterative process supported by a strong governance culture



Reality and Vision

Poor Quality Models
Regulatory Scrutiny
High Cost
Inconsistency
Frustrated Users

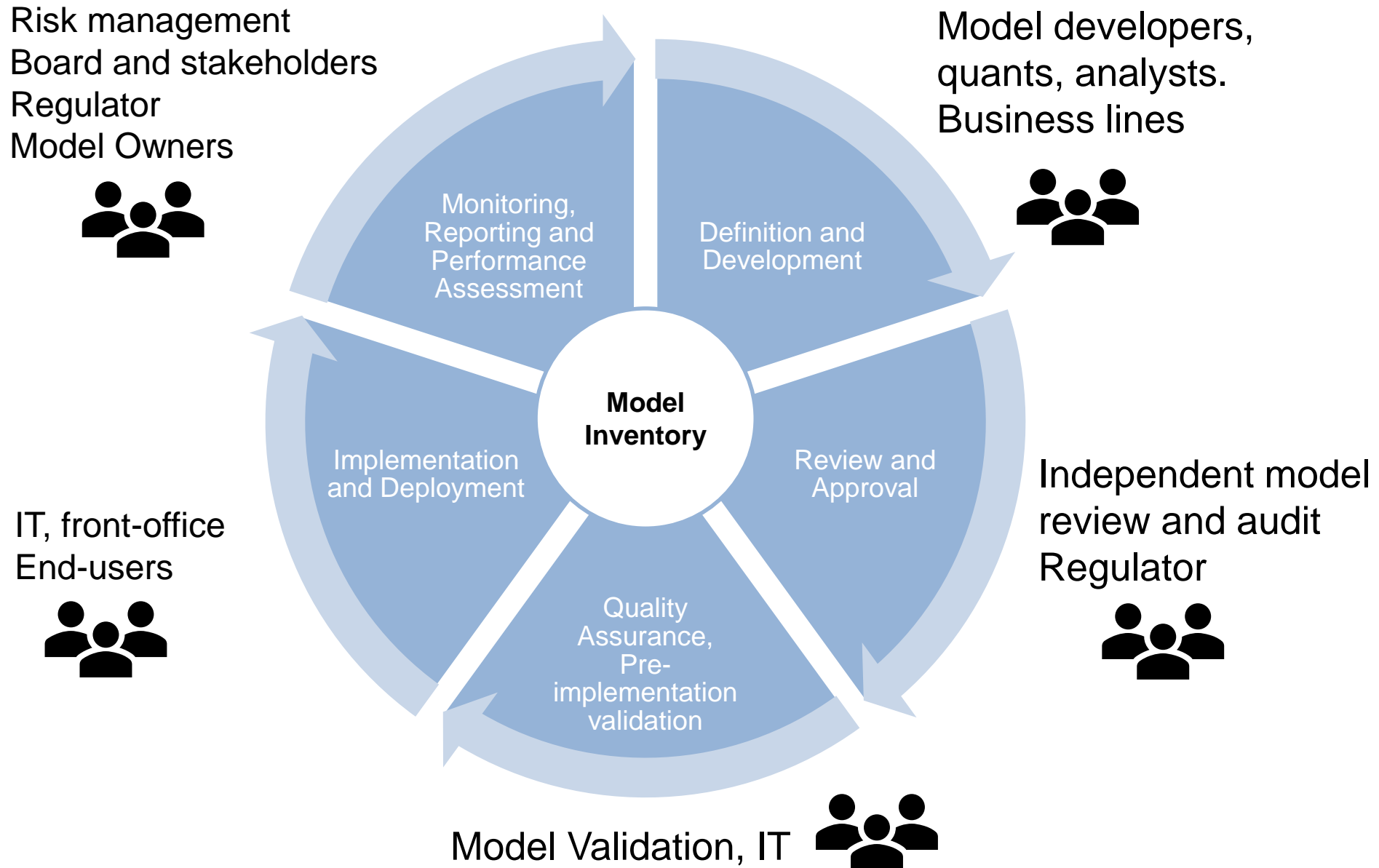
SDLC Vendor
Driven



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

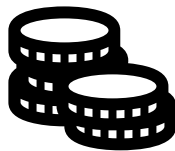
Agile/DevOps
Focused

Model Lineage throughout the Model Risk Management cycle



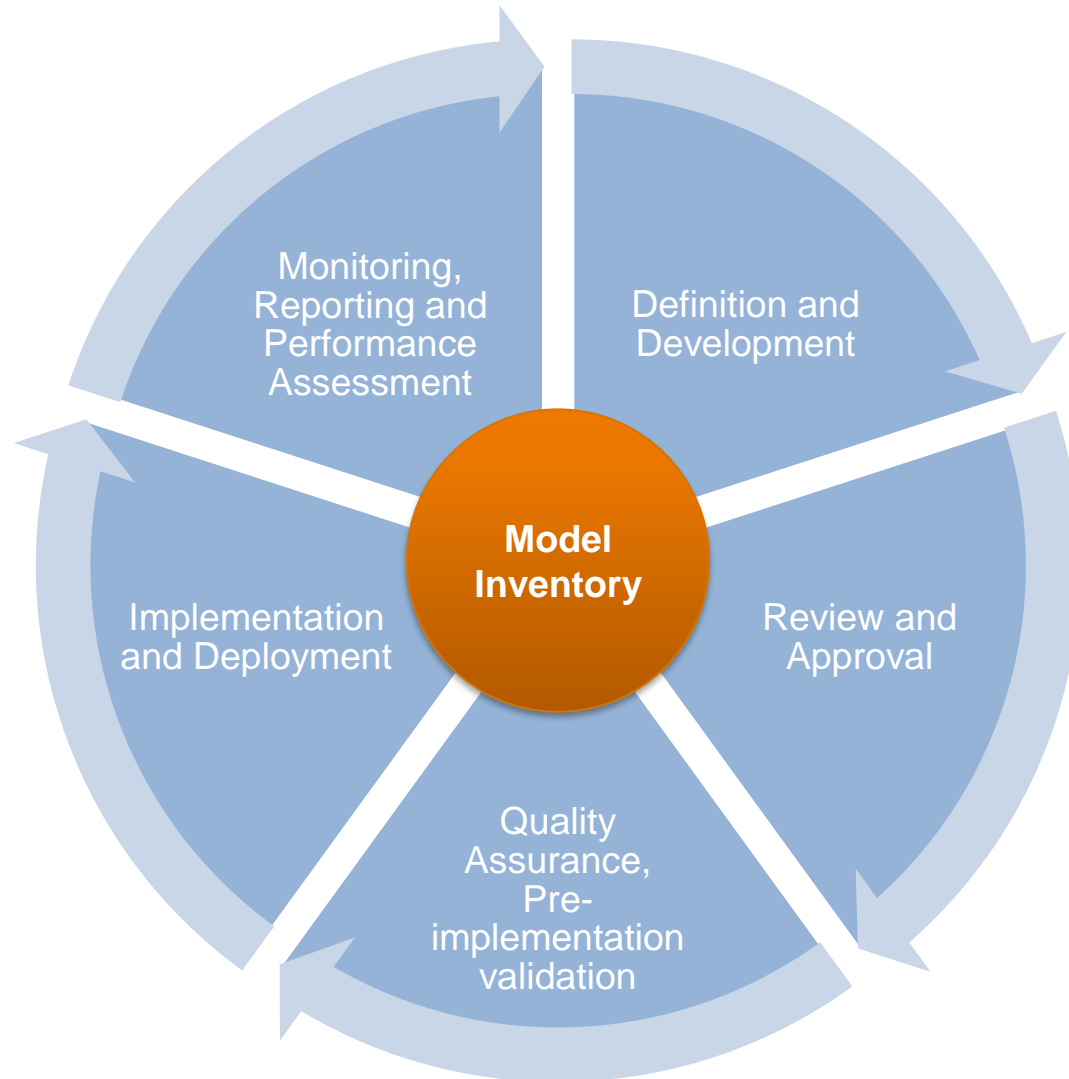
Opportunity for Cost Savings with Model Risk Management

- 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

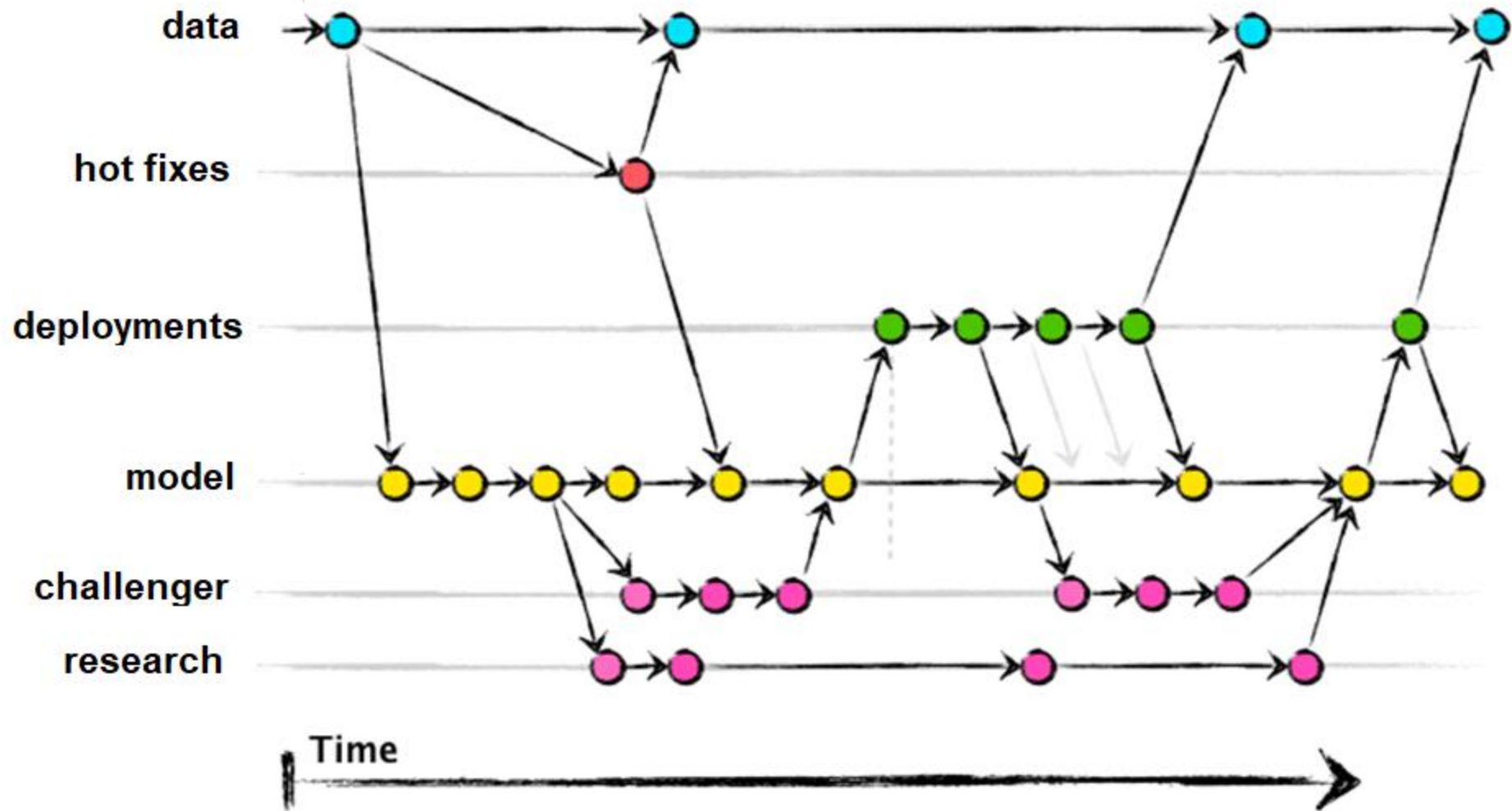
Vetting data quality

No unified data model or interpretation

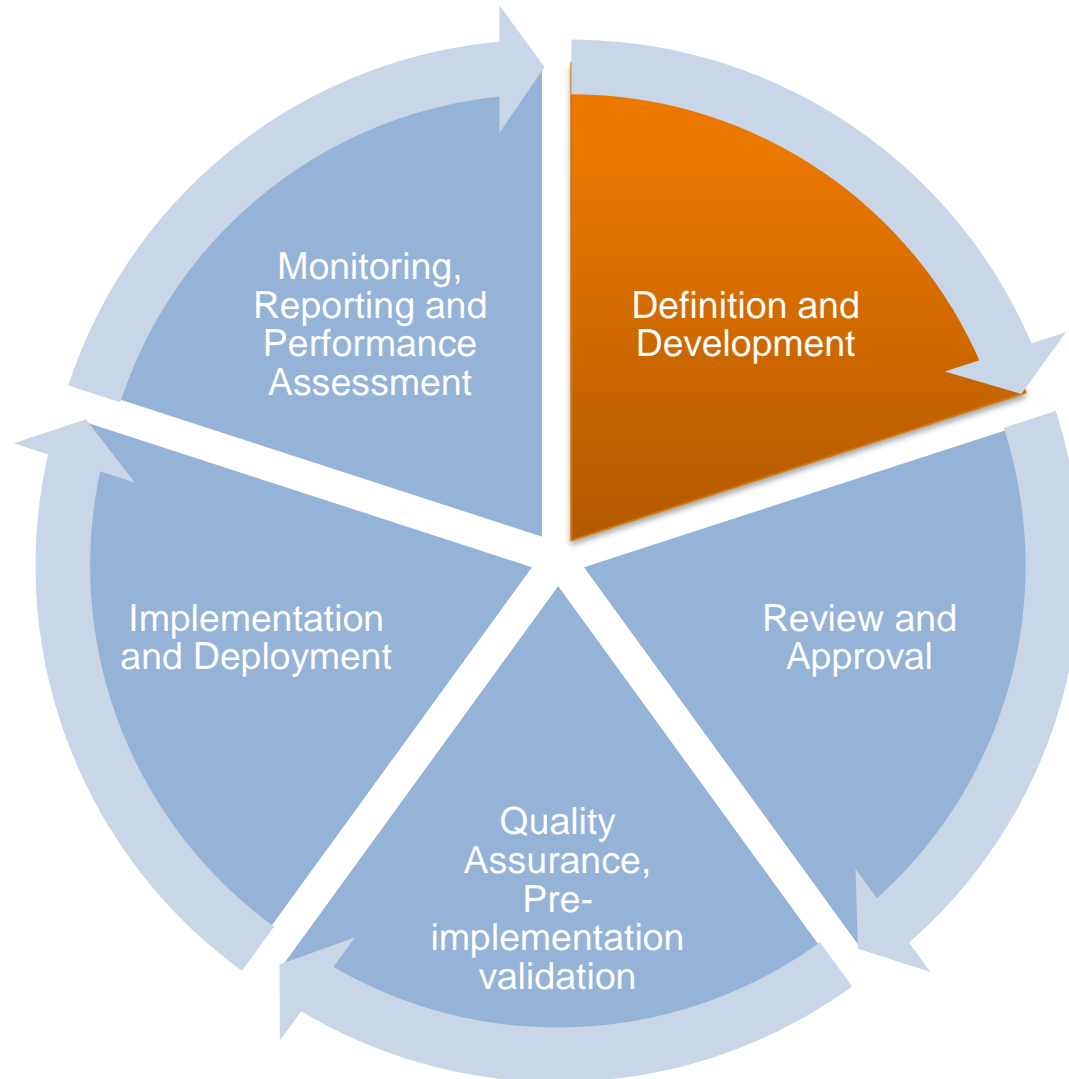
Inconsistent handling of data by location and over time

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)

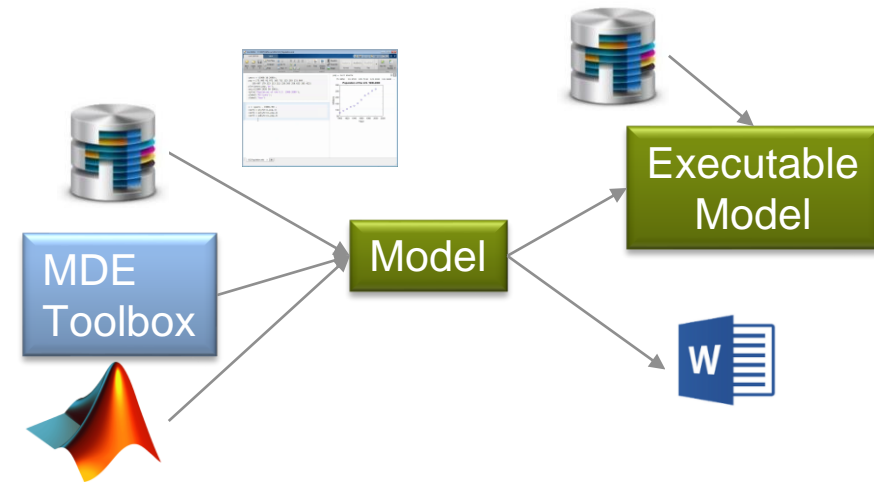
Mission: ***Improve the pace, transparency and reproducibility of the model development and review processes through user-friendly tools that encourage a consistent approach.***

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

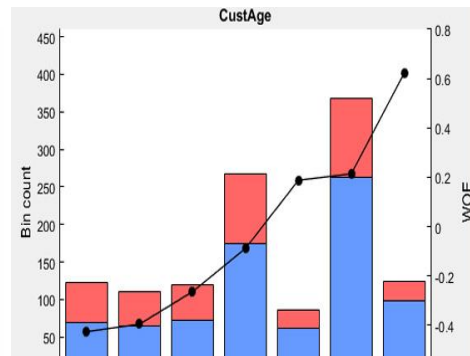


Building Models as a Sequence of Steps

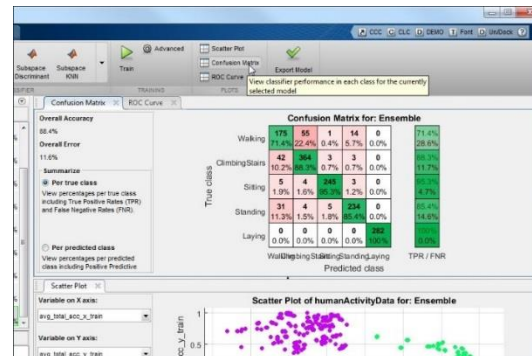
1. Data loading and pre-processing
2. Exploratory Data Analysis
3. Sampling and Segmentation
4. Feature Engineering
5. Train Models
6. Model Validation
7. Documentation
8. Deployment

	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

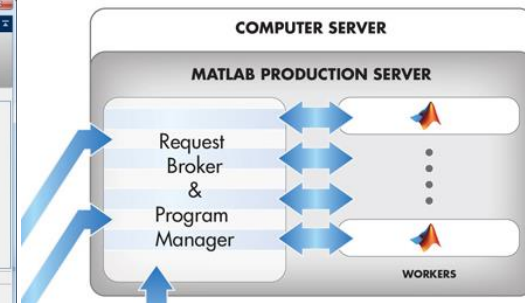
Access and Explore Data



Process Data and Create Feature

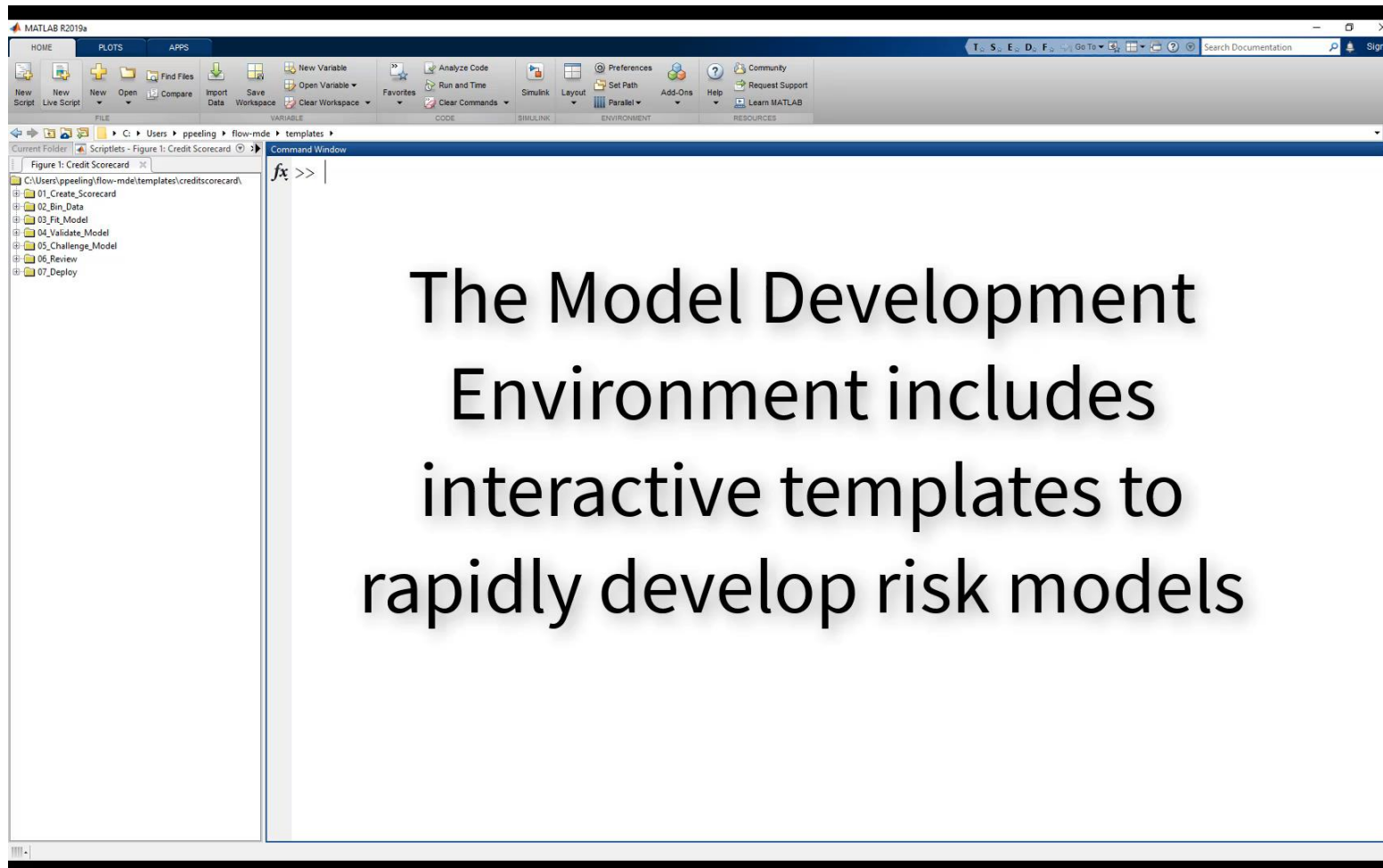


Build and Validate Models



Deploy Model Review Model

Building a credit scorecard

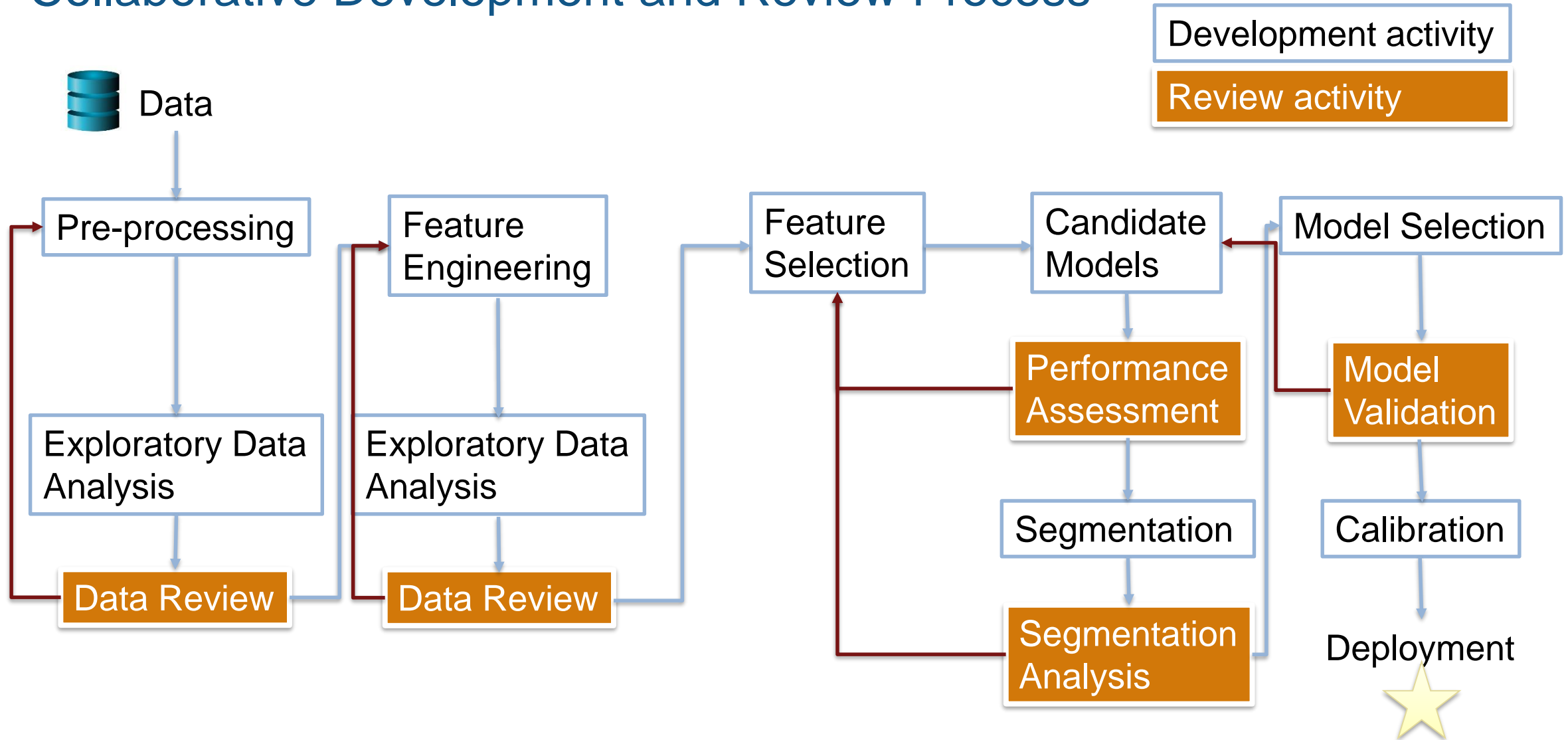


Model Review Environment (MRE)



- ✓ 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 columns. The left column 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 column contains a form titled 'Document Management Control' with the following sections:

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)			

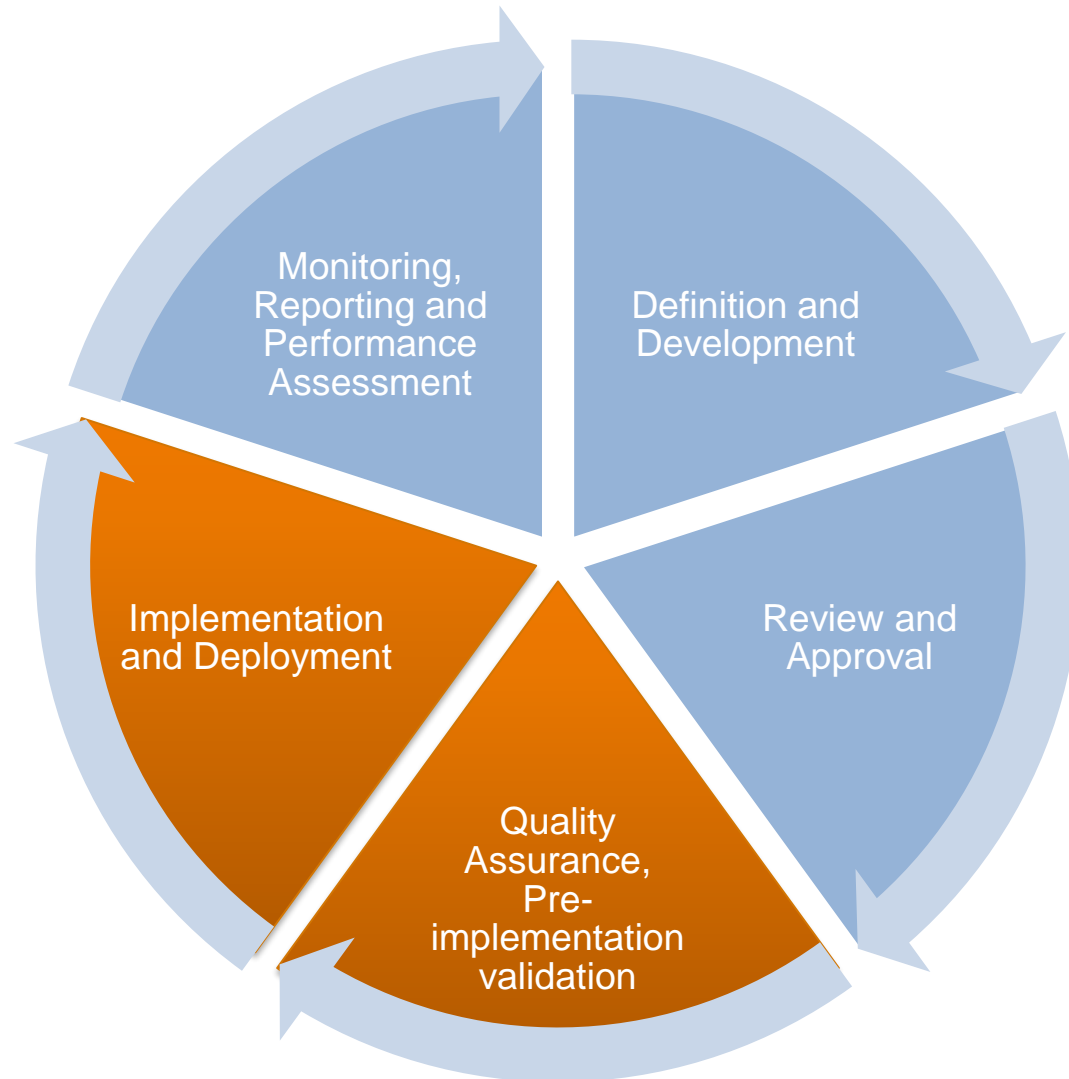
Document issue details

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

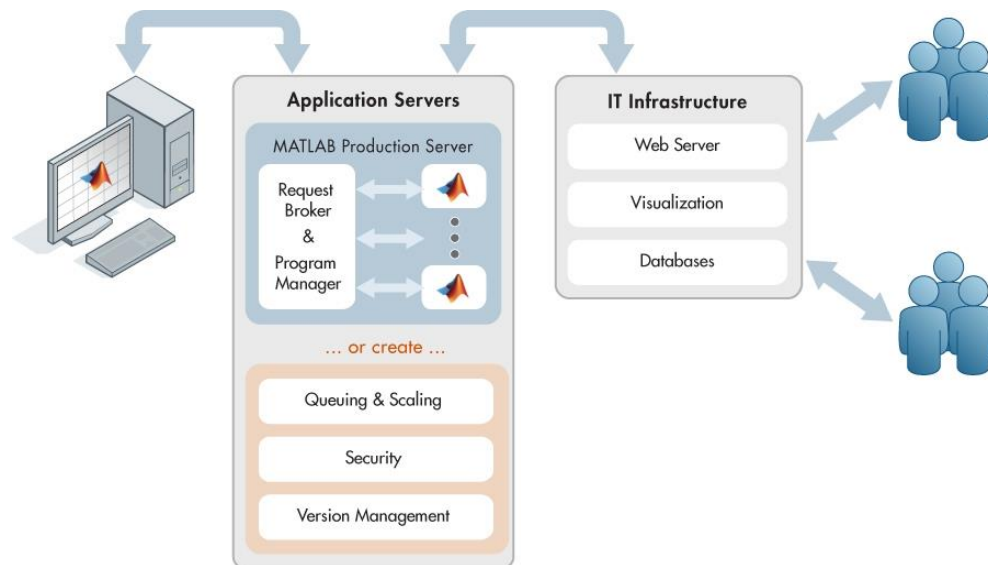
Model Execution Environment (MEE)



- ✓ 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. The header includes the logo and navigation links for **Home** and **About**. Below the header is a 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 are two data rows for rating events:

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

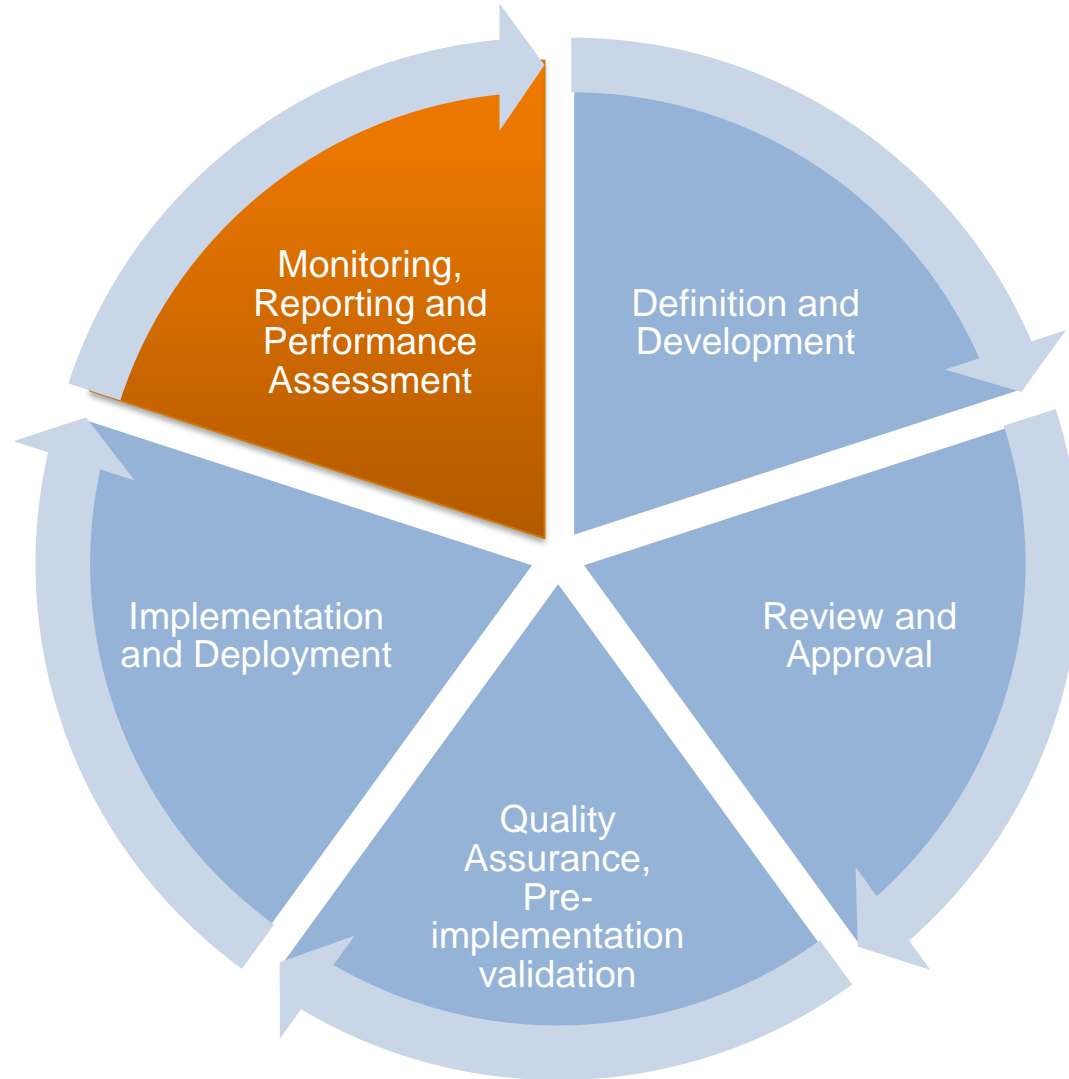
Below the table is a progress bar with four steps: **1 Rating Approach**, **2 Raw Rating**, **3 Modifiers**, and **4 Approval** (highlighted in red). Underneath, several key performance indicators are listed:

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

The **Operating Environment** section includes:

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

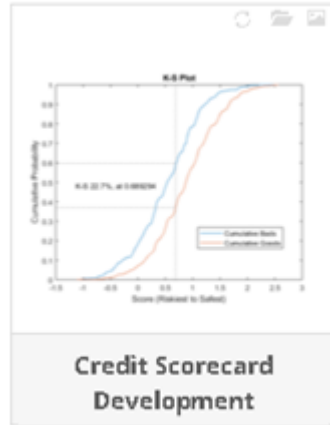
Model Monitoring Dashboard (MMD)



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

Model Monitoring Workflow

MDE



Publish

MEE

Rating Event	Proposed	Last Modified
CHABOUR CONTINENTAL FOR TRAD	4.2	07 Sep 2017 at 15:13:32 (43015601)
AATCO FOOD INDUSTRIES LLC	4.3	07 Sep 2017 at 14:56:43

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

App Designer

Analyse

Monitor

MMD
by MathWorks
Model Monitoring Dashboard for Model Risk Management
version 1.0

MMD

Deploy

Model Monitoring

pppeeling logout about support

Model Health Credit Scorecard Monitoring VaR Monitoring

Model Health Dashboard

Executor Status

Executors

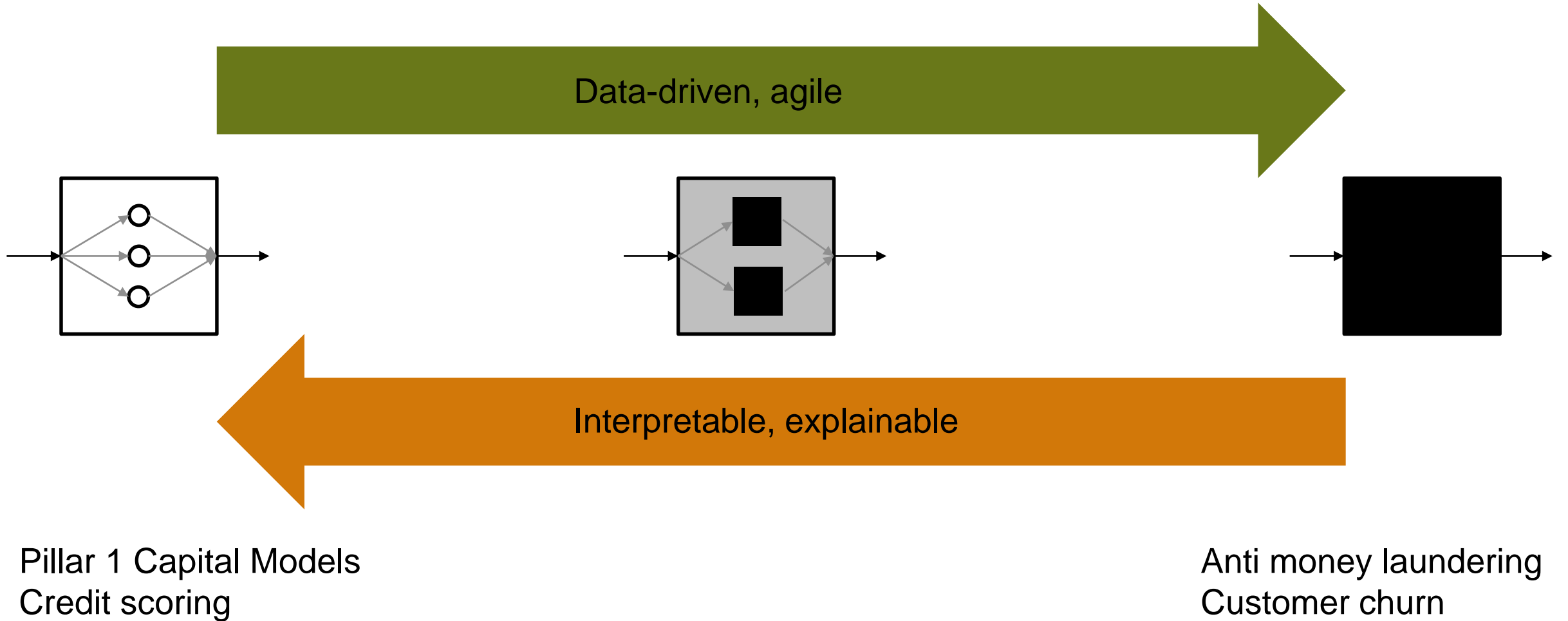
Pipeline

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

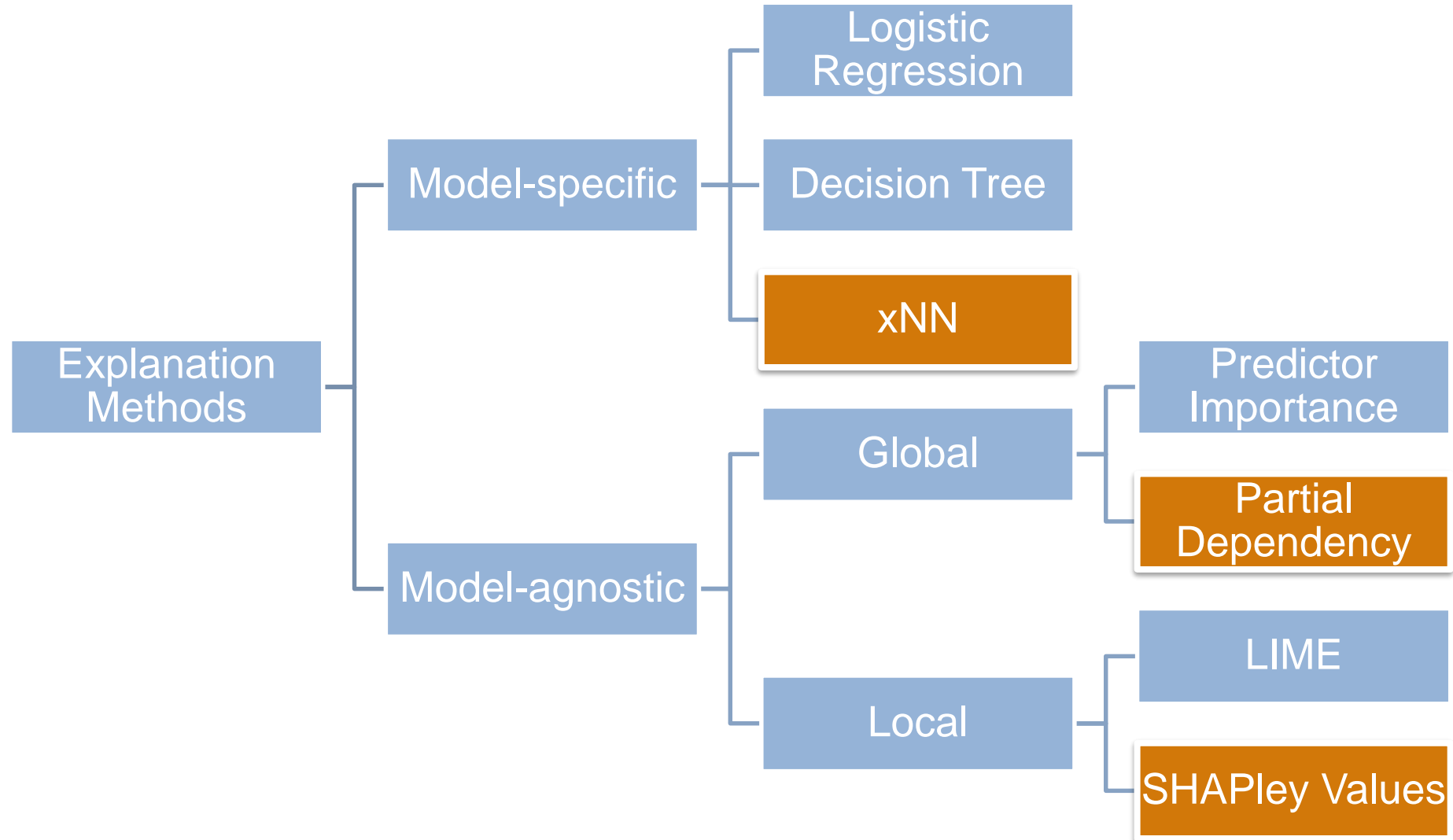
Opportunity for Artificial Intelligence in Model Risk Management



Pillar 1 Capital Models
Credit scoring

Anti money laundering
Customer churn

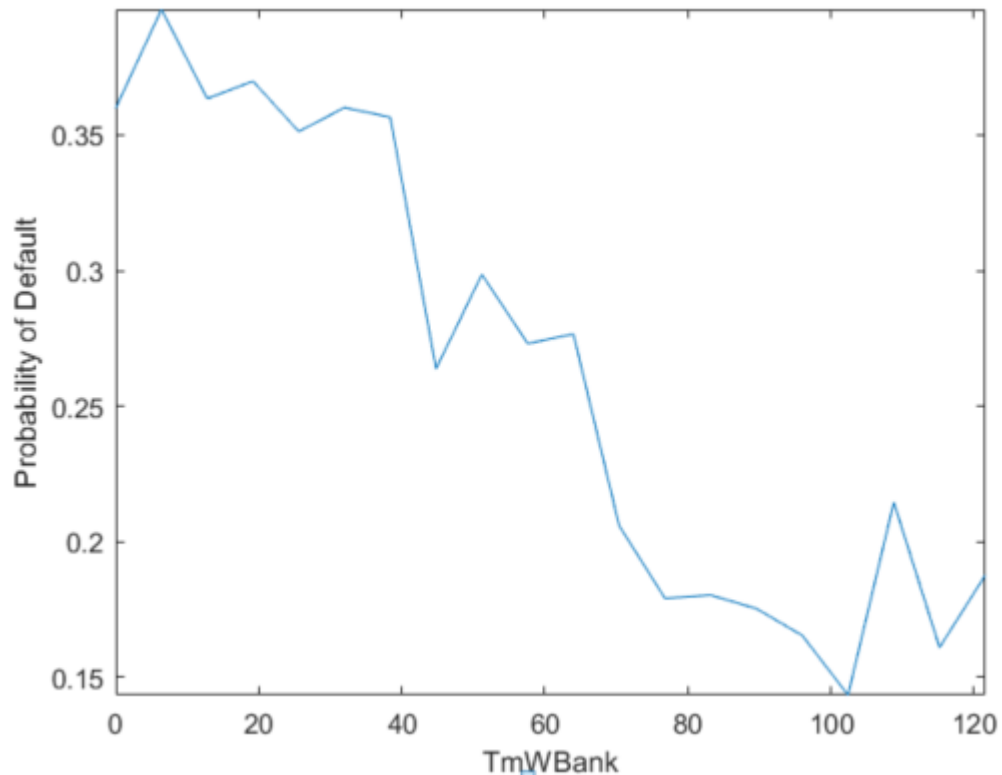
Explaining Machine Learning



Explaining Machine Learning

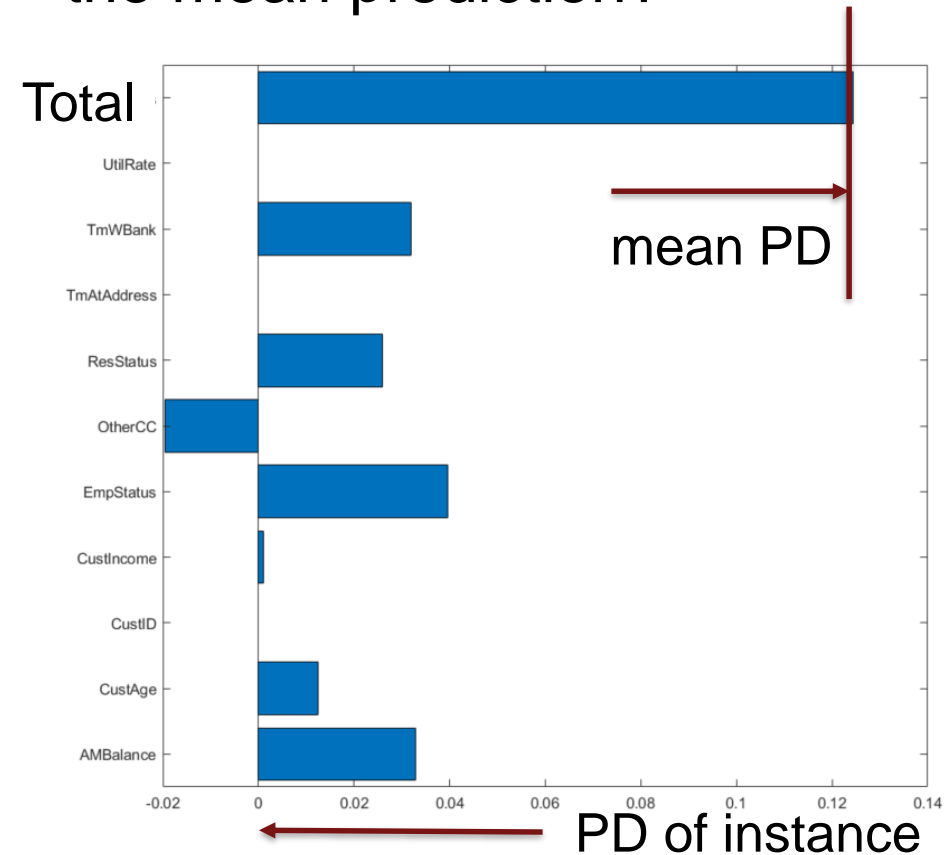
Partial Dependency Plots

Marginal effect of a feature on the prediction

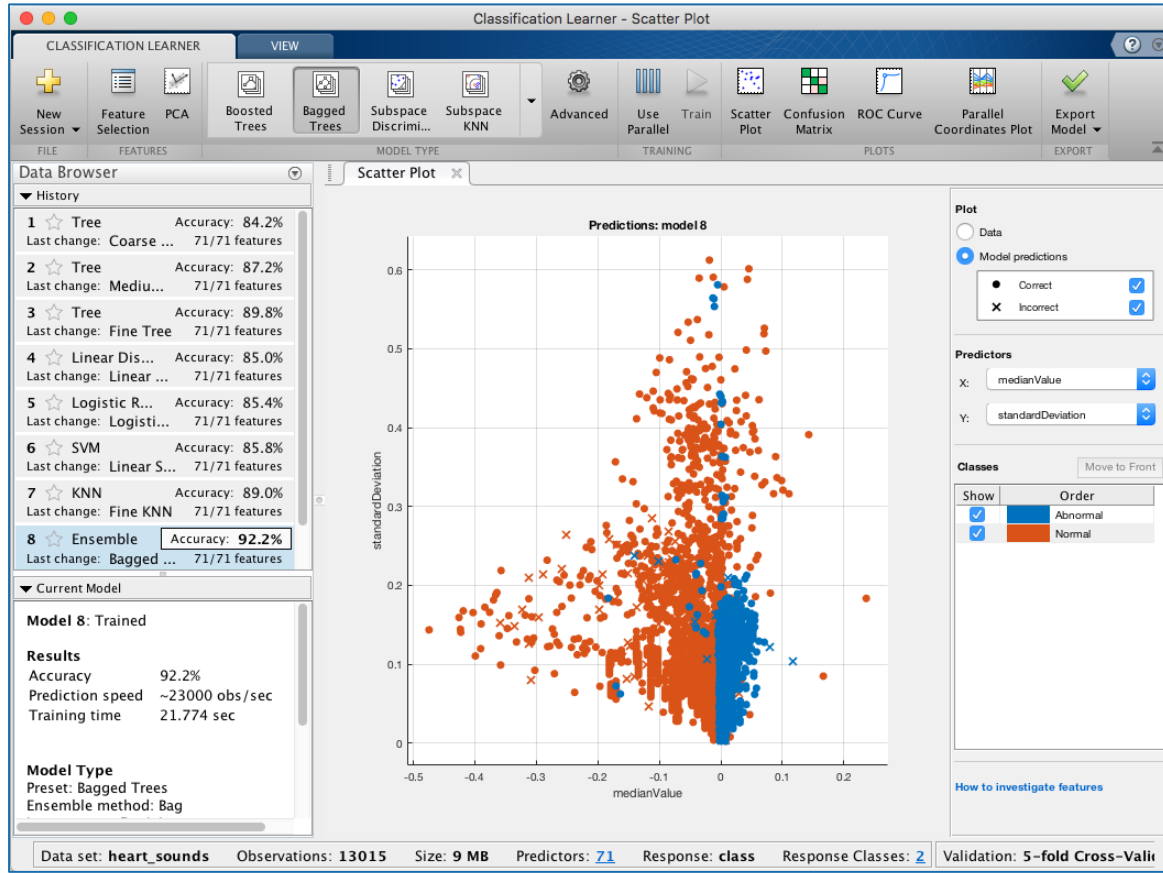


SHAPley Values

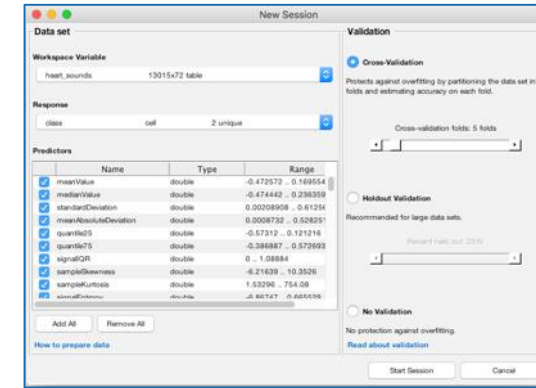
How far is the instance away from the mean prediction?



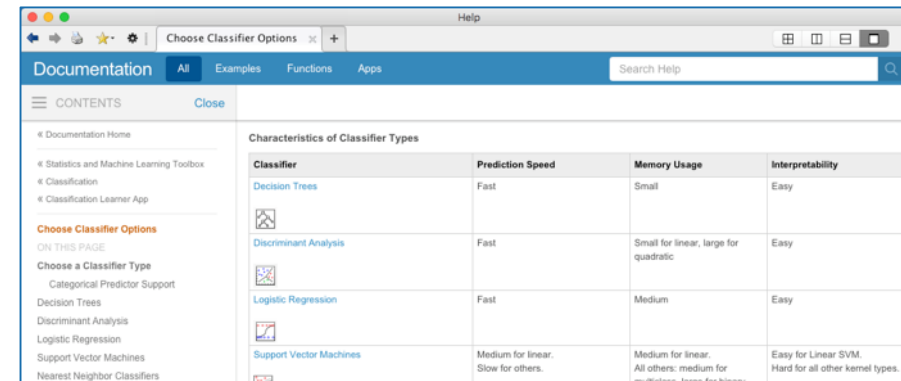
Machine Learning **Ease-of-Use**



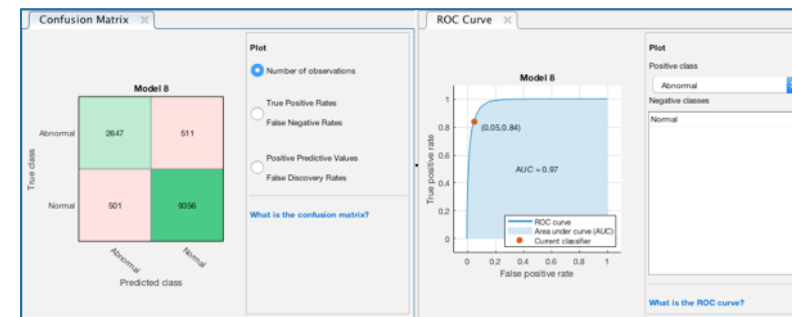
Classification Learner app



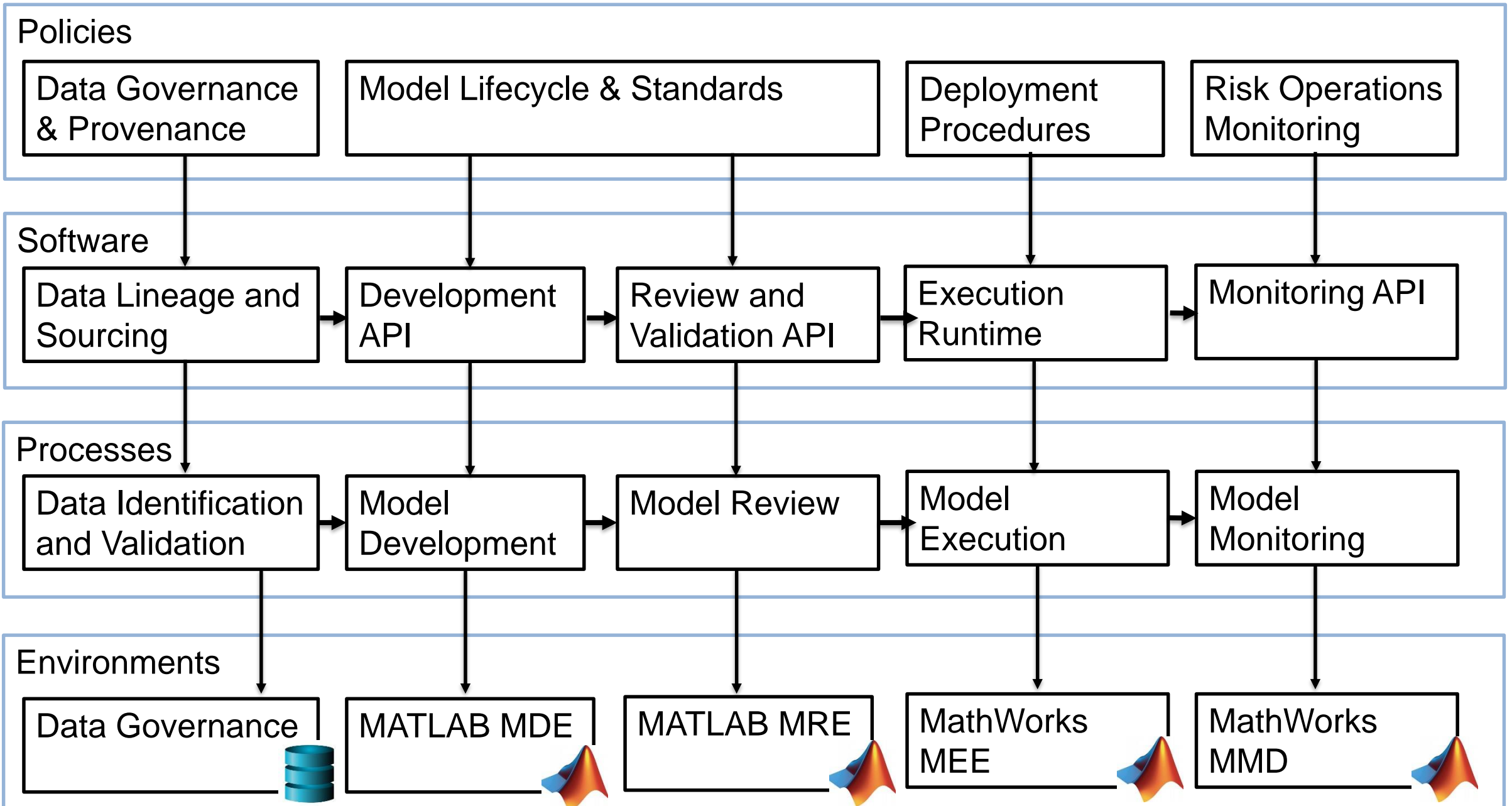
Protect Against Overfitting



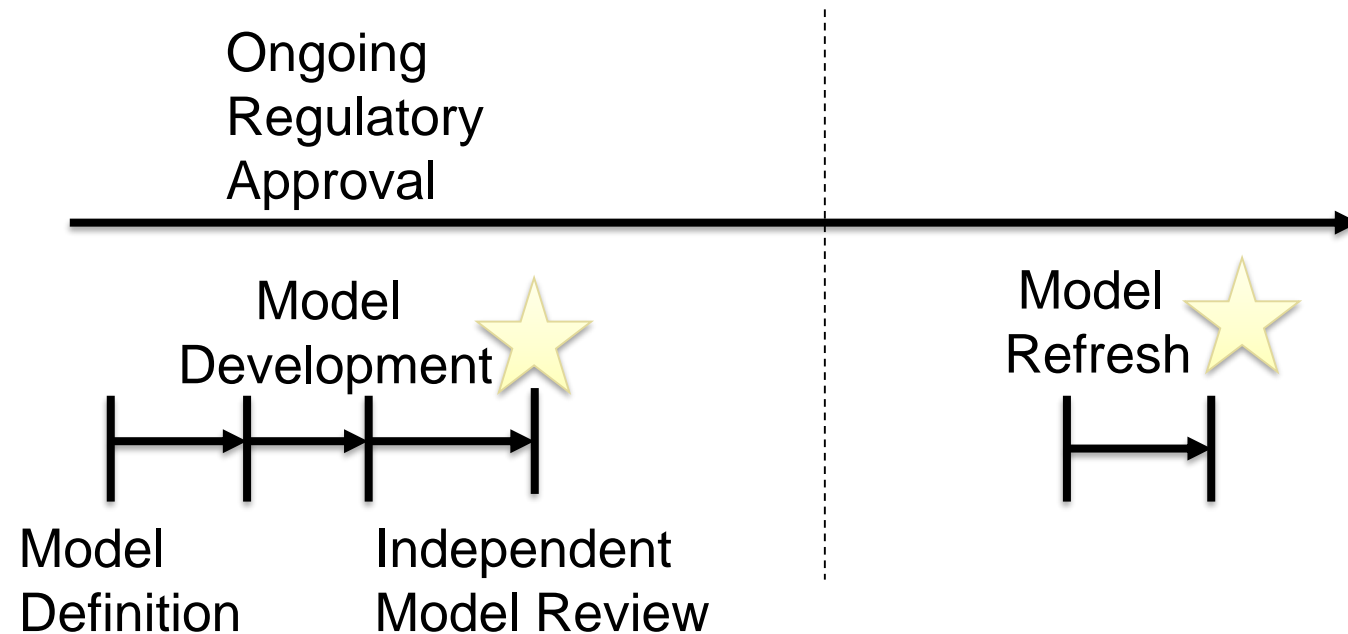
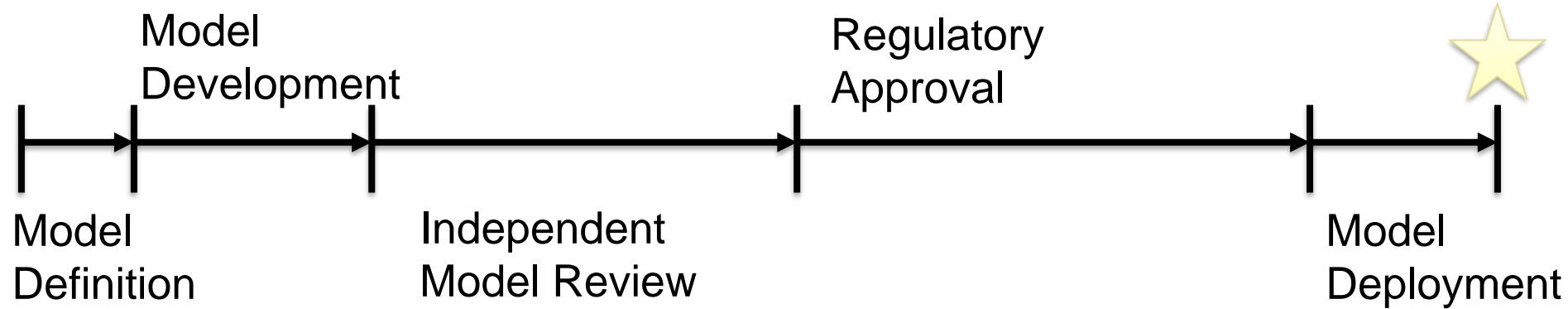
Learn About Model Types



Compare Models with a Variety of Evaluation Metrics

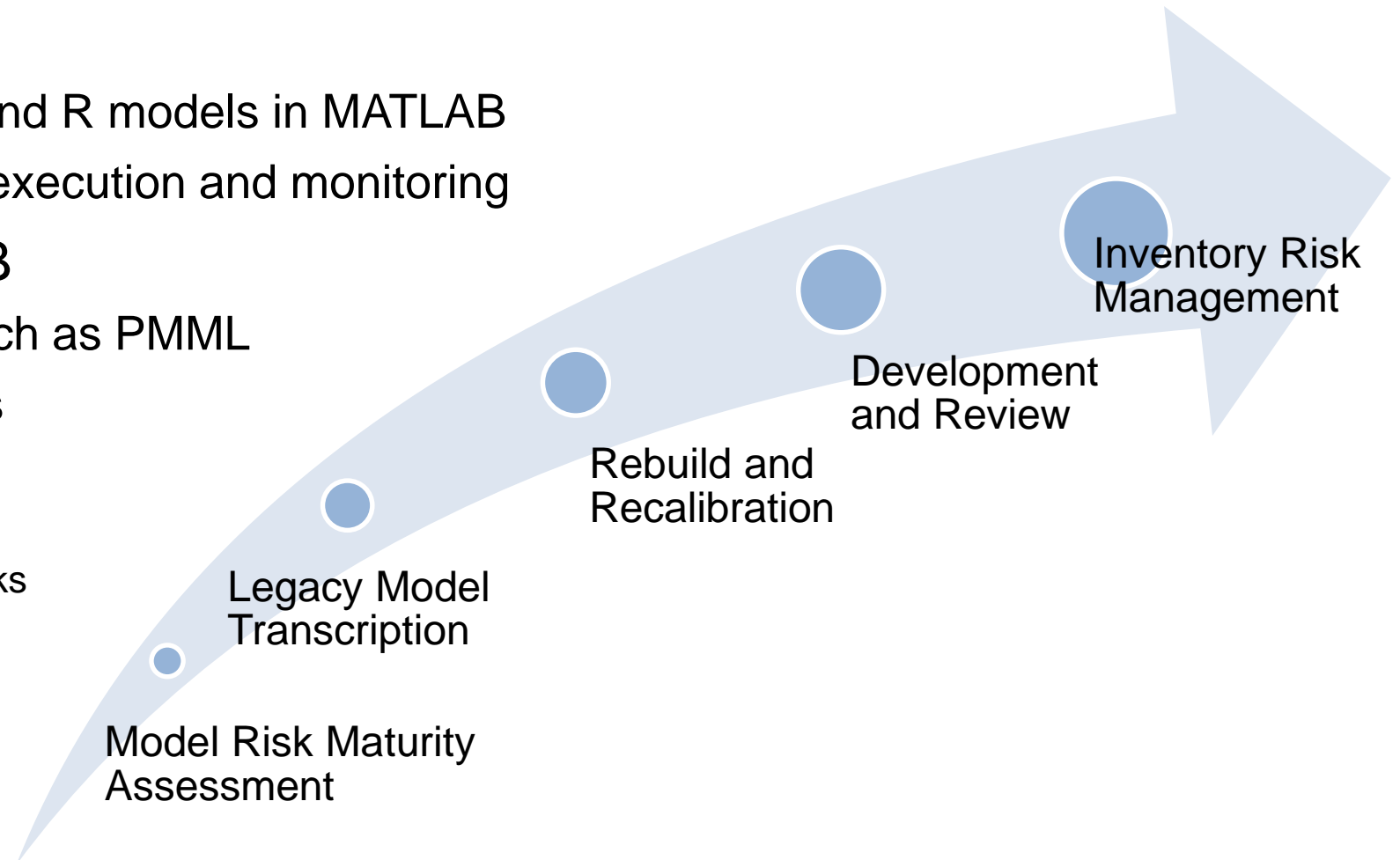


Reducing the approval, deployment and refresh timeline



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