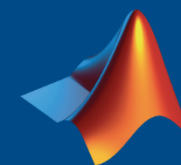


The Model Risk Manager's and Model Validator's Toolbox

MathWorks Computational Finance Conference

Paul Peeling

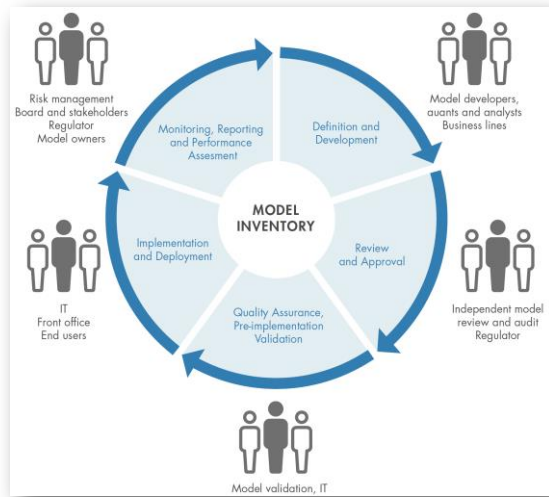
September 27th 2021



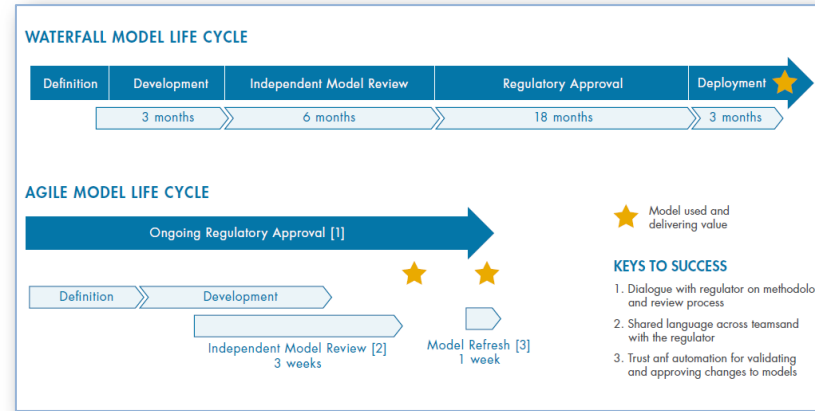
MathWorks®

Accelerating the pace of engineering and science

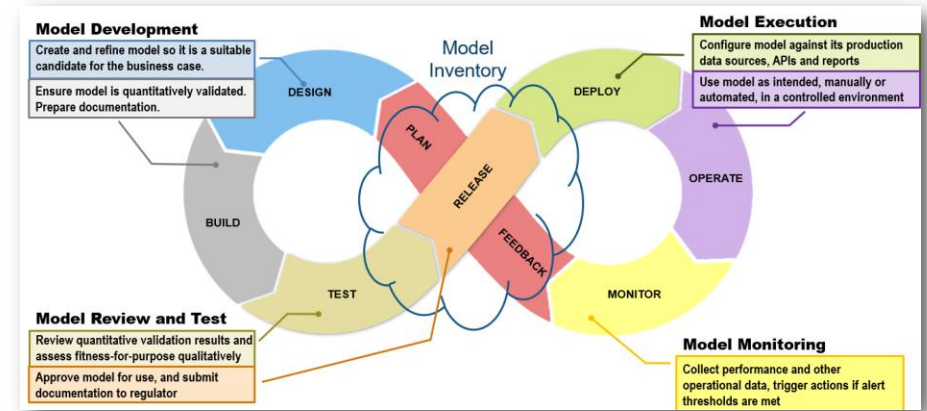
MathWorks helps you manage model risk with a platform and technology for your entire organization.



Model Governance

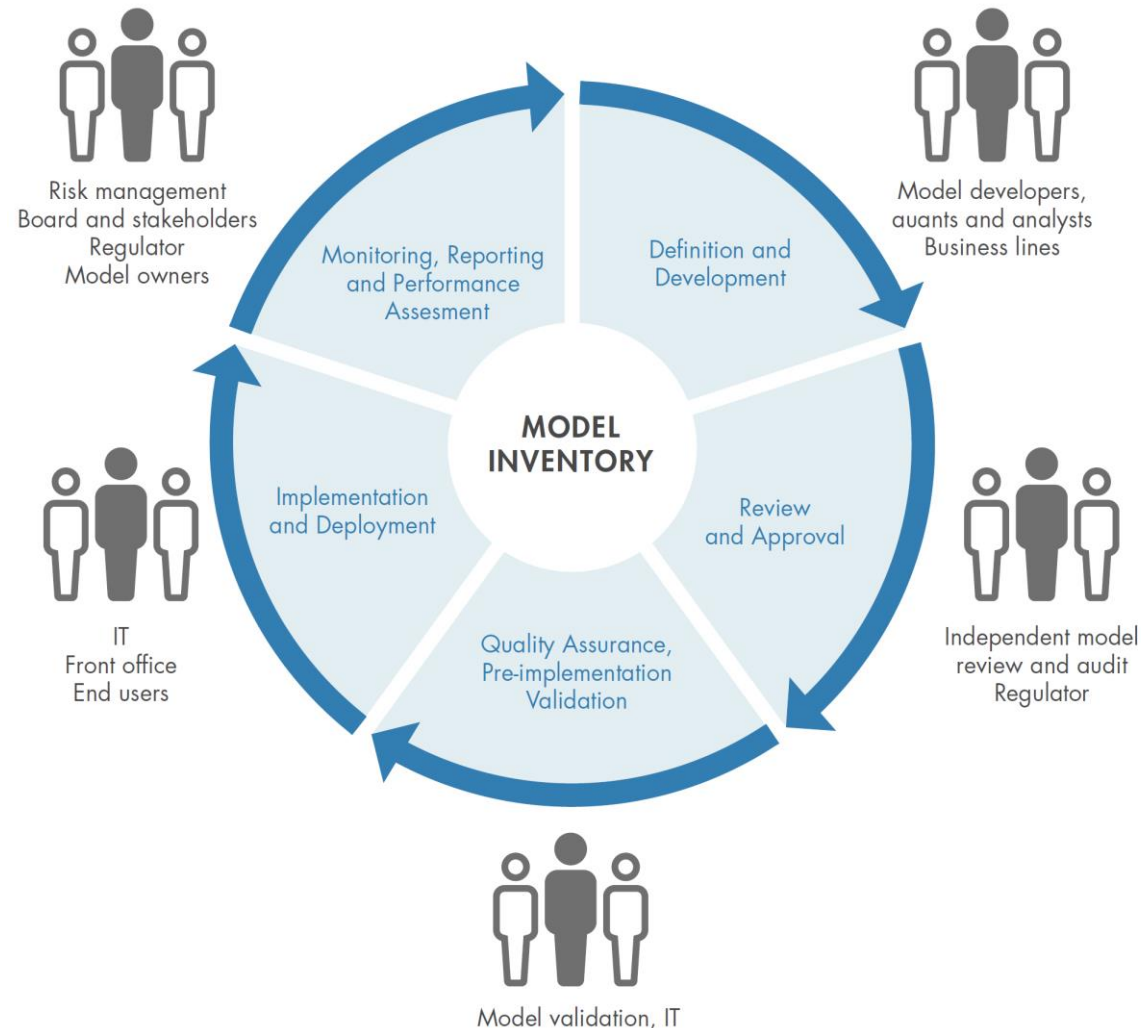


Model Validation



Model DevOps

Many teams, users and stakeholders collaborate to bring a model from research to production.

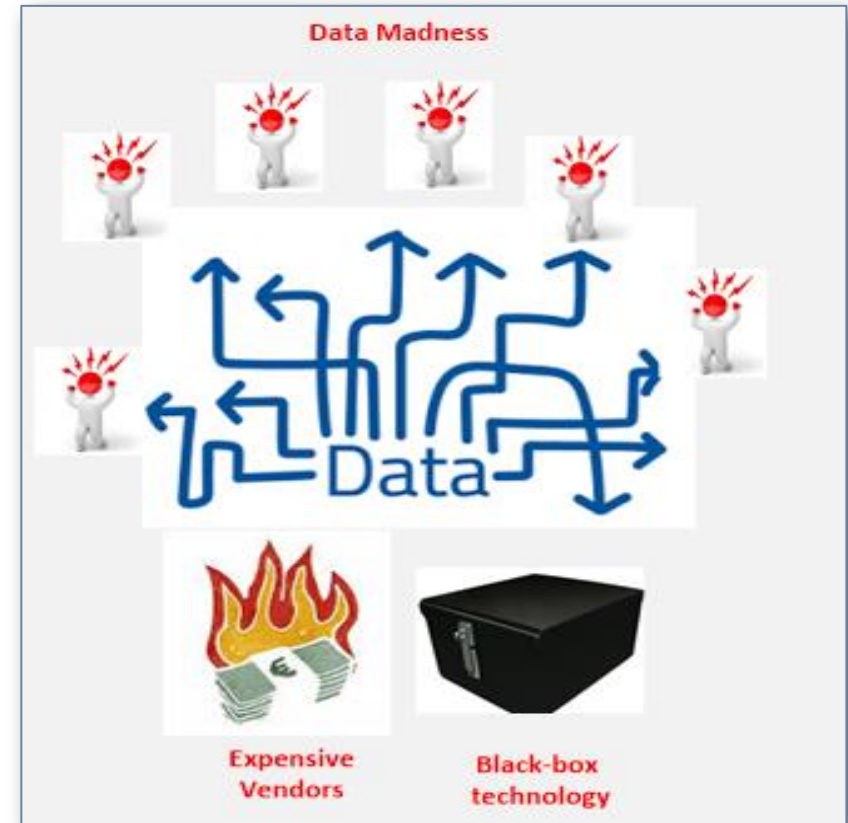


The 1st and 2nd lines of defence have well defined roles and responsibilities.

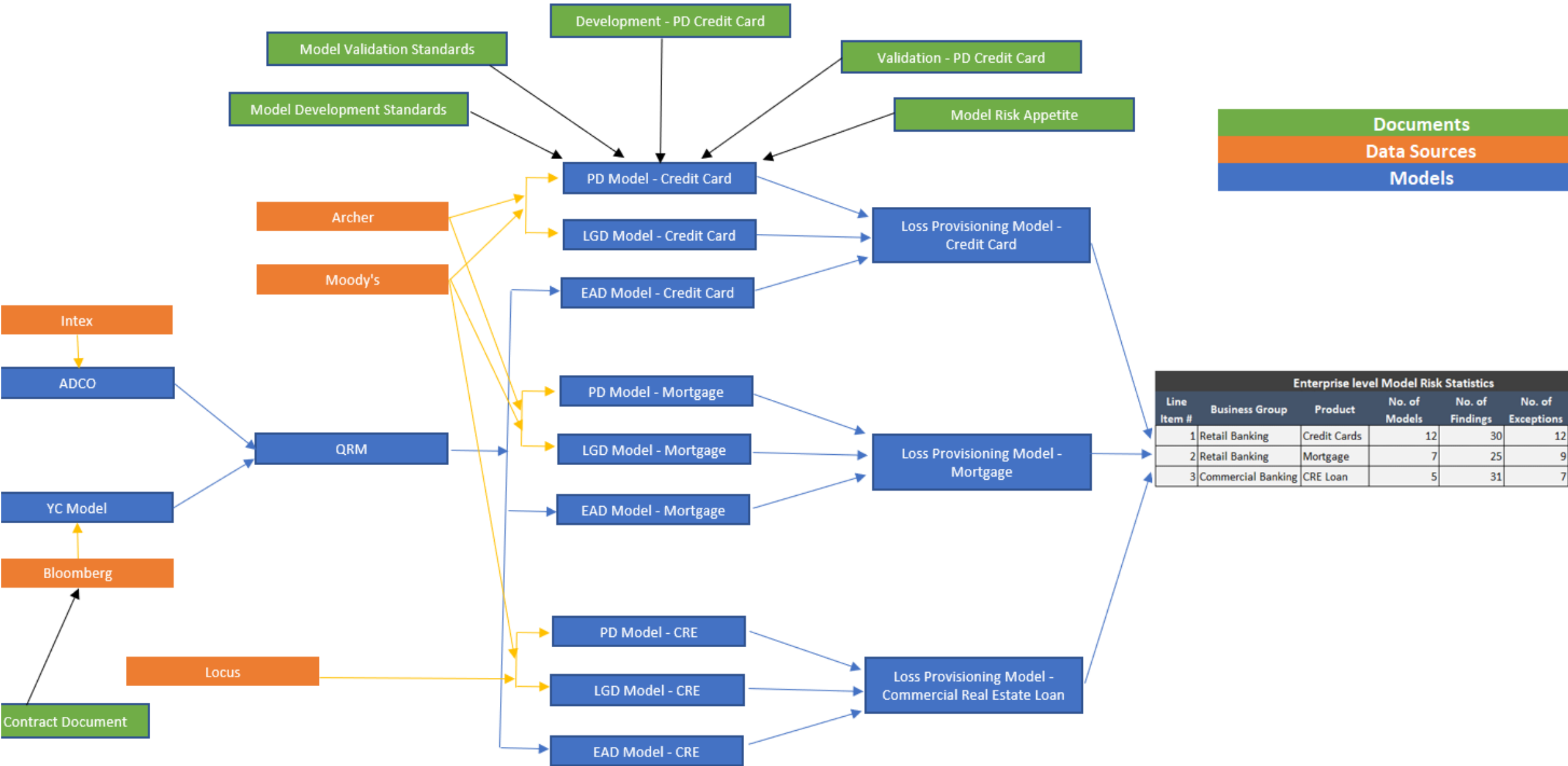
The business, quants and IT are involved throughout.

It is difficult to reach a sustainable and cost-effective MRM strategy if tools and processes are not coordinated.

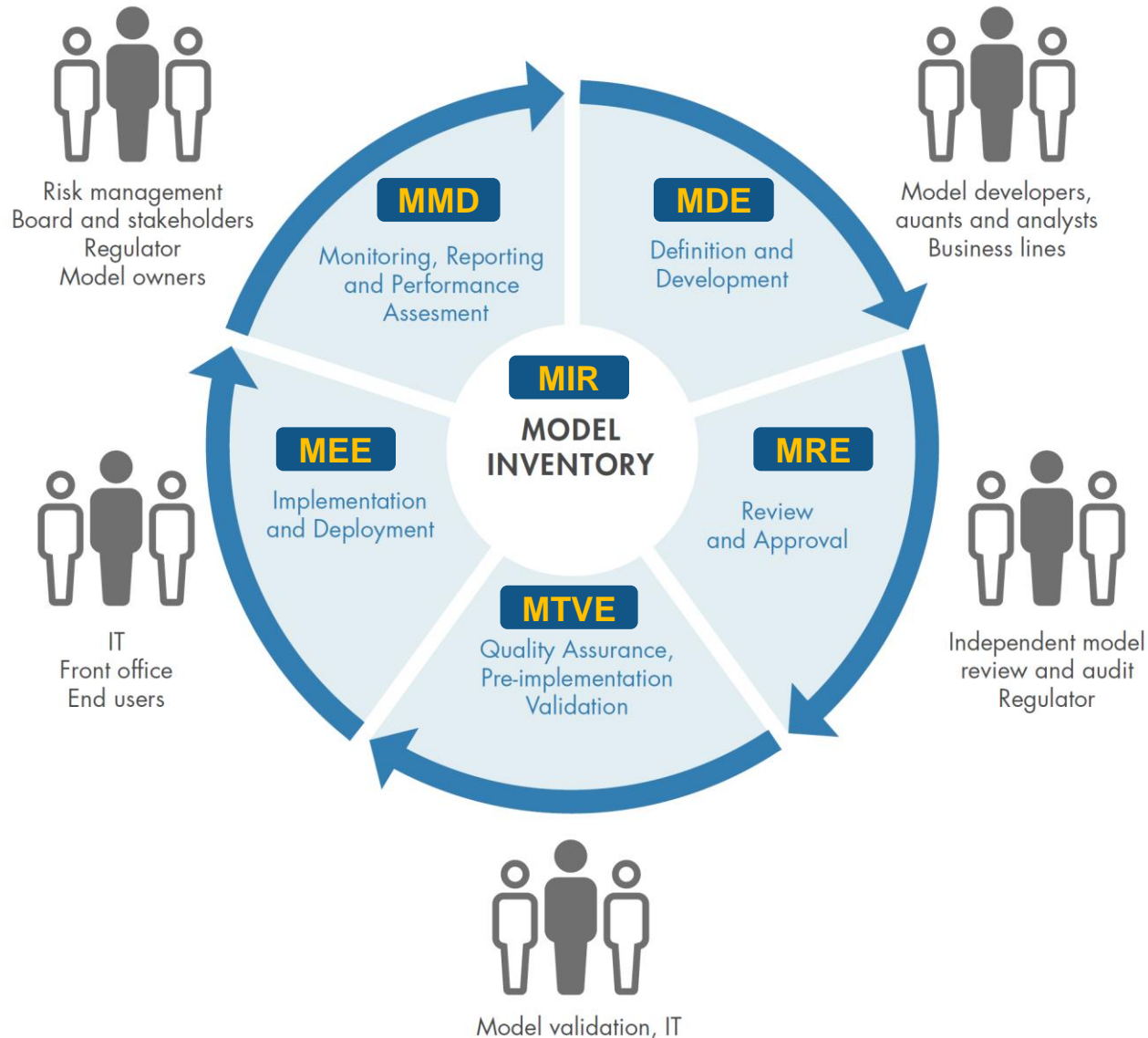
- Poor quality models
- Regulatory scrutiny
- High cost
- Inconsistency
- Frustrated users
- Low automation



Risk Management is a complex system with interconnected parts.



The MathWorks Model Risk Management Solution supports all users and every step of a model's lifecycle.



Model Inventory & Repository (MIR)

Centralized access to models, lineage, audit trail, risk scoring, and model risk reporting

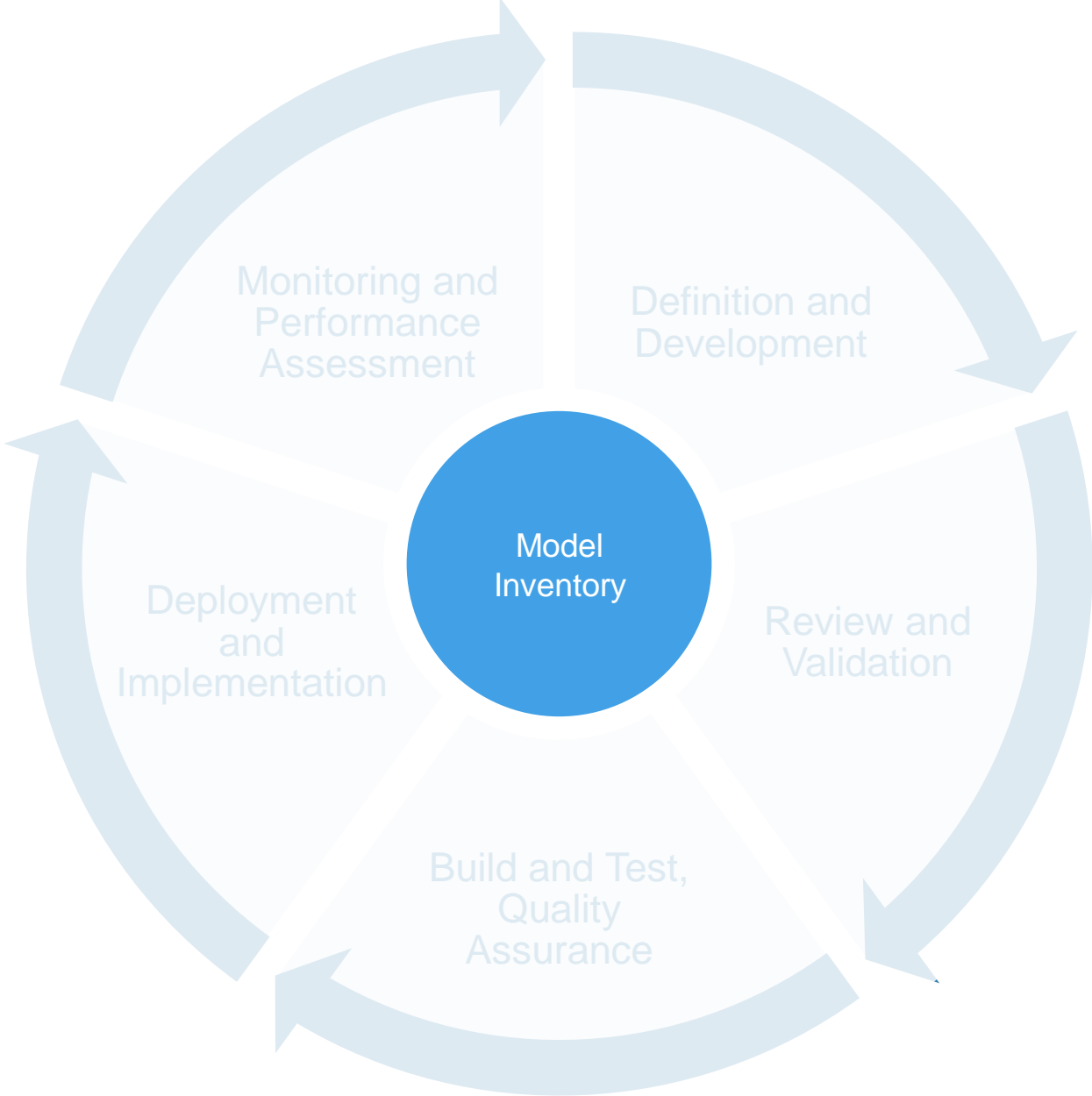
Model Development Environment (MDE)

- Explore, develop, back-test, and document models and methodologies
- Improve transparency and reproducibility of model development process
- Create reusable model templates
- Auto-generate model documentation

Model Review Environment (MRE)

- Perform independent model reviews
- Perform interactive what-if and sensitivity analysis on model parameters
- Comment and flag various aspects for response and resolution

Model Inventory

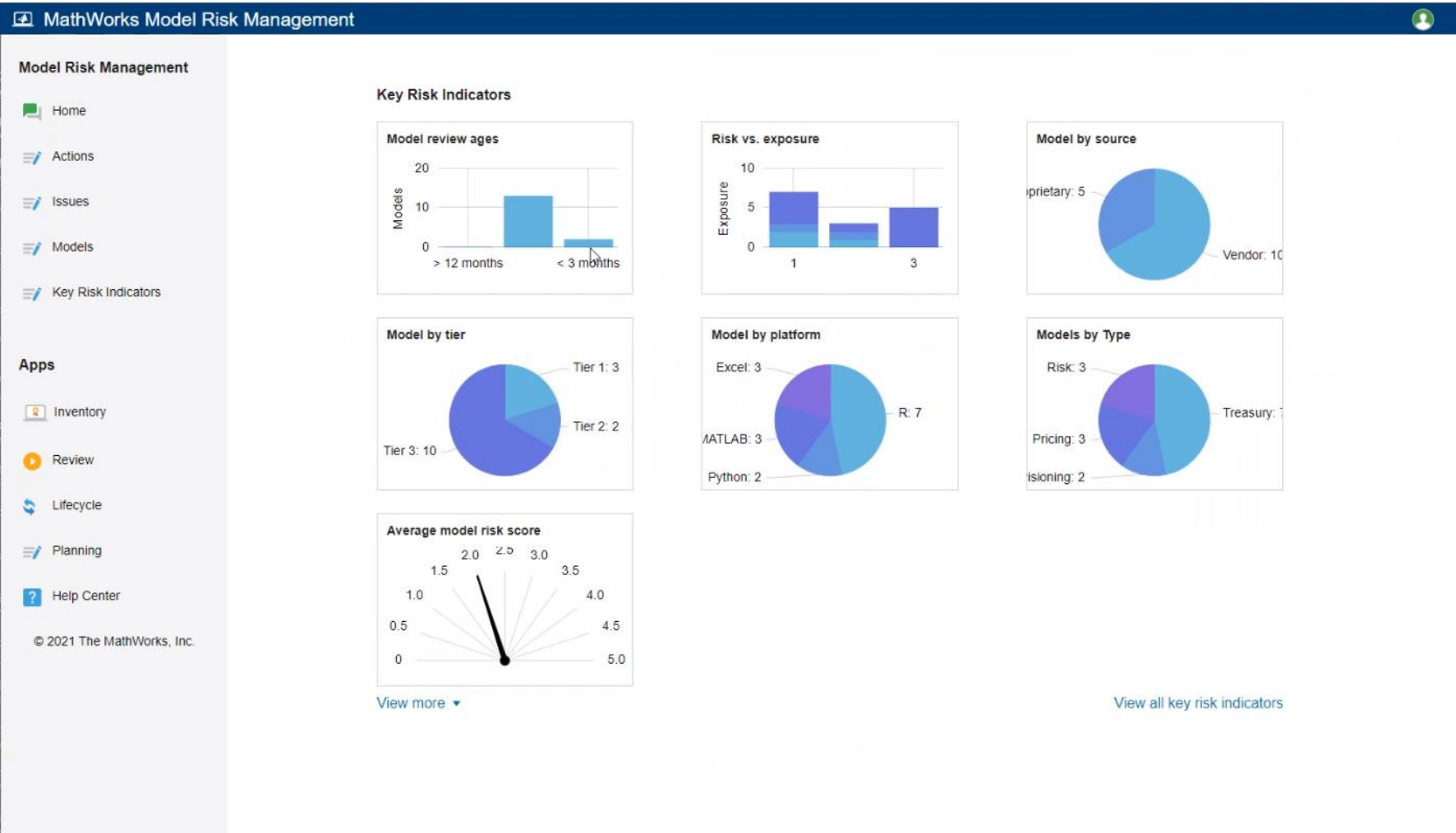


The Model Inventory is the point of entry, showing the complete model landscape across business lines.



Centralized access to model risk management data and processes through MATLAB Online Server.

Customizable views, providing aggregated and drill-down information.



Every model is tracked, linked to code and documentation, and information is maintained as the model evolves.



LEDGER

ID	Business Group	# Models	Model Risk Score
1	Treasury	3	3.0000
2	Commercial Banking	4	2.5000
3	Retail Banking	8	3.6250

MODEL

Name	Last Validated	Next Review	State	Type
PD_CreditCard	NaT	NaT	In Production	Risk
LGD_CreditCard	NaT	NaT	In Production	Risk
EAD_CreditCard	NaT	NaT	In Production	Risk
PD_Mortgage	NaT	NaT	In Production	Risk
LGD_Mortgage	NaT	NaT	In Production	Risk
EAD_Mortgage	NaT	NaT	In Production	Risk
PD_CRE	NaT	NaT	In Production	Risk
LGD_CRE	NaT	NaT	In Production	Risk
EAD_CRE	NaT	NaT	In Production	Risk
ADCO	NaT	NaT	In Production	Risk
YieldCurveModel	NaT	NaT	In Production	Pricing
QRM	NaT	NaT	In Production	Treasury

Model 5 Details

- Model Complexity Score: 4
- Model Materiality Score: 4
- Model Risk Tier: 1
- Model Risk Score: 5
- Model Risk Rating: High
- Next State: In Production

Workflow Diagram

```
graph LR; Draft((Draft)) --> CreateProject[Create Project Repository]; CreateProject --> Developing((Developing)); Developing --> Validating((Validating)); Validating --> FirstReview{First Review}; FirstReview --> InitialApproval((Initial Approval)); InitialApproval --> SecondReview{Second Review}; SecondReview --> Approved((Approved)); Approved --> InProduction((In Production)); InProduction --> Decommissioned((Decommissioned)); Decommissioned --> Discarded((Discarded)); Discarded --> Draft; Developing --> CreateTask[Create Development Task]; Validating --> CreateTask; FirstReview --> Feedback1((Addressing Feedback 1)); SecondReview --> Feedback2((Addressing Feedback 2)); Feedback1 --> FirstReview; Feedback2 --> SecondReview;
```

Customizable fields and links to external databases.

Workflows for model creation, review and deployment.

Integrated with code and document control systems.

The Model Inventory is the centralized application to perform all model risk management activities.



Dashboard x Model Dependencies Model 5 x Model Risk Questionnaire - Model 5 x

Risk Tiering

Fill in the questions and provide justifications and considerations where indicated. Once complete, save and close the document and choose if you want to save the changes to the model.

Model Use

Does the model measure risk, price or value?
 Used for critical business decisions, regulatory purposes or financial reporting?

Model Exposure

Exposure Level Medium

Preliminary Risk Rating

High risk tier

Final Risk Rating

Are there other significant considerations that would justify overriding the preliminary risk rating?

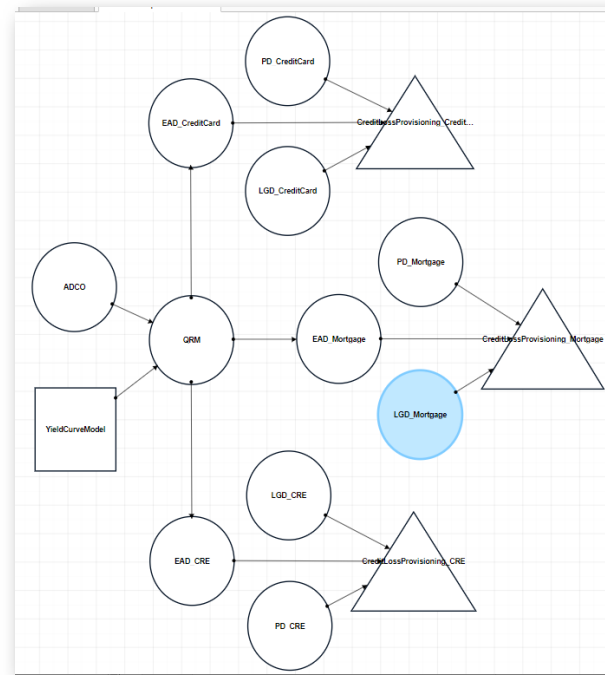
Overlay considerations:

Overlay Risk Rating High risk tier

Final risk rating:

High risk tier

Risk Tiering



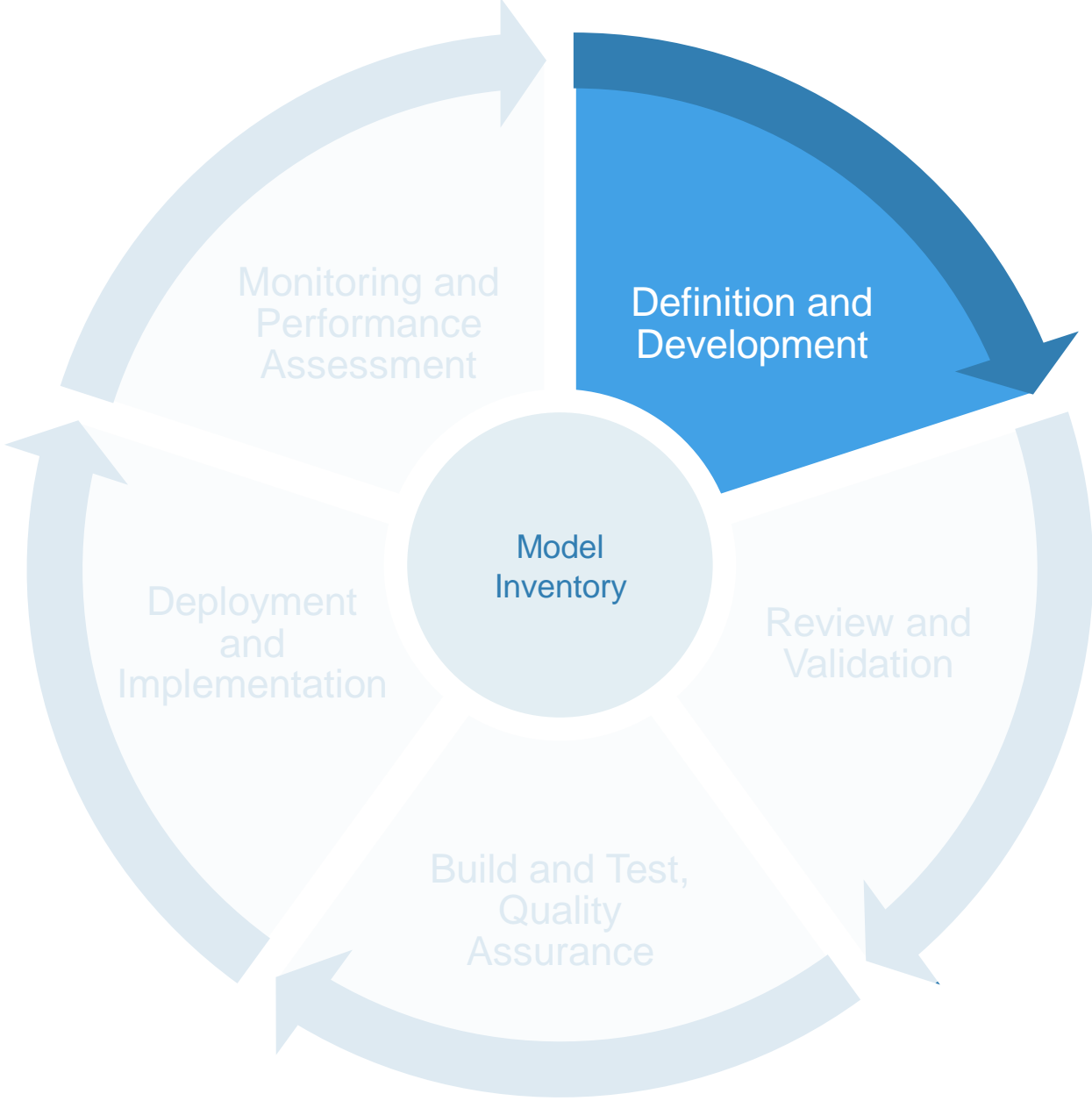
Impact Analysis

View: Requirements

Index	ID	Summary	Implemented
model_development_standards*			<input type="checkbox"/>
> 1	#6	Model requirements	<input type="checkbox"/>
> 2	#13	Model use requirements	<input type="checkbox"/>
> 2.1	#15	Business process	<input type="checkbox"/>
> 2.2	#16	Business units	<input type="checkbox"/>
> 2.3	#17	Portfolios	<input type="checkbox"/>
> 2.4	#18	Embedding of models	<input type="checkbox"/>
> 2.5	#19	Training and documentation	<input type="checkbox"/>
> 2.5.1	#74	Manual describing use and where to p...	<input type="checkbox"/>
> 2.5.2	#75	Provision of training	<input type="checkbox"/>
> 3	#1	Need assessment	<input type="checkbox"/>
> 3.1	#20	Expression of need	<input type="checkbox"/>
> 3.2	#21	Previous experience in model develop...	<input type="checkbox"/>
> 3.3	#22	Criteria by which concepts are assess...	<input type="checkbox"/>
> 3.4	#23	Alternative concepts explored	<input type="checkbox"/>
> 3.5	#24	Reasoning for choosing methodology	<input type="checkbox"/>
> 3.6	#25	Reuse of existing methodology	<input type="checkbox"/>
> 3.7	#27	Appropriate theoretic framework	<input type="checkbox"/>
> 3.8	#28	Key assumptions	<input type="checkbox"/>
> 3.9	#29	Expert Judgments	<input type="checkbox"/>
> 3.10	#30	Anticipated Model Limitations	<input type="checkbox"/>
> 3.11	#31	Issues and limitations in data sources	<input type="checkbox"/>
> 3.12	#26	Development decision	<input type="checkbox"/>
> 4	#33	Model landscape	<input type="checkbox"/>
> 5	#45	Model development plan	<input type="checkbox"/>
> 6	#82	Model processing	<input type="checkbox"/>
> 7	#122	Justifications	<input type="checkbox"/>

Planning

Model Development Environment



The Model Development Environment produces documentation as you explore data and build models.



Project - scorecard

Live Editor - C:\Users\vmckenna\OneDrive - MathWorks\Desktop\Scorecard\Scorecard.mlx *

Scorecard.mlx * x +

Tree Visualization

Visualize the decision tree. Paths are colored based on the probability it will be transversed. Trees can also be viewed by using the command:

```
view(modelTree, 'mode', 'graph')
```

99
100
101

```
showLabels = off  
viewTree(modelTree, "Labels", showLabels);  
viewTree(modelTree, 'Labels', value)
```

Labels value
"off"
"on"

Working With Big

Now that we have a sense of data distribution and binning, let's fit our scorecard model against the entire dataset which will have the form:

$$\ln\left(\frac{\mu}{1-\mu}\right) \sim 1 + \text{var}_1 + \text{var}_2 + \dots + \text{var}_{199}$$

Since this dataset may not fit in memory, we can easily scale by using a datastore to point to the repository of data and using a **tall table** to process the data in the same manner as before with the smaller dataset.

ROC Curve

showLabels = "off"

Richly annotated code as a basis for documentation.

Interactive controls and visualizations promoting model insight and challenge.

We provide reusable and customizable templates for every step of the model development process



Screen Risk Factors
filteredTable, exclusionTable = Subtable of dataMissing with 7 risk factors excluded

Select data
Input table: dataMissing | Response variable: defaultInd | Criteria: myCriteria

Analyze data variables

Variable Names	Status	Exclude	Comment
CustID	Red	<input checked="" type="checkbox"/>	Fails InfoValue, AccuracyRatio
CustAge	Green	<input type="checkbox"/>	All tests pass
TmAtAddress	Red	<input checked="" type="checkbox"/>	Fails AccuracyRatio
ResStatus	Red	<input checked="" type="checkbox"/>	Fails InfoValue, AccuracyRatio
EmpStatus	Red	<input checked="" type="checkbox"/>	Fails InfoValue

CustAge

InfoValue	0.1770	Green	(0.1, 0.5]
AccuracyRatio	0.1672	Green	(0.1, 0.4]
AUROC	0.5836	<undefined>	<undefined>
Entropy	0.8879	<undefined>	<undefined>

Histogram (pdf) for each response

Display results
 Filtered table Preview summary tables

```
scriptlets
├── creditscorecard
│   ├── 02_Bin_Data
│   │   ├── launch_binning_explorer.mlx
│   │   ├── perform_automatic_binning.mlx
│   │   └── review_binning.mlx
│   ├── 03_Fit_Model
│   └── 04_Validate_Model
```

Script Snippets and Live Tasks covering every step.

Project - Refaat 2011 Credit Card Model

PROJECT SHORTCUTS
commitScriptlet
insertScriptletTask

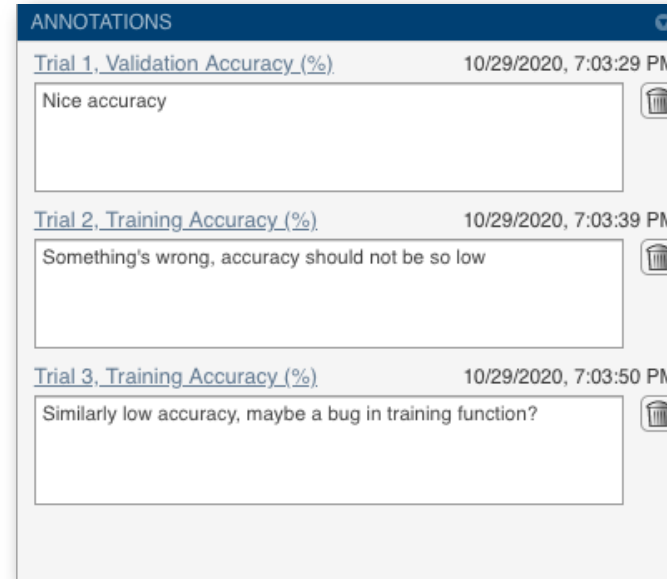
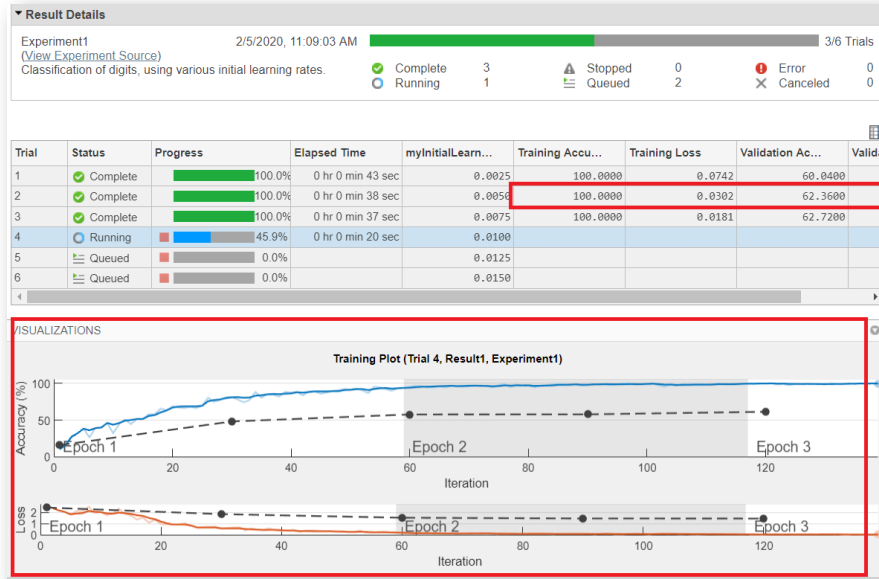
Views: All | Project (115) | Modified (189)

Name	Status	Git	Classification
resources	✓	+	
mrm	✓	+	
documents	✓	+	
creditscorecard-template.dotx	✓	+	
Refaat 2011 Credit Card Modelv1...	✓	+	Artifact
json	✓	+	
scriptlets	✓	+	
utilities	✓	+	
commitScriptlet.m	✓	+	Design
consumer_credit_scorecard.mlx	✓	+	Design
consumer_credit_scorecard_complete.mlx	✓	+	Design
insertScriptletTask.m	✓	+	Design
logistic_reg.py	✓	+	
PatientsDisplay.mlapp	✓	+	Design
python.mlx	✓	+	Design
README.md	✓	+	
startup.m	✓	+	Design
tfin.py	✓	+	
X.csv	✓	+	
Y.csv	✓	+	

Project structure and Word templates.

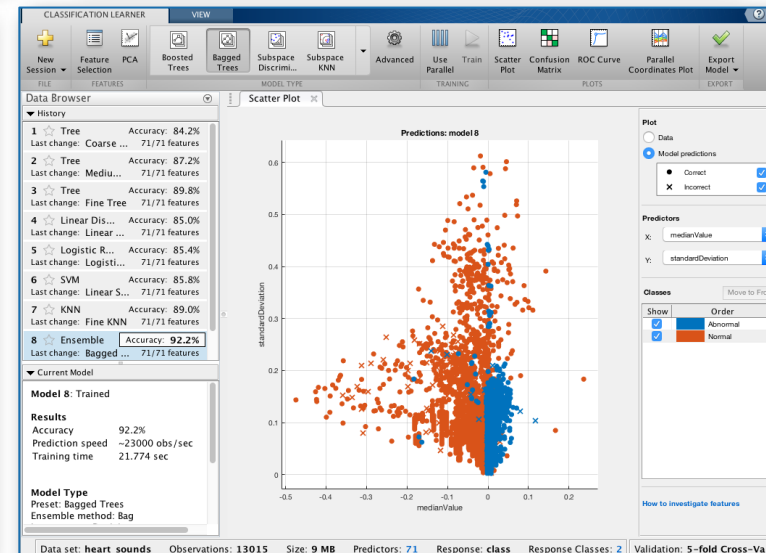
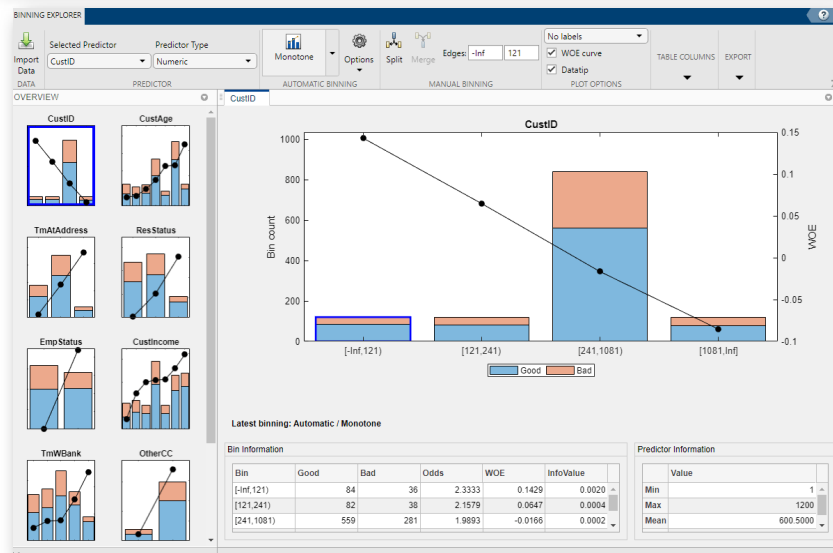
Automation, consistency, reusability of model artefacts.

Candidate models are trained, compared and calibrated in the Experiment Manager.



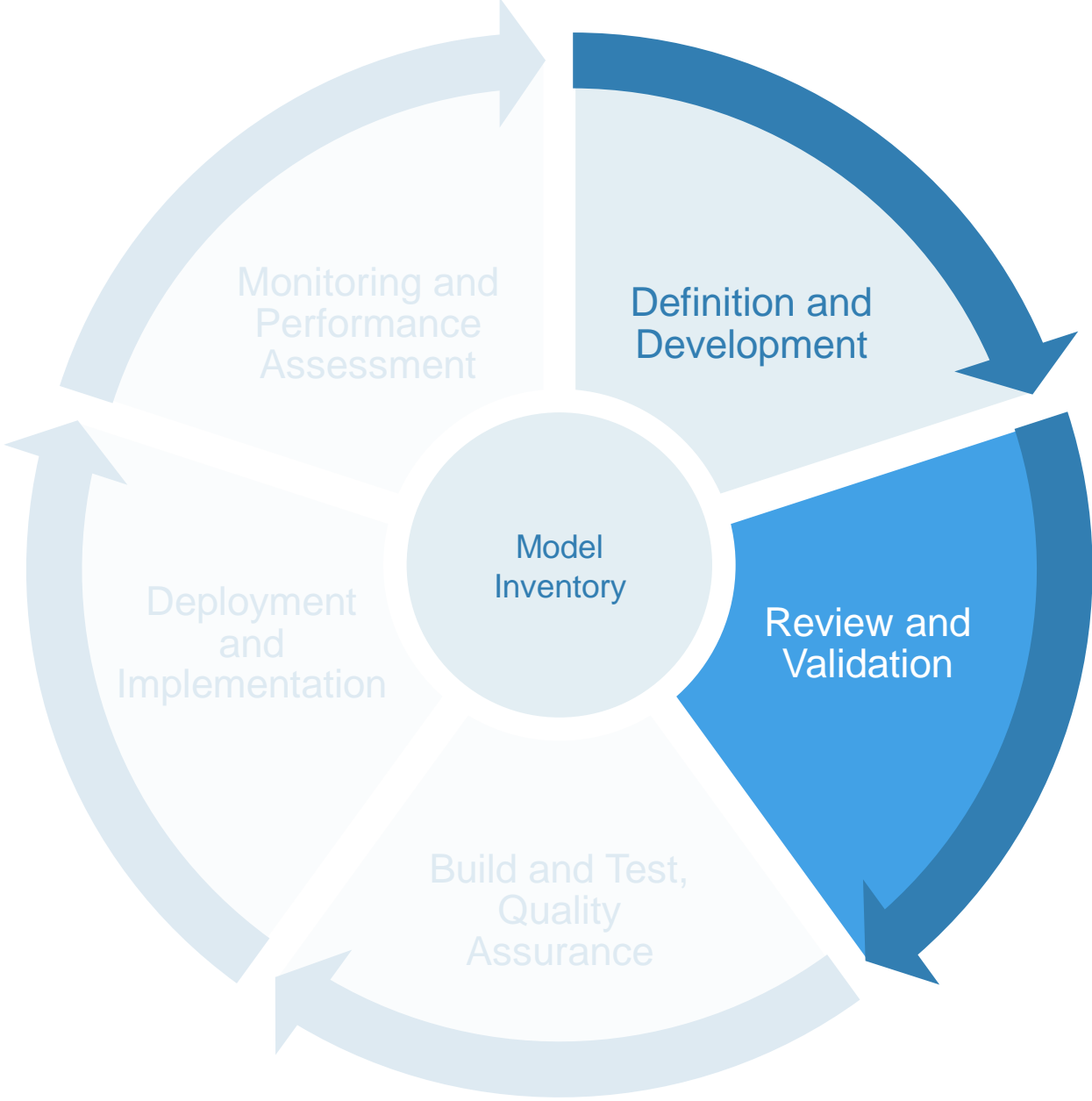
Reproducibility of model builds.

Tracking of validation metrics and annotation of results for documentation.



Encompass existing workflows around learner and modelling Apps.

Model Review Environment



Developed models are submitted through the Model Review Environment to be assessed and approved.



The screenshot shows the MATLAB Model Review environment. The interface includes a top navigation bar with 'REVIEW' and 'LIVE EDITOR' tabs. Below this is a toolbar with icons for 'New Script', 'Original', 'New Revision', and various document icons. The main workspace is divided into several sections:

- Code Editor:** Contains a script with the following code:

```
44 [Stats,T] = validateModel(sc_fitted,'Plot',{'CAP','ROC','KS'})
```
- Challenger Model:** A text block describing the model's purpose:

We compare the performance of the logistic regression fitted with the scorecard data with alternative machine learning methods.

To do this, we extract the binned WOE values from the scorecard.
- Scriptlets:** A section for running code snippets, currently showing:

```
45 binnedFeatures = bindata( sc_fitted );
```

```
46 predictorVars = sc_fitted.PredictorVars;
```
- Visualizations:** A 'K-S Plot' showing cumulative probability vs. score. The plot includes two curves: 'Cumulative Bad' (blue) and 'Cumulative Good' (orange). A vertical dashed line indicates the 'K-S 22.5% at 0.880046'.
- Statistics Table:** A table titled 'Stats = 4x2 table' with the following data:

	Measure	Value
1	'Accuracy Ra...	0.3201596
2	'Area under ...	0.6600798
3	'KS statistic'	0.2247616
4	'KS score'	0.8800463

Access to up-to-date model code and documentation through a browser (MATLAB Online Server).

Model analysis can be executed in-place to support “what-if” scenarios.

Streamline communication between 1st and 2nd lines of defence.

Quantitative information required for internal and regulatory documentation is automatically produced.

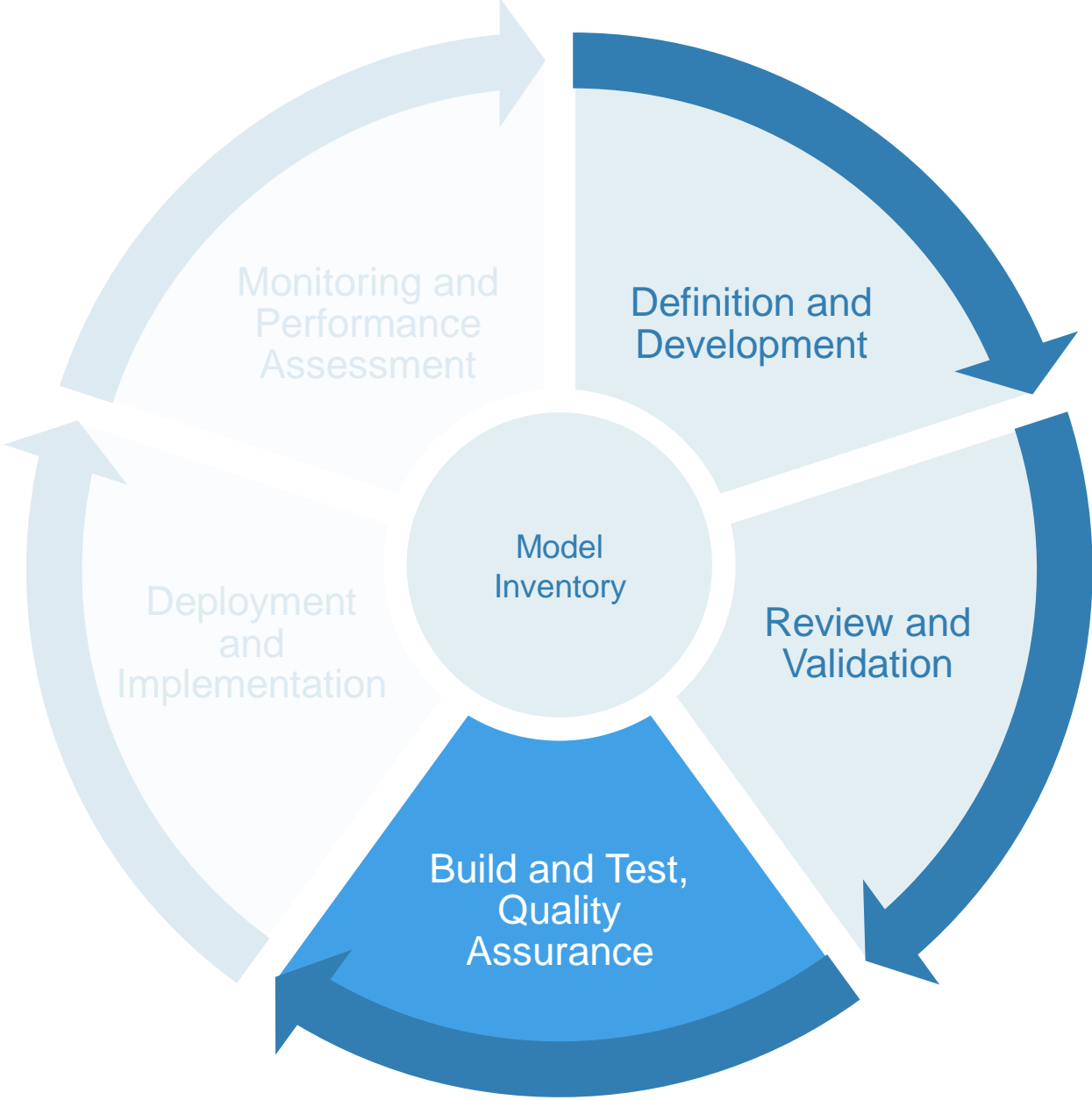


	Name of the validation report document	Section Number	Page	Coverage in internal validation
Portfolio information	<input type="text"/>	<input type="text"/>	<input type="text"/>	ASSESSED ▼
Predictive Ability	<input type="text"/>	<input type="text"/>	<input type="text"/>	ASSESSED ▼
Discriminatory power	<input type="text"/>	<input type="text"/>	<input type="text"/>	ASSESSED ▼
Qualitative Validation Tools	<input type="text"/>	<input type="text"/>	<input type="text"/>	ASSESSED ▼
Stability	<input type="text"/>	<input type="text"/>	<input type="text"/>	ASSESSED ▼

Information is produced by running quantitative tests automatically on models.

Supplemental information populated from inventory and model documentation.

Model Test Environment



Rigor and trust in models is established through a Model Test Environment accessible through CI/CD



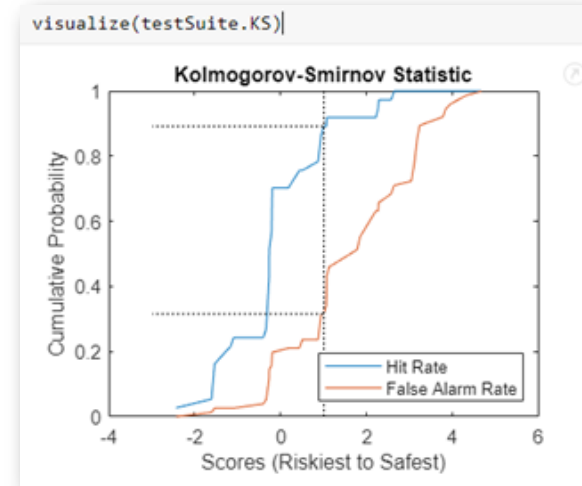
```
test_scriptBasedUnitTest.mlx
```

Automated Model Testing

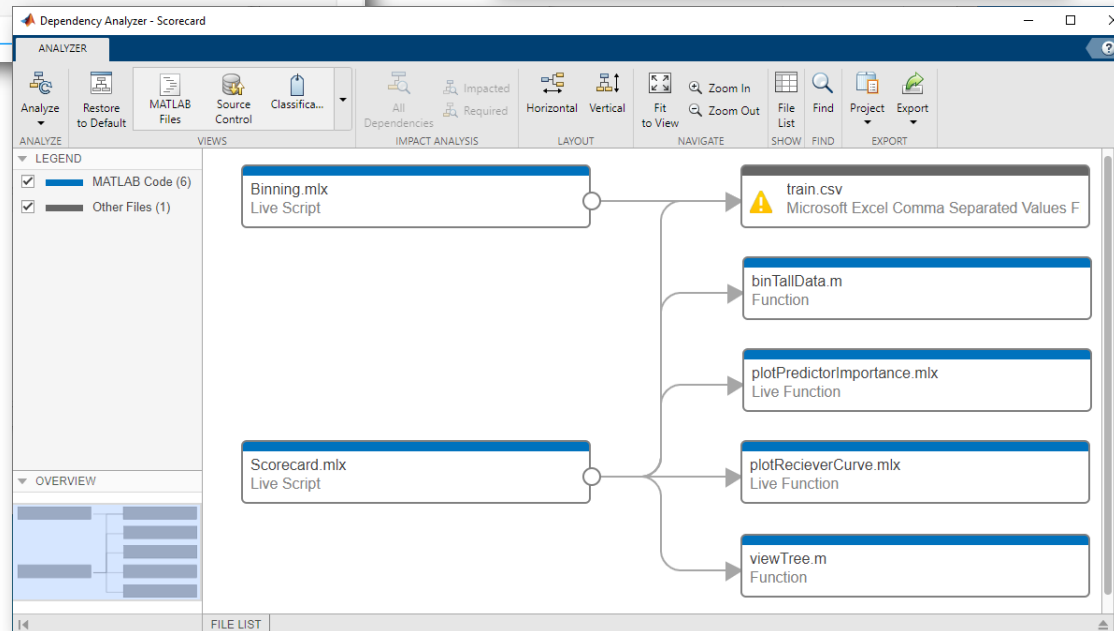
Perform unit tests to determine scorecard is above accuracy thresholds.

Test: Conditional Information Entropy

```
1 sc = py.scorecard.create('scorecardData.csv')
2 data = py.scorecard.getScores(sc)
3
4 entropy = validateEntropy(data, 'Plot', 'CIER')
5
6 entroy_threshold = 0.5
7 assert(entropy < entroy_threshold)
```

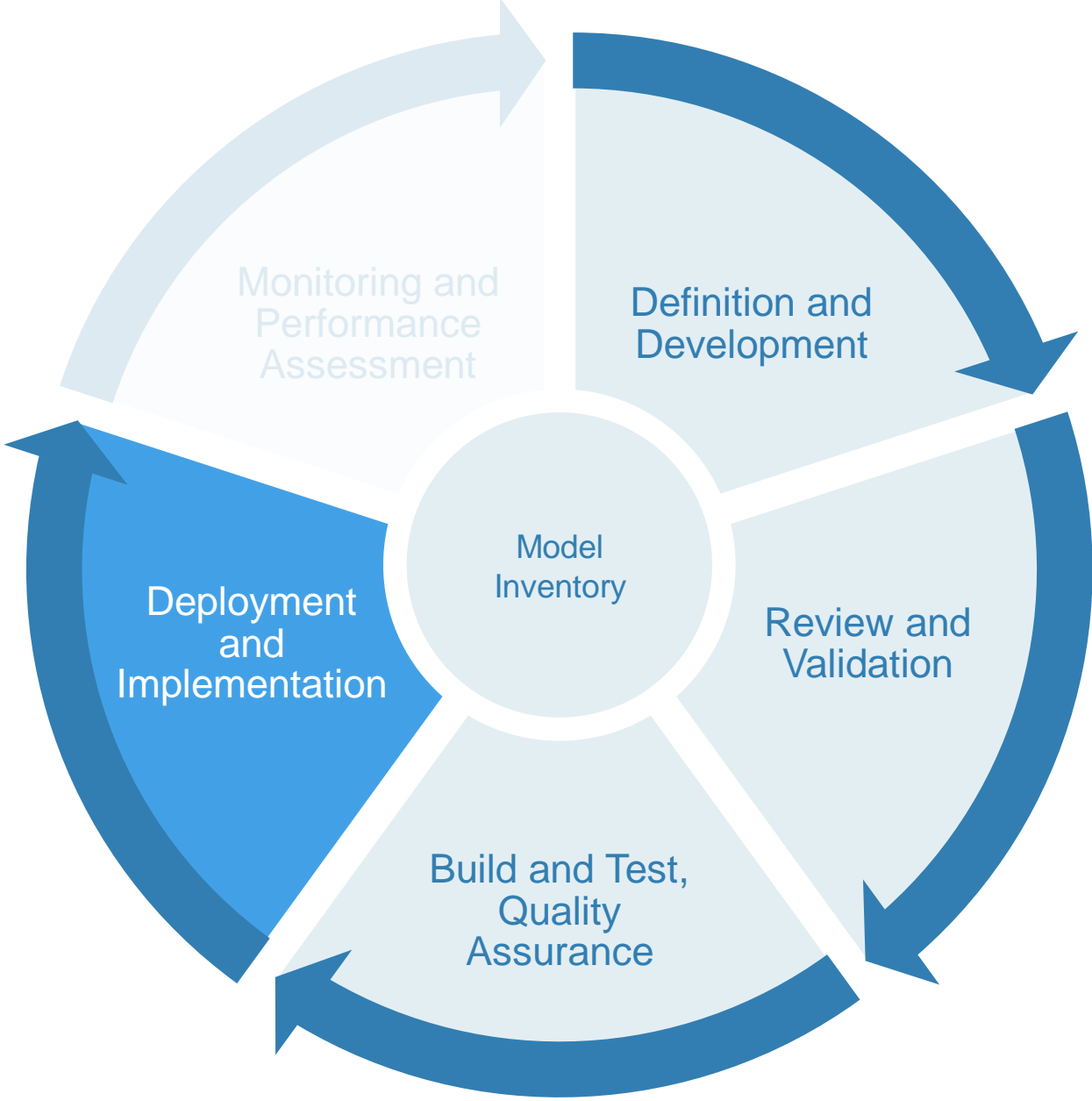


Quantitative unit and performance test suites covering regulatory reporting requirements.



Interoperability with Python and Jupyter.

Model Execution Environment



Approved and tested models are deployed to production with a REST API supporting discovery end execution.



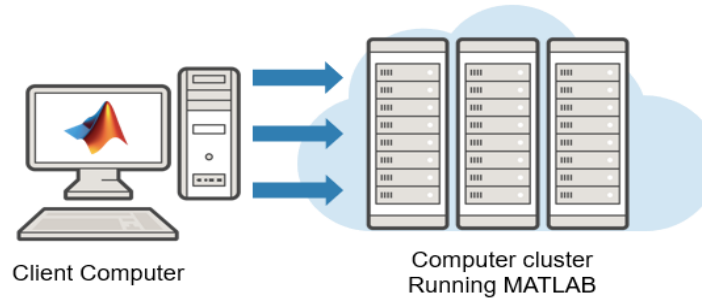
Model Discovery

POST /getModels List of models

POST /getModel Get model

POST /getModelInputs List of inputs needed for model

POST /getModelOutputs List of outputs produced by model



Execution

POST /{datasource}/requestInput Request input data from datasource

POST /{modelId}/executeModel Run the model with complete set of inputs

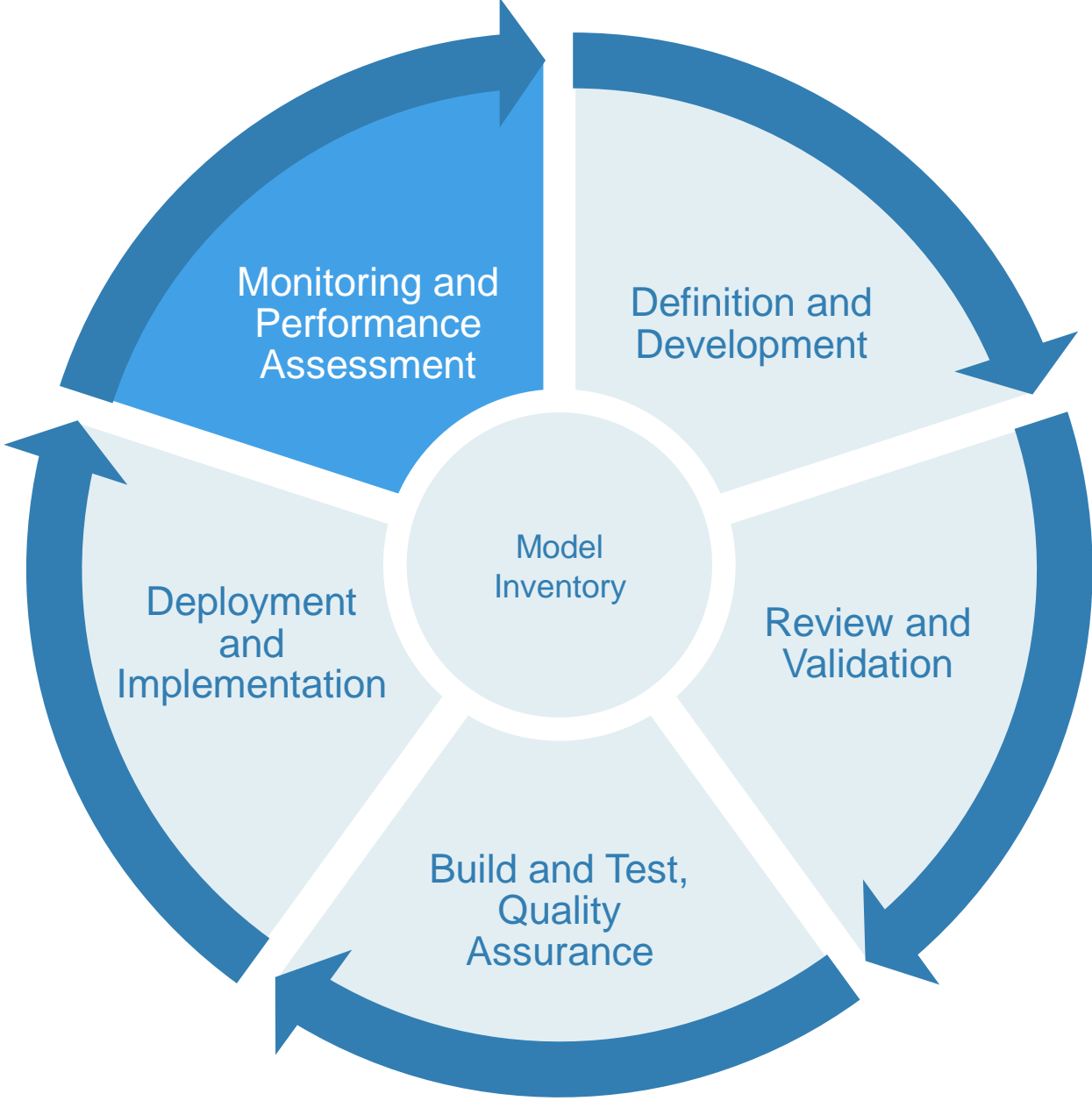
Authorize and audit model usage.

Horizontally and vertically scalable.

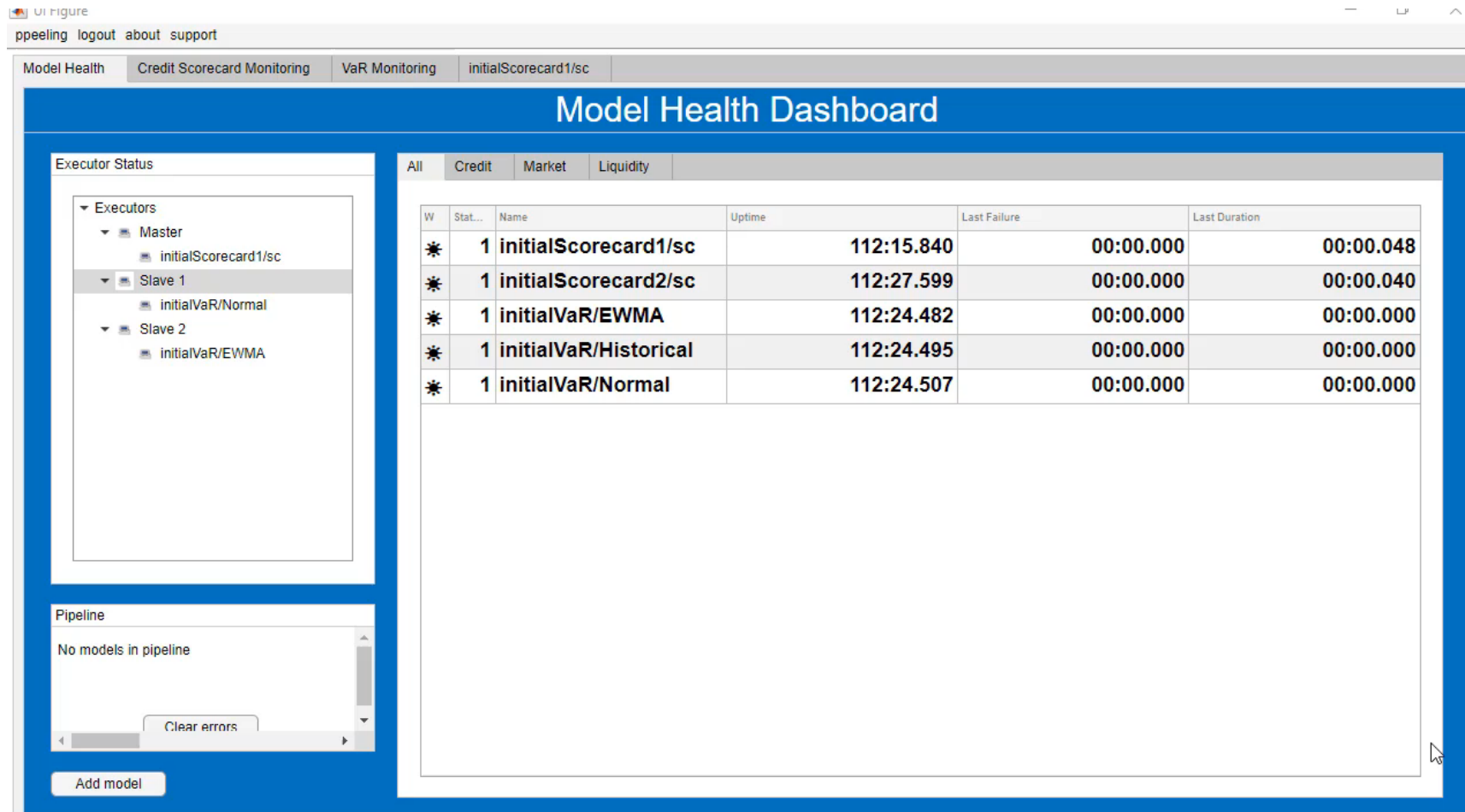
Integrate with business systems with no re-coding.

Language and implementation agnostic.

Model Monitoring



Metrics used in model review and validation are monitored on production models.

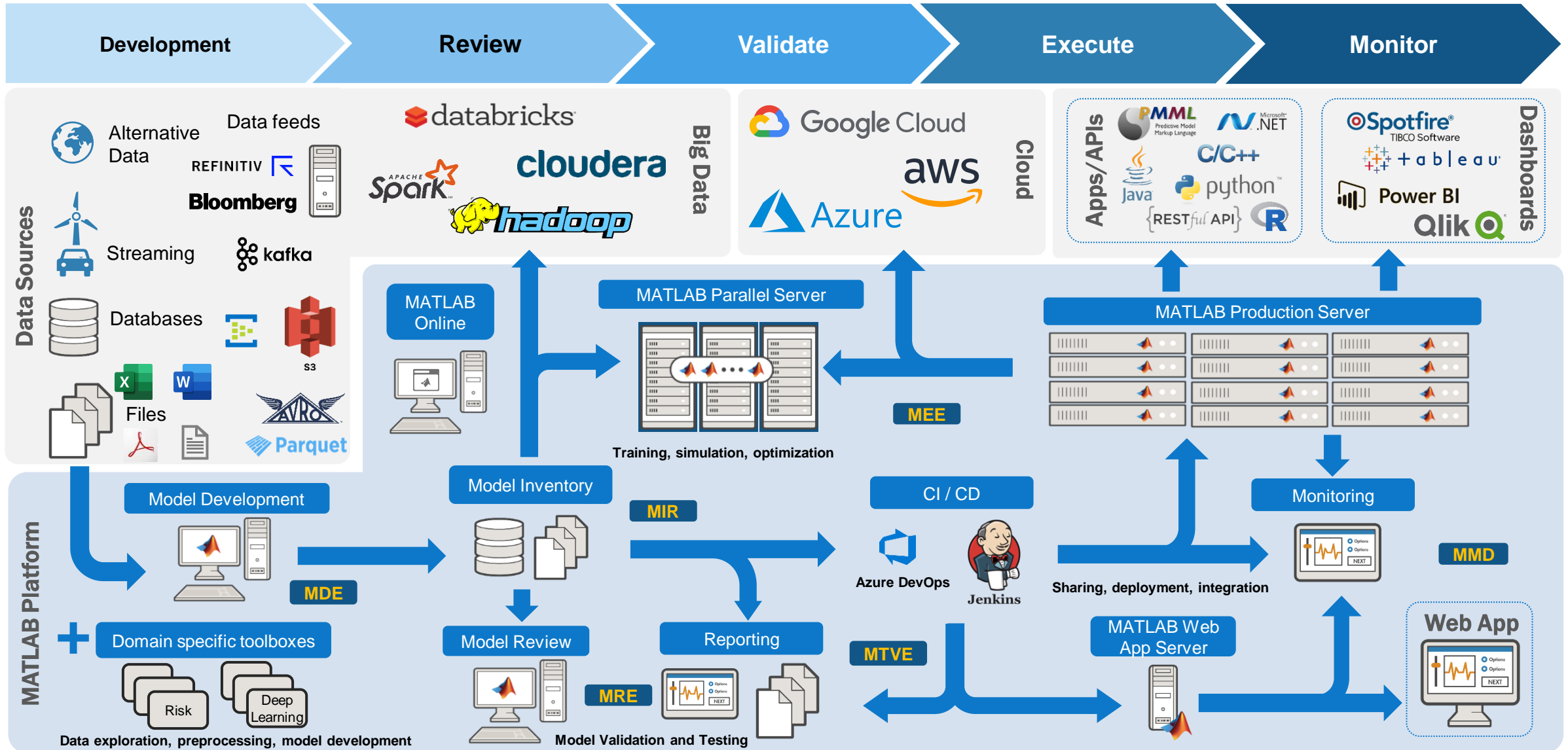


Build and deploy using App Designer and MATLAB Web App Server.

Alerts when metrics fall outside of approved usage.

Dashboards, KPIs and metrics accessible to model users and stakeholders.

MATLAB seamlessly interoperates with open source and third-party technology platforms across the modeling life-cycle



Key Benefits of MathWorks MRM Solution

- **Unified system** of technologies addressing key business, modeling, workflow, and governance needs
 - Manage model risk with **automation** and **transparency**
- Modeling platform integrated across 1st & 2nd lines of defense, covering **research to production**
 - ✓ Eliminate inefficiencies, reduce cost/time
 - ✓ Enhance communication
 - ✓ Accelerate regulatory approval

modelriskmanagement@mathworks.com



Perform end-to-end modeling **faster, better, cheaper**