



## 腾戈智慧半导体

Top provider of Web-native EDA  
for semiconductor yield improvement



# Test Time Reduction – Item Filter

# Problem Description

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## 1. Background

According to ITRS 2.0, as the packaging technology improves, Test Time Reduction(TTR) will become more significant in advance IC test.

The main idea of TTR is to reduce test items without losing product quality, there are two general methods below :

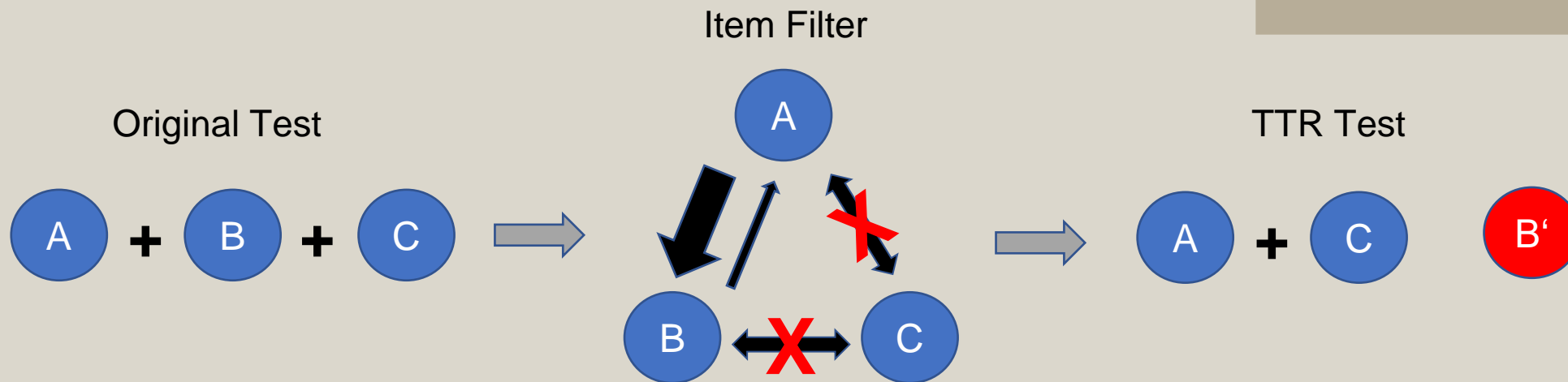
1. By the large number of ICs, remove zero failure rate items.
2. By the large number of ICs, remove low PPM failure rate items.

**But none of these considering the variation of product line, and most important of all, these can not alarm quality shift.**

# Problem Description

Find the potential items(TTR items) that can be replaced by other test items immediately, and monitoring it by Virtual Metrology(TM).

## 2. Strategy



## Data Collection

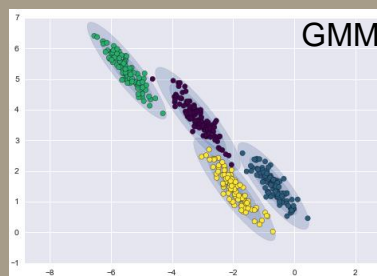


- Remove Binary Items & Non-Completed dice.
- According to test sequence, split data with 70/30 rule.

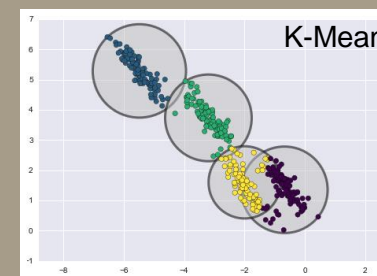
## Cluster Sampling



- Gaussian Mixture Model(GMM) for clustering, and execute Stratified Sampling.



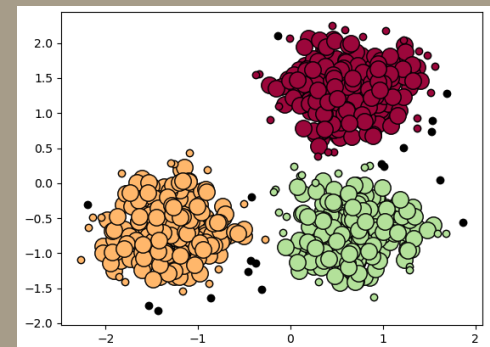
V.S.



## Outlier Detection



- K-Nearest Neighbor + Density-Based Spatial Clustering of Applications with Noise(KNN-DBSCAN) for detecting and excluding outliers.



## Modeling and Feature Selection

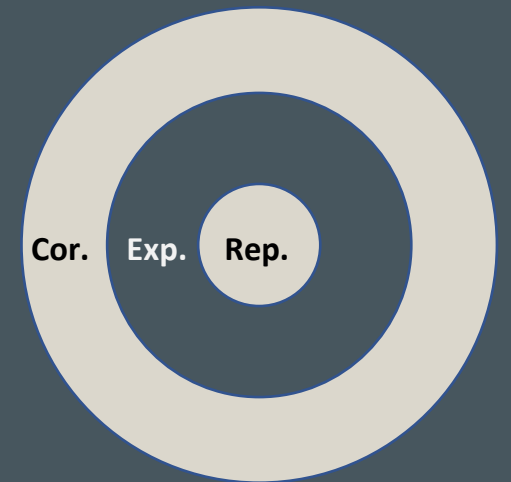


- Partial Least Square Regression(PLSR) for modeling.
- Backward Feature Elimination for choosing the right model of TTR items.

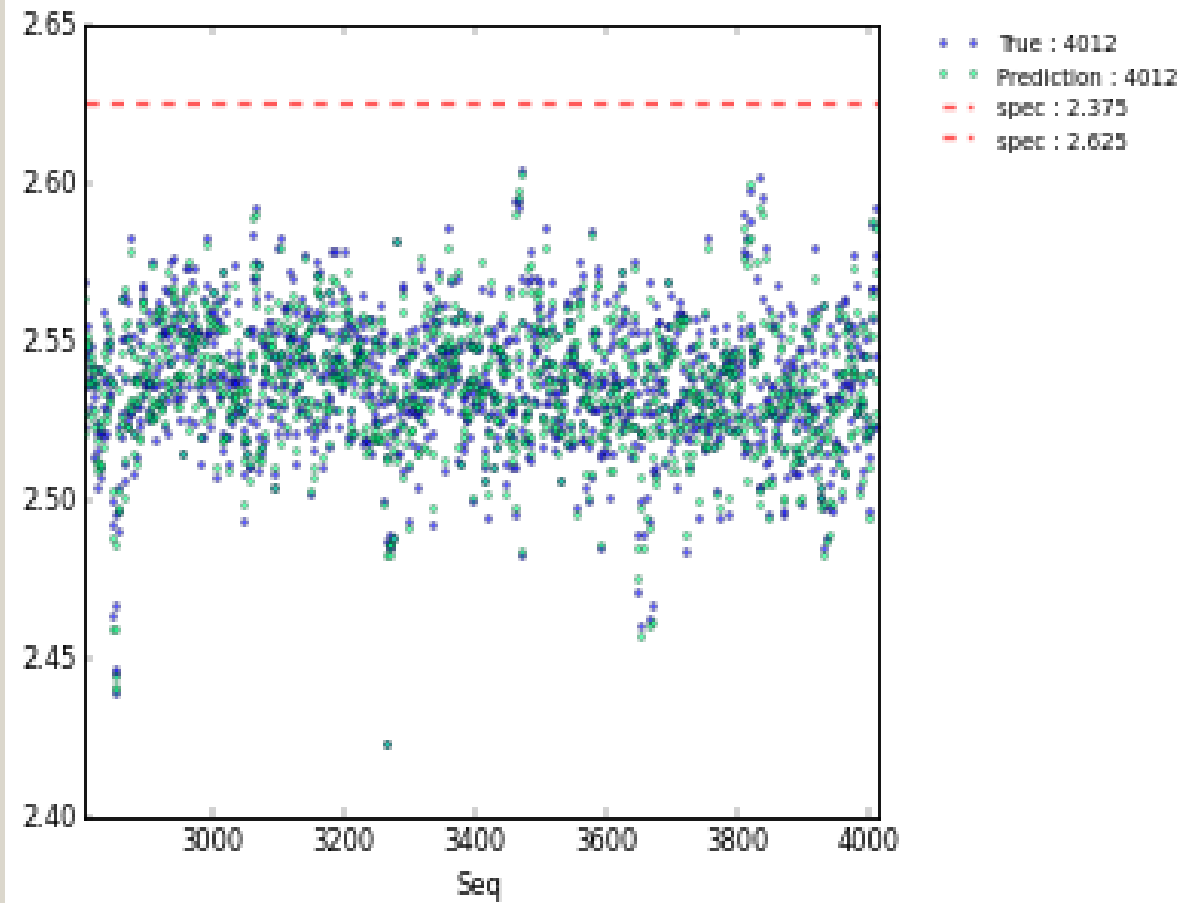
# Item Filter

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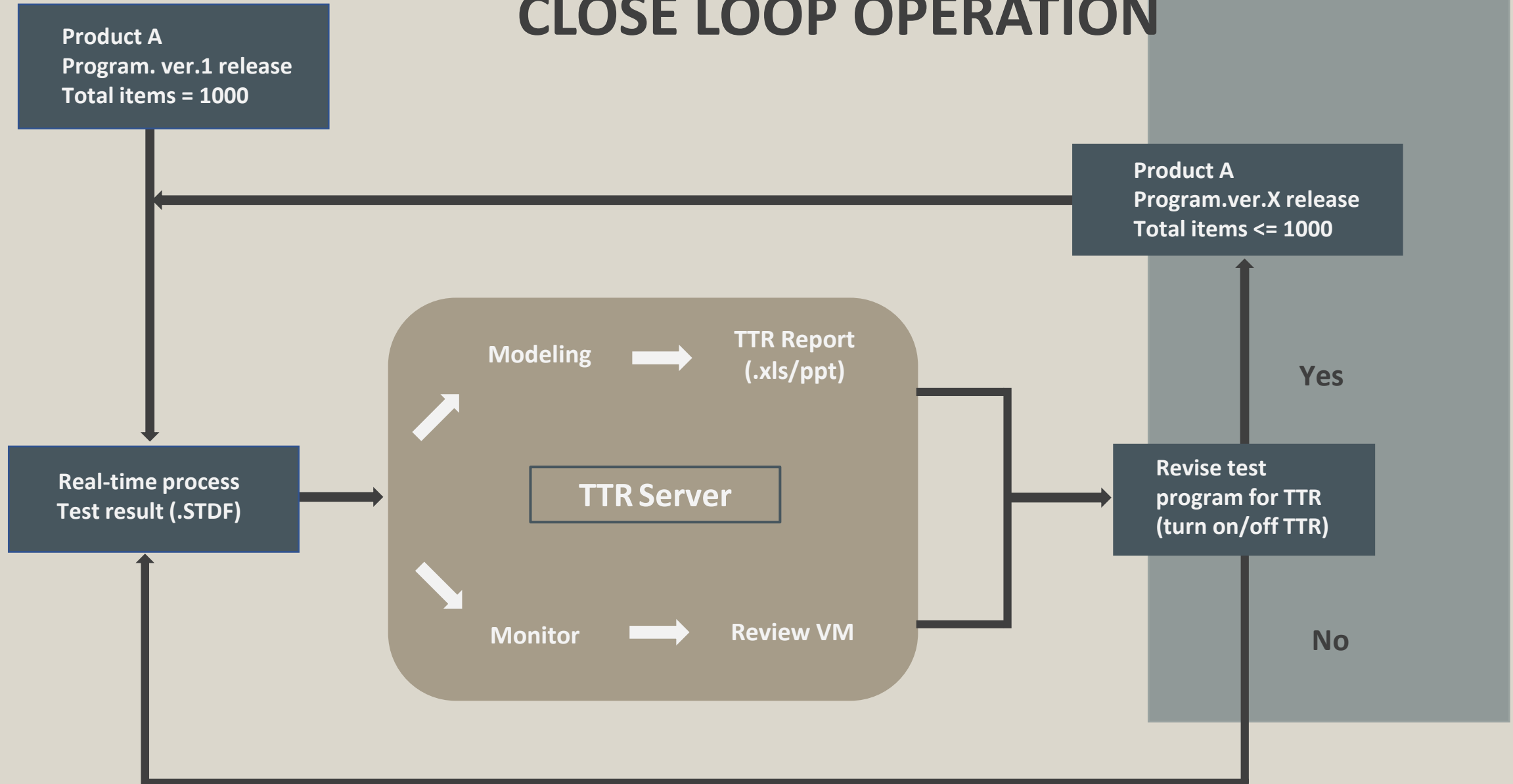
- Find the TTR items
  - 1. Correlation
    - ✓ check correlation of all test items, build prediction model for TTR items
  - 1. Explanation
    - ✓ assess if model predicting closed to baseline: Coefficient of Determination( $R^2$ )
  - 1. Replacement
    - ✓ assess if model predicting accurately: NRMSE、99%CI of Prediction、Skew、Kurtosis
- Generate TTR Report for supporting information
  - ✓ TTR Summary - Effectiveness
  - ✓ VM Report - Accuracy of model
  - ✓ Correlation Report - Robust of model
- Calculate VM value
  - ✓ monitor shift of each TTR items(non-testing)



# 4637:LDOMIII1\_MII3\_Vout\_V25Check LDOMII\_OUT\_1 147



# OFF-LINE TTR – CLOSE LOOP OPERATION





## Data

- Lot / Wafer = I5H80 / #11,12
- Total / Fail Dice = 4194 / 160 ea.
- Total / Fail Datalog Items = 3367 / 85 items

- According to test sequence, split data with 70/30 rule
- The minimum samples is 100

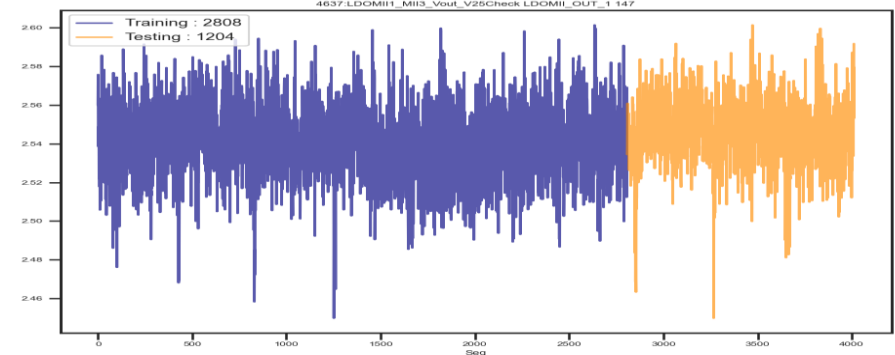
## Exclude data

Remove Non-Continuous Binary Items  
& Non-Completed dice.

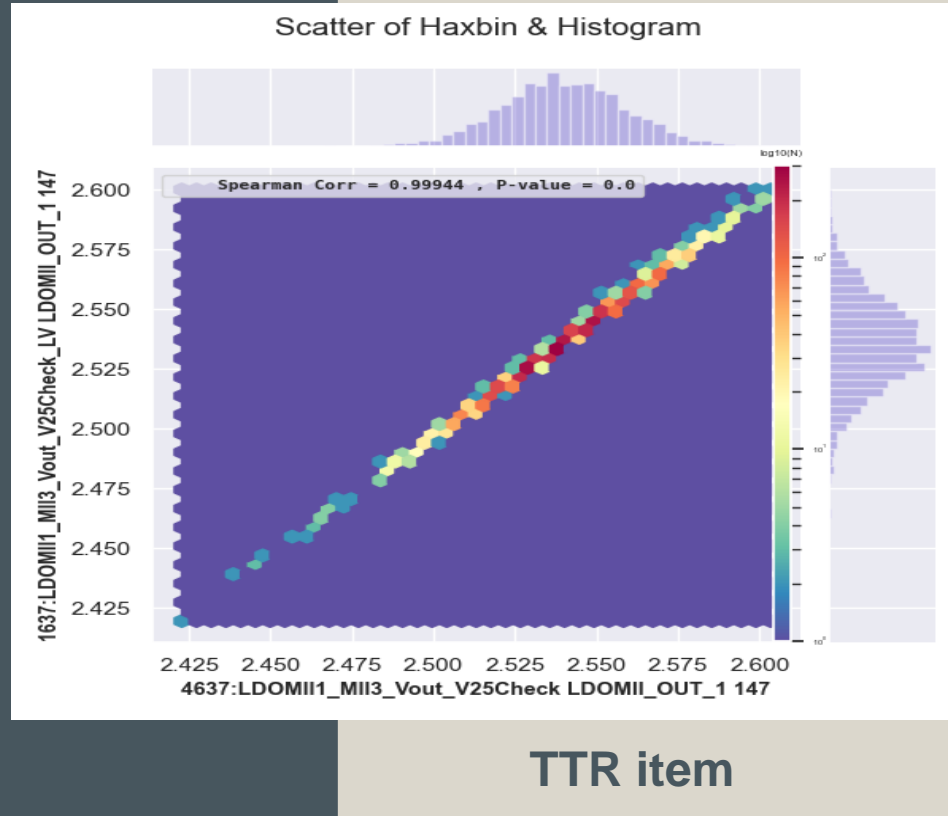
## Data Collection

Lot No.	: I5H80	<div></div>	Lot Status	: <a href="#">AutoSh</a>
VdrLot	: I5H80		Wafer Qty.	: 2 PCS
Process	: CP1D		Start Time	: 2018-0
Lot Yield	: 96.19%		Gross Die	: 2097 (96.19%) <sup>#1</sup>
TestHouse	: RT		LotType	: <a href="#">Production</a>

No.	OCR-ID	Status	Tester	ProbeCard	LoadBoard	Program	Yield(%)	Total	Pass	Test Yield(%) <sup>#2</sup>	StartTime	EndTime	ElapsTime
<a href="#">11</a>	P60Y36-11E2	<a href="#">AutoShip</a>	J750-45	RL-WPC-026	RL-WLB-002	<div></div>	95.99 <div></div>	2097	2013	95.99	2018-07-01 15:20:38	2018-07-03 00:22:01	1981.4
<a href="#">12</a>	P60Y36-12D5	<a href="#">AutoShip</a>	J750-45	RL-WPC-026	RL-WLB-002		96.38 <div></div>	2097	2021	96.38	2018-07-03 00:48:47	2018-07-04 06:48:49	1800



Cor. item

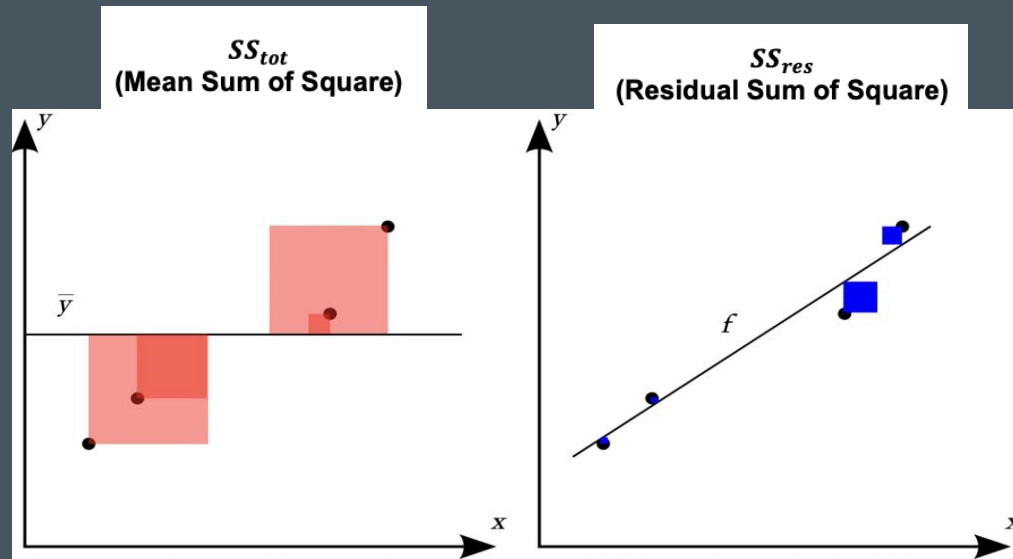


# Item Filter - Correlation

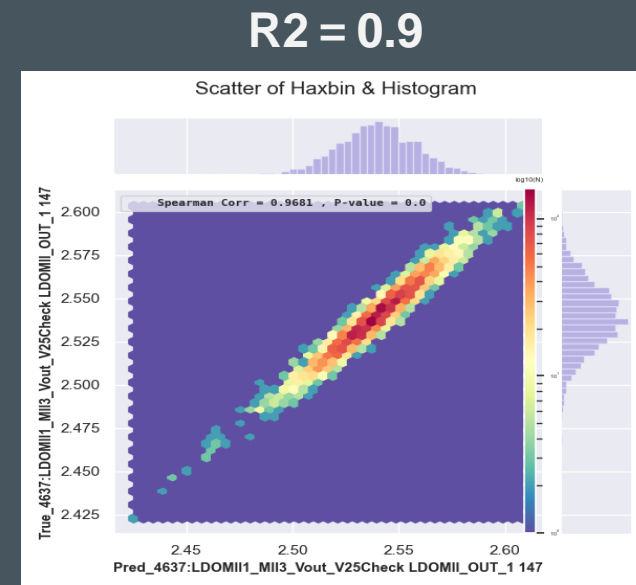
- Check correlation of all test items, build prediction model for each TTR items.
- Example: if Y can be replaced by X1, X2, then Y is predicted by X1, X2.

$$y = ax_1 + bx_2$$

Coefficient of Determination( $R^2$ ): 
$$R^2 = 1 - \frac{SS_{res}}{SS_{tot}}$$



Real



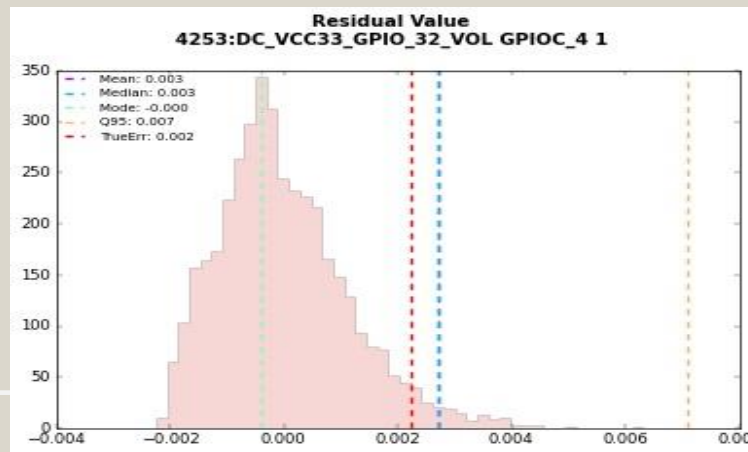
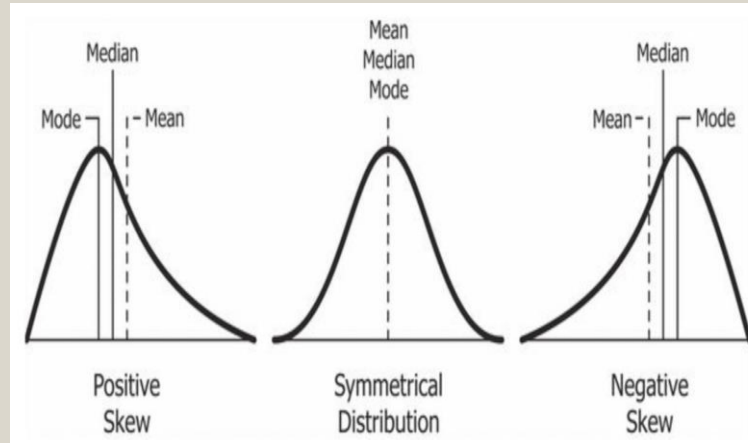
VM

# Item Filter - Replacement

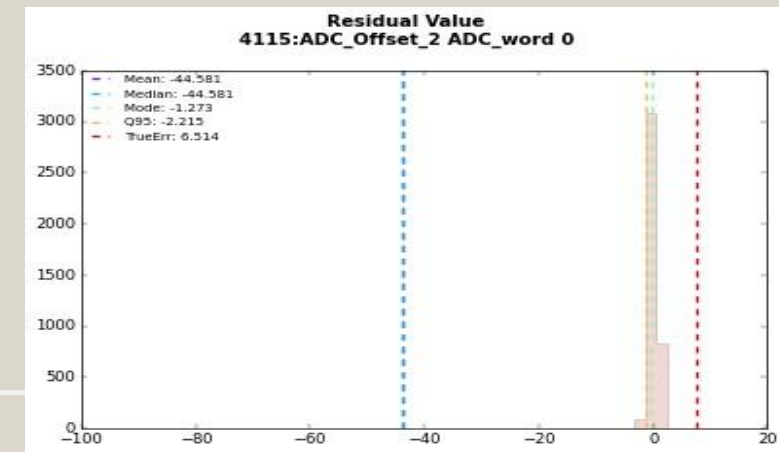
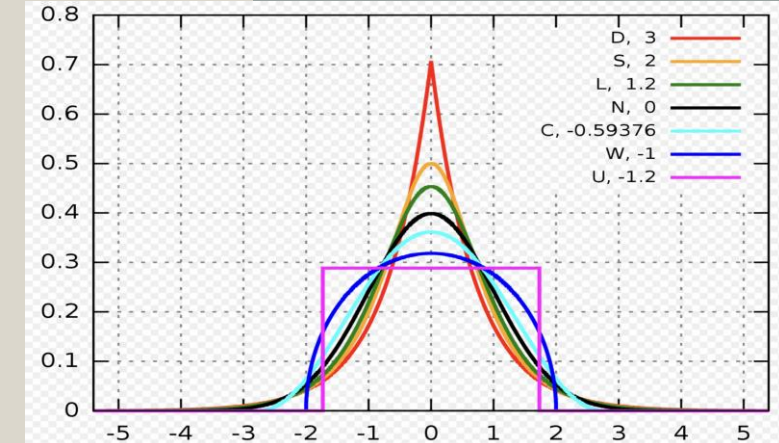
## Diagnosis the error of model

- NRMSE
  - Model bias
- 99% CI of Prediction
  - Model variance
- Skew
  - accept the tail of error distribution skew to right
- Kurtosis
  - accept the distribution of error is centralized

## Skew



## Kurtosis



# TTR Report - TTR Summary

Correlation	Explanation	Replacement	Sample-Die	OOS	Testing-Item	Excluded-Item	TTR-Item	TTR-Rate(%)	TTR-OOS	TTR-Coverage(%)
Initial			4194	4182	3367	0	0	0	0	0
Excluded			4012	2002	2764	603	0	0	0	0
V	90	V	4012	2002	2764	603	338	12.229	2002	100.000
V	80	V	4012	2002	2764	603	572	20.695	2002	100.000
V	70	V	4012	2002	2764	603	799	28.907	2002	100.000
V	60	V	4012	2002	2764	603	890	32.200	2002	100.000
V	50	V	4012	2002	2764	603	913	33.032	2002	100.000

## - Present different levels of TTR items

- There are 338 TTR items that satisfy Correlation & Explanation >90% & Replacement.
- There are 913 TTR items that satisfy Correlation & Explanation >50% & Replacement.

## - Suggestion

- Priority High: Correlation & Explanation >90% & Replacement, Trimmed Rate 12.23%
- Priority Low: Correlation & Explanation >50% & Replacement, Trimmed Rate 33.03%

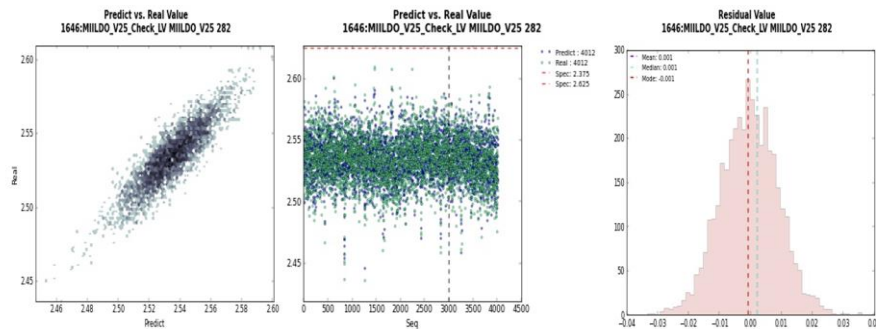
# TTR Report – VM & Correlation

## TTR VM Report: Prediction of each TTR items

1646:MIILDO\_V25\_Check\_LV MIILDO\_V25 282

Type	Set	Count	Mean	Std	Min	Max
Real	Train	3009	2.536	0.019	2.436	2.610
	Test	1003	2.532	0.019	2.461	2.594
Pred	Train	3009	2.536	0.017	2.446	2.601
	Test	1003	2.534	0.017	2.459	2.585
Error	Train	3009	0.000	0.009	-0.033	0.036
	Test	1003	-0.002	0.009	-0.032	0.032

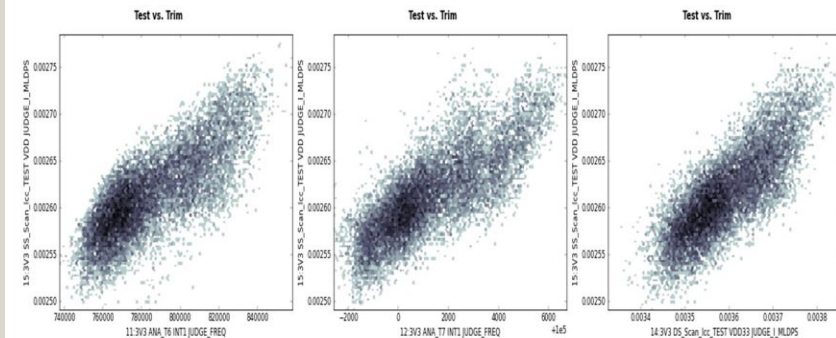
Type	Set	R2	nRMSE	Skew	Kurtosis	PredOOC	RealBre aks	PredBre aks	Precision	Recall
Model	Test	0.763	0.070	0.027	3.135	0.000	0.000	0.000	1.000	1.000



## TTR Correlation Report: Top 3 correlated items in each TTR model

15:3V3 SS\_Scan\_Icc\_TEST VDD JUDGE\_I\_MLDPS

Type	Set	Count	Mean	Std	Min	Max
Real	Train	9466	0.003	0.000	0.002	0.003
	Test	3155	0.003	0.000	0.003	0.003





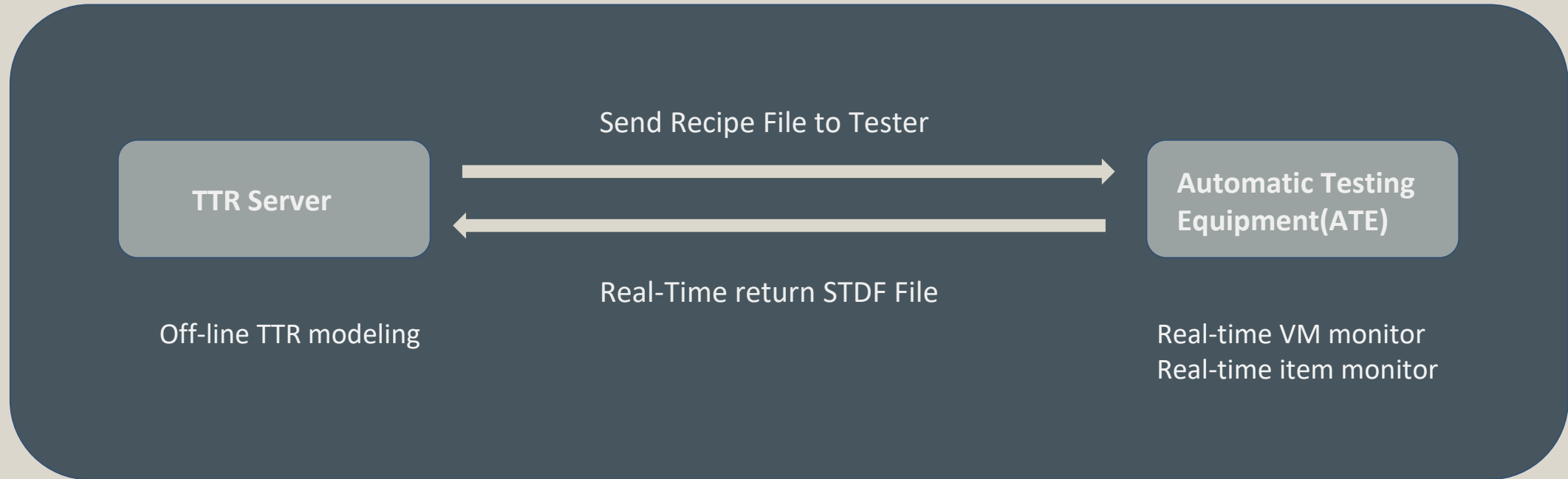
# Summary

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- **Item Filter can diagnosis correlation of all test items and suggest TTR items automatically.**
- **TTR Report can be a supporting information for executing Test Time Reduction which including,**
  - a. TTR Summary: Effectiveness.
  - b. VM Report: Accuracy of model.
  - c. Correlation Report: Top 3 correlated items of model.
- **After Test Time Reduction, user can monitor these items by VM value.**
- **Model has significant effectiveness in**
  - a. Program have high correlation in each items.
  - b. Program have completed data.
  - c. Program have continuous items.

# Future Work

## Real-Time TTR

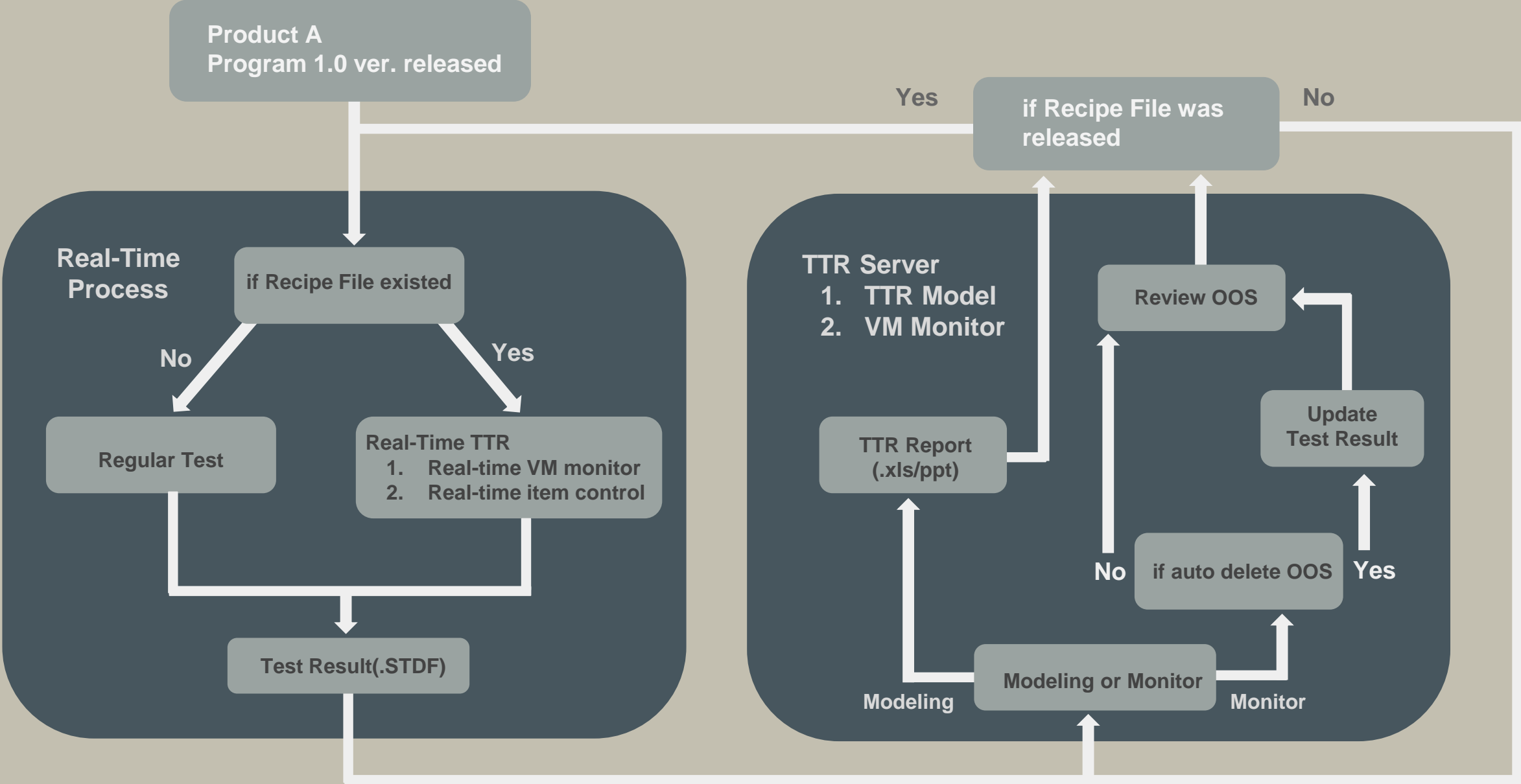


Item control and VM monitor by Recipe File online.





# Real-Time TTR – Close Loop Operation



## 联系 Tango-AI



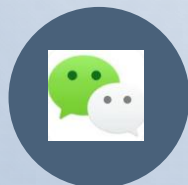
<https://www.itanggo.com>



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# Thank you

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# Appendix

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## Data Collection



1. Remove Binary Items & Non-Completed dice
2. According to test sequence, split data into 70/30%, 70 for Correlation, 30 for Explanation & Replacement

## Item Filter



1. Correlation
  - Check correlation of all test items, build prediction model for TTR items
2. Explanation
  - Calculate Coefficient of Determination( $R^2$ )
3. Replacement
  - Diagnosis the error: NRMSE、99%CI of Prediction、Skew、Kurtosis

## TTR Report & Recipe File



1. Export TTR Report: 1. Summary 2. VM Report 3. Correlation Report
2. User confirm TTR Report、decide TTR List and generate Recipe File
3. Send file to ATE and execute TTR(on-line)
4. Modify Recipe File, turn on/off TTR

## VM Monitor



1. Object: TTR VM(Prediction)
  - SPC: Spec Control, routine review Out of Spec(OOS) dice
  - PAT: Spec Control, online delete OOS dice and review