

**Suggestion of Testing Method**

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**For Industrial Level  
Cyber-Physical System  
in Complex Environment**

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InSTA 2019

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# CPS are increasing, operate in complex conditions

More advanced testing methods are required.

- ▶ Cyber Physical System
- ▶ Field Test
- ▶ SW Control



**TEST will be more important**

**However, How can we test everything consider reality?**



# Smaller HW, Larger SW, Need way to test complex SW of CPS

Each HW and SW part with interface can be testing separately

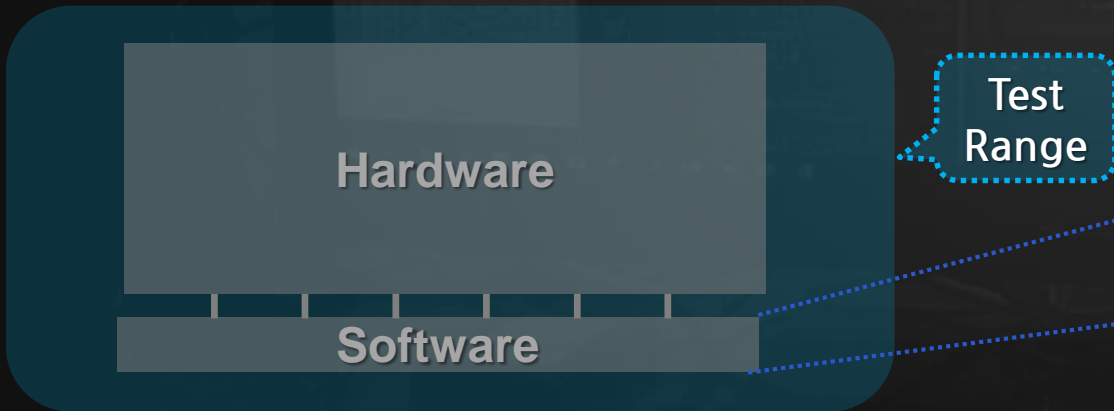
## Previous HIL Test

Input data  
(Analog Signal) or (Digital Signal)  
10010100101

Input data

CPS

Output data



Output data  
(Processed Analog Signal) or (Processed Digital Signal)  
011010110100

## Proposed Modified HIL Test

Real World data

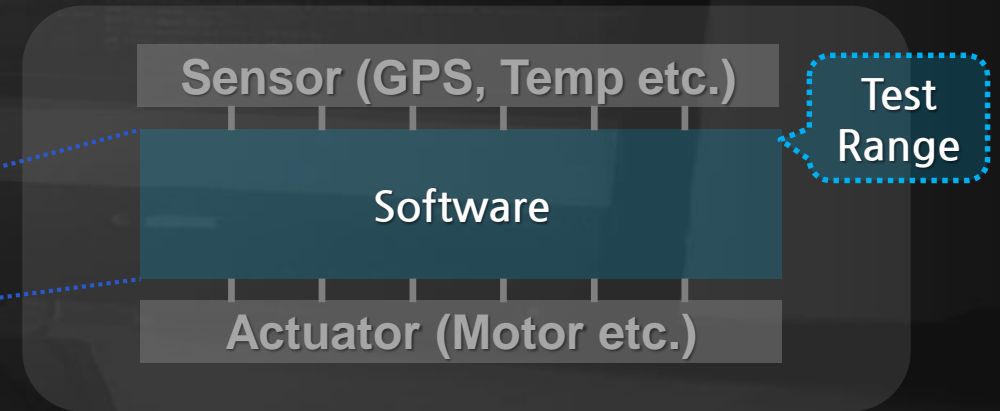
Sensor (GPS, Temp etc.)

Software

Actuator (Motor etc.)

Test Range

Result Action  
(Flight, Stop etc.)



# We can test SW functions on CPS without real condition.



Test Case



### Test Management System

Test Execution  
Result: Failed      Success Factor: 45.45%      Time Spent: 1 min 4 sec

Test Cases Status

- 5 Passed
- 5 Fail
- 3 Skipped
- 0 Not Executed

Execution summary

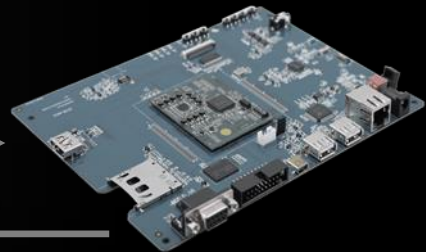
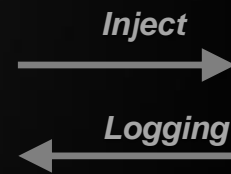
Test Cases Total:	11	Executed (%):	100%
Executed:	11	Failed (%):	27%
Failed:	3	Passed (%):	45%
Passed:	5	Skipped (%):	27%
Skipped:	3	Pending (%):	0%
Pending:	0		

Defects reported: 1

Created By: Abhimanyu G.

Assigned To: Abhimanyu G. (11 test cases)

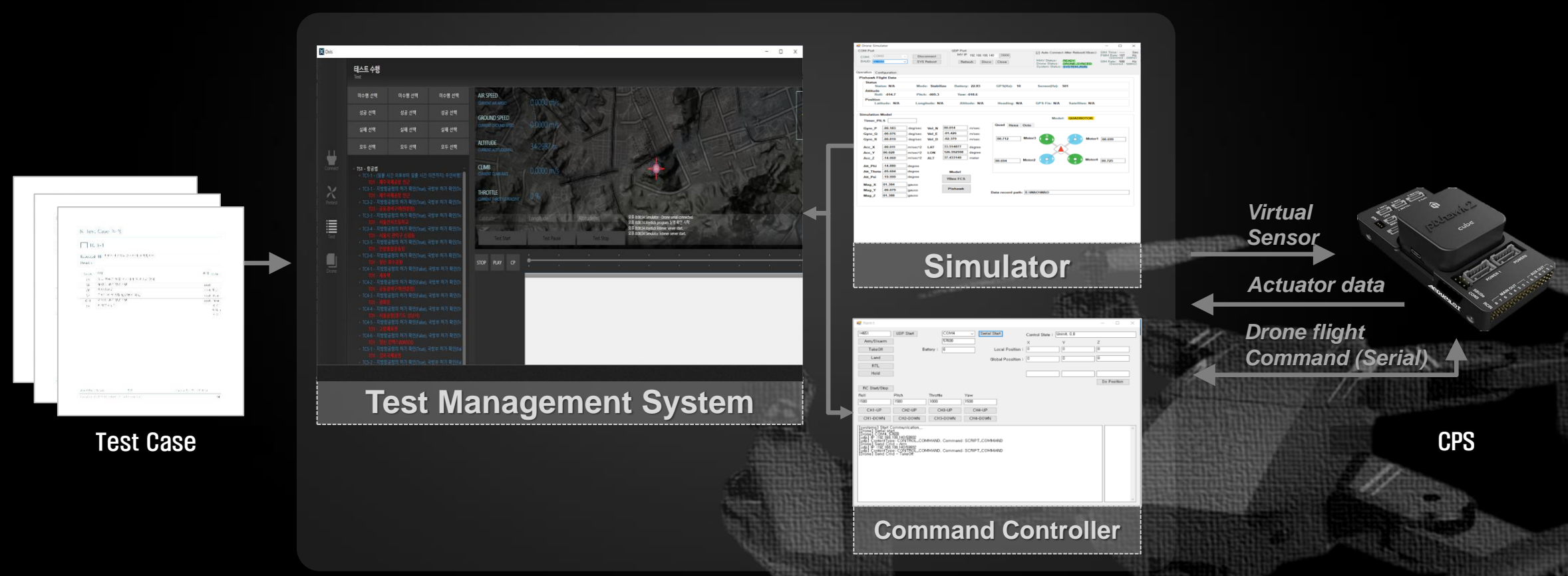
Requirements Management	Assigned To	Status	Time Spent	
<input type="checkbox"/> Requirement management feature can be enabled/disabled as per project configu	Abhimanyu G.	Fail	5 sec	View
<input type="checkbox"/> Test cases can be linked with one or more requirements	Abhimanyu G.	Skipped	19 sec	View
<input type="checkbox"/> Users can use linked issue manager as their requirements management tool	Abhimanyu G.	Skipped	1 sec	View
<input type="checkbox"/> Users can use external requirement management tool easily	Abhimanyu G.	Skipped	1 sec	View
<input type="checkbox"/> Users can see visual traceability matrix	Abhimanyu G.	Pass	7 sec	View
<input type="checkbox"/> Users can filter test cases by requirements on execution page and manage page	Abhimanyu G.	Pass	11 sec	View
<input type="checkbox"/> Requirement links should be updated when requirement management source settin	Abhimanyu G.	Fail	5 sec	View
<input type="checkbox"/> test case	Abhimanyu G.	Pass	3 sec	View
<input type="checkbox"/> Test Execution				
<input type="checkbox"/> View	Abhimanyu G.	Pass	9 sec	View
<input type="checkbox"/> Time tracker	Abhimanyu G.	Pass	2 sec	View
<input type="checkbox"/> Add	Abhimanyu G.	Fail	1 sec	View



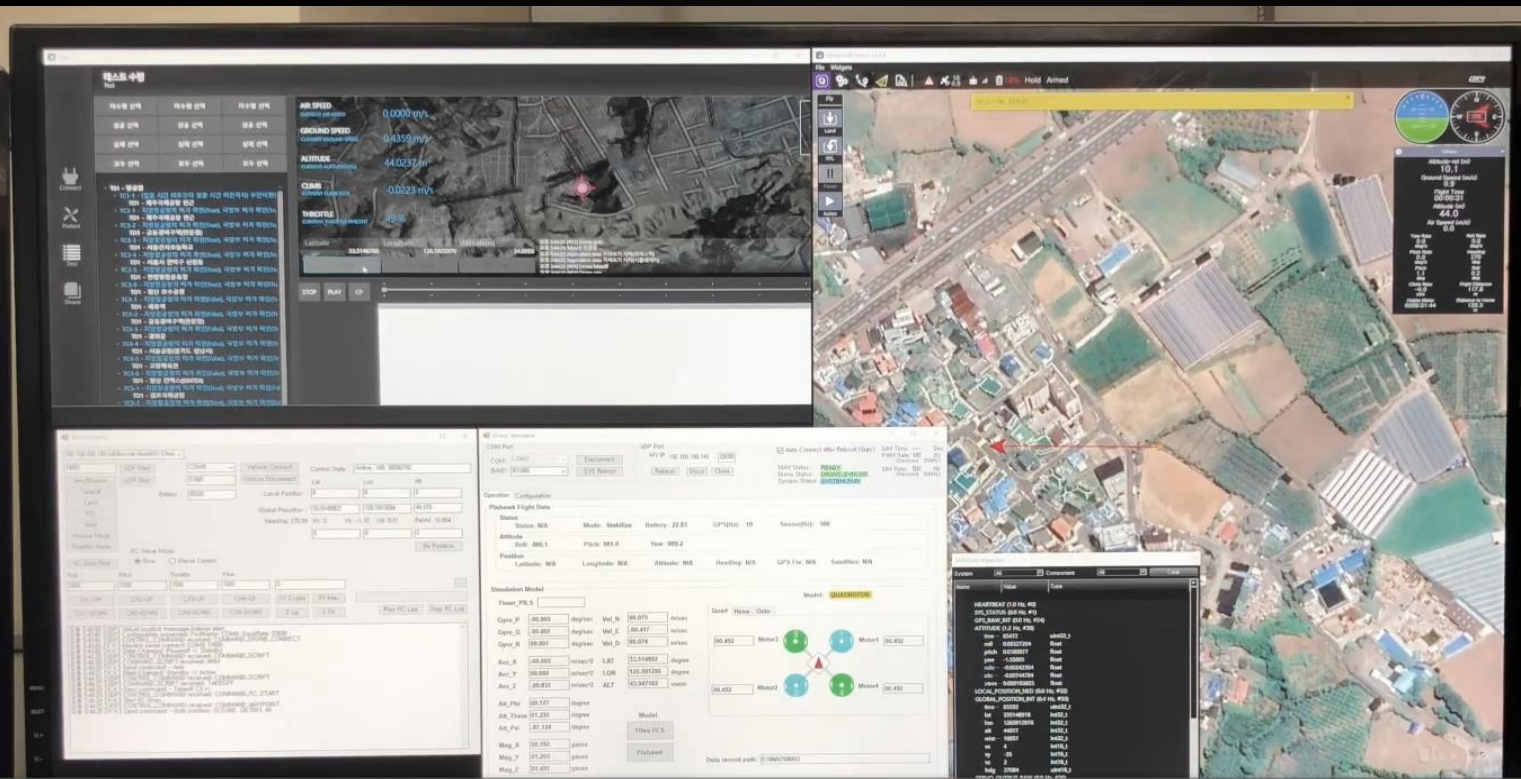
CPS

# E.g. Test the safety flight SW of drone without real fly.

Load test cases, simulator generate sensor data, read motor control data



# E.g. Test the safety flight SW of drone without real fly.



The PC send sensor data by serial communication

After self-processing, it transmits control signal to motor

Deliver the control signal to the PC without the actual motor

The PC checks the sensor and control signal data and judges the test results.

# 3 constraints should be satisfied to test the SW module in a virtual environment,

## Previous work

1. Test case should be designed as many as sufficient

To have confidence  
the CPS works safely

Suggestion of

Practical Quantification Measuring Method of  
Test Design Which Can Represent the Current Status  
- 2017, IEEE



Methods on Engineering



## Body

2. Test automation should be possible

Test cases might too many



## Future Work

3. Test results of real and virtual  
should be same

To test instead of real world

Example: Simulation Braking Result in rainy road  
= Actual braking result in rainy road



# (Const. 2) Test automation should be possible

Difficult for a manually test many TCs

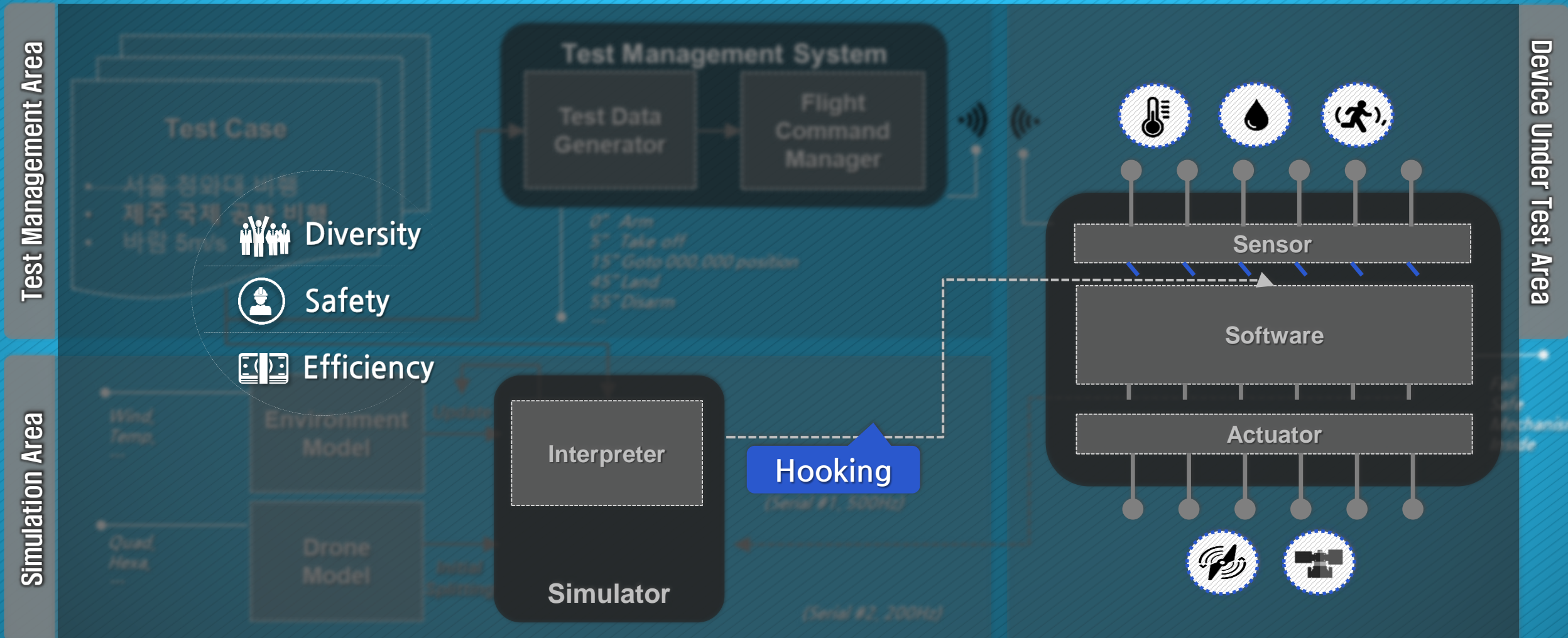
Defined 7 requirements for automated testing of the CPS SW module

- 1 Hooking
- 2 Sniffing
- 3 Interpret of actuator control raw data
- 4 Disarm fail safe mechanism
- 5 Avoid Probe Effect
- 6 Convert the abstract test scenario to physical level virtual data
- 7 Support Test Recording and Replay



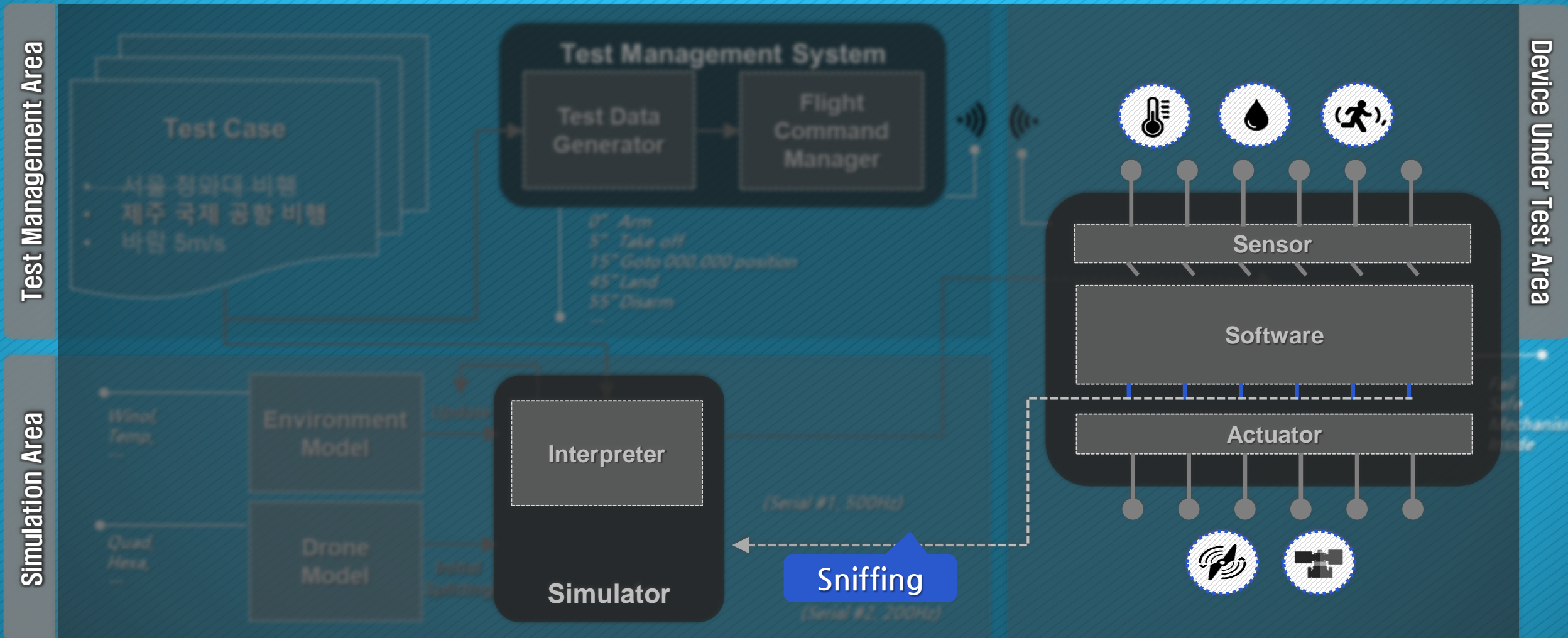
# Req.1 Hooking

Inject virtual data directly into the SW module of the CPS



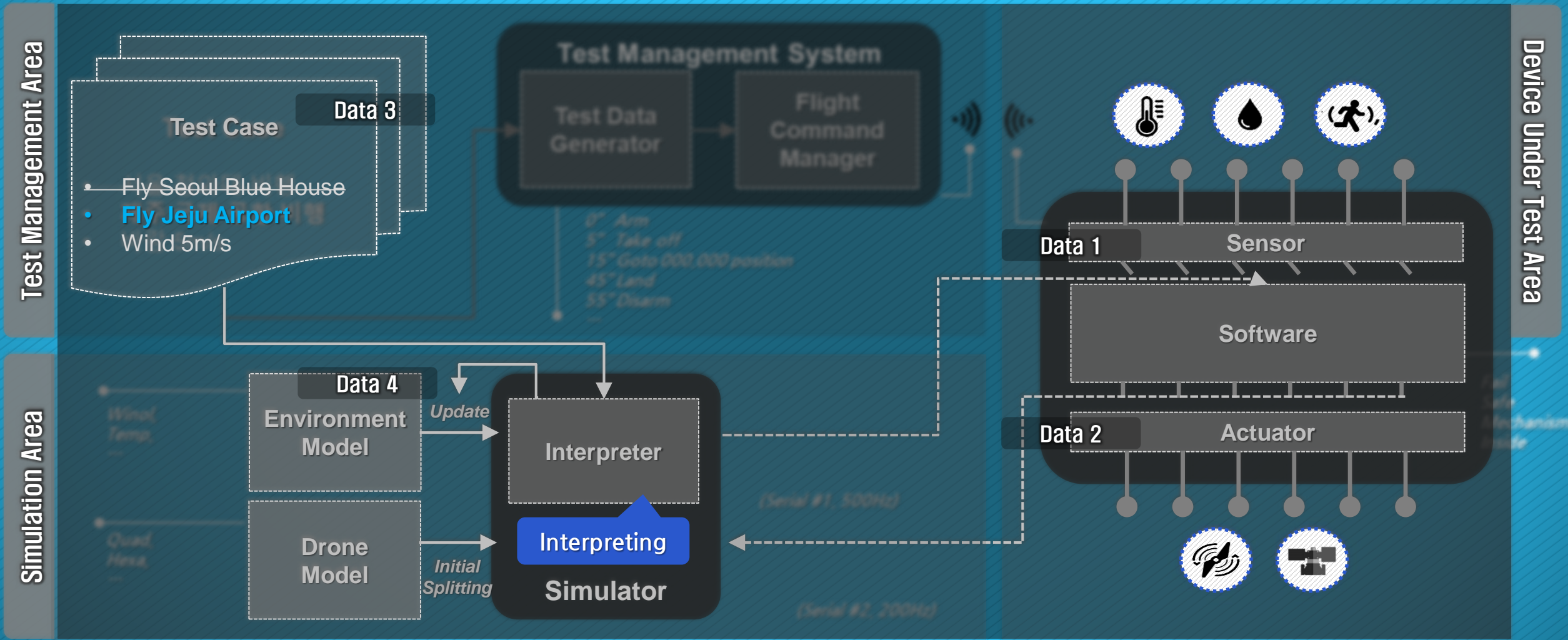
# Req.2 Sniffing

Intercept the actuator data from the SW model



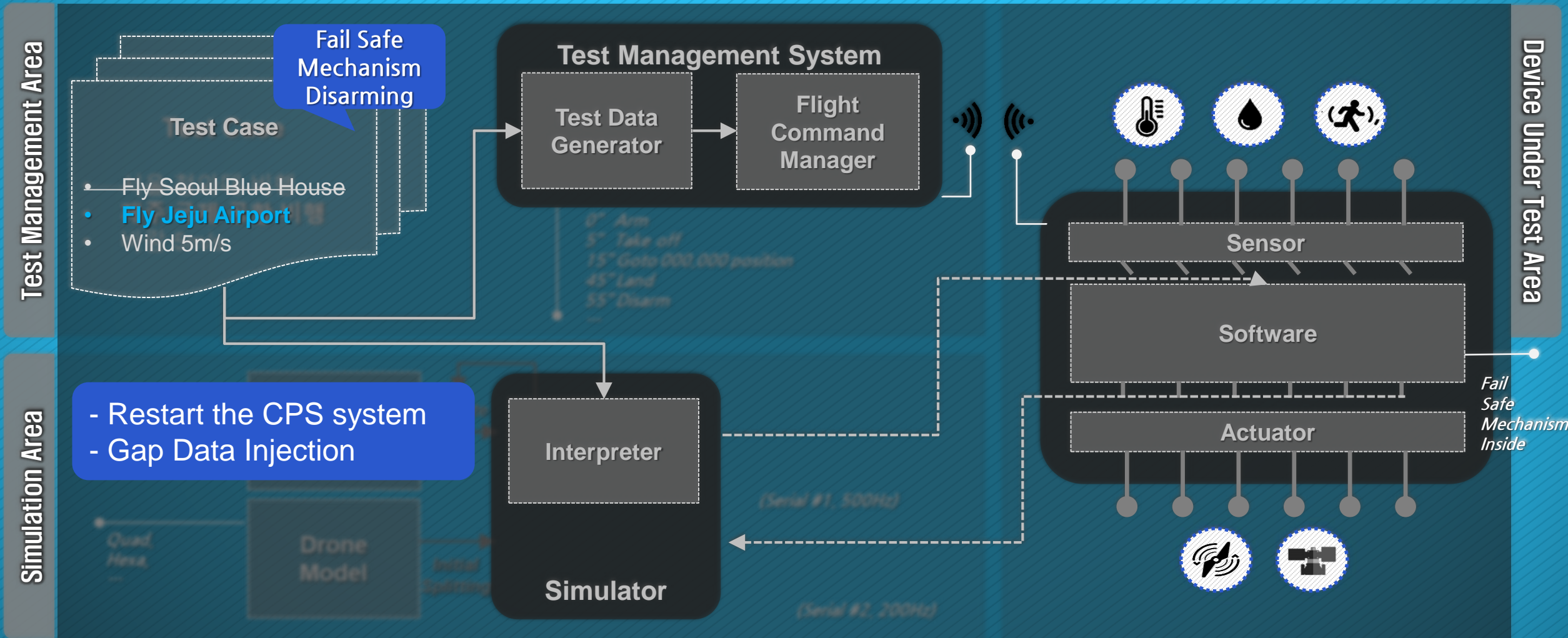
# Req.3 Interpretation of actuator data

Generate next virtual data using 4 data - TC, curr. Virtual data, curr. Actuator data, Environment Model



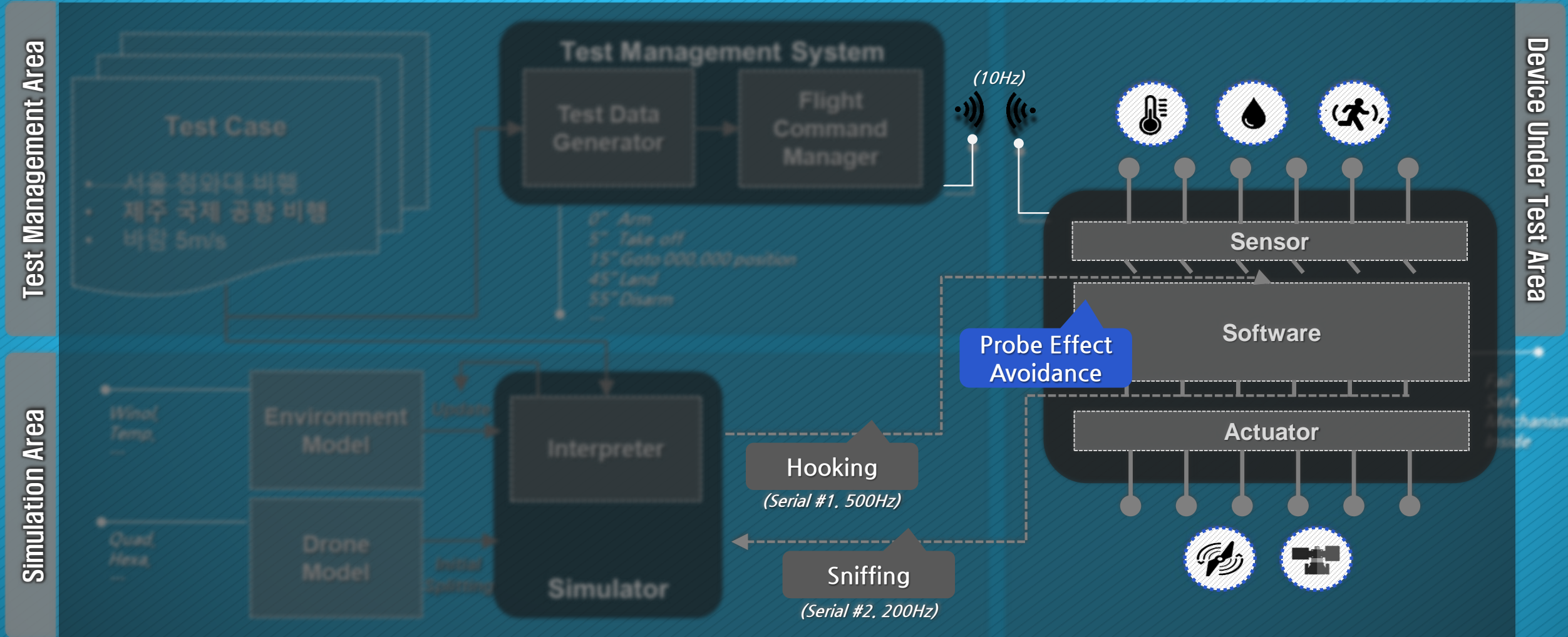
# Req.4 Disarm fail-safe mechanism

By disarming the fail-safe mechanism, it shortens the time for tests.



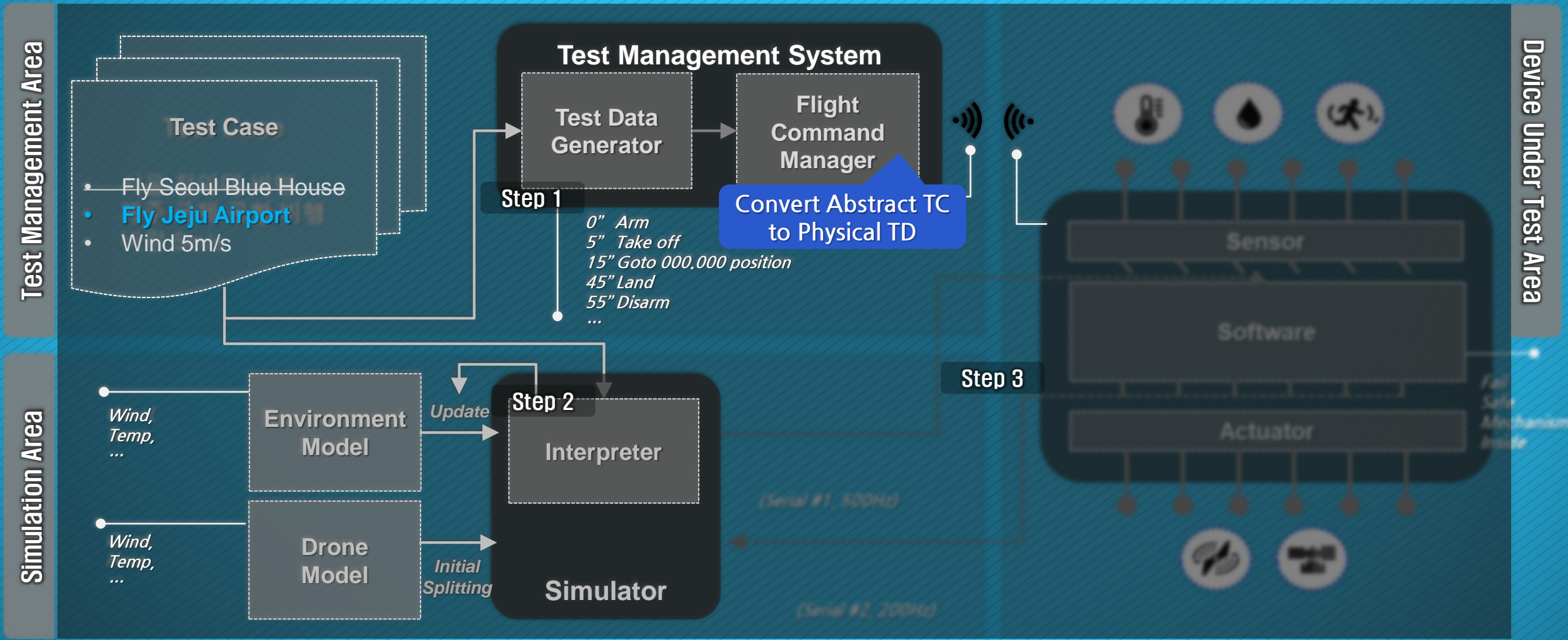
# Req.5 Avoid Probe Effect

Hooking virtual data & sniffing actuator data without interfere working



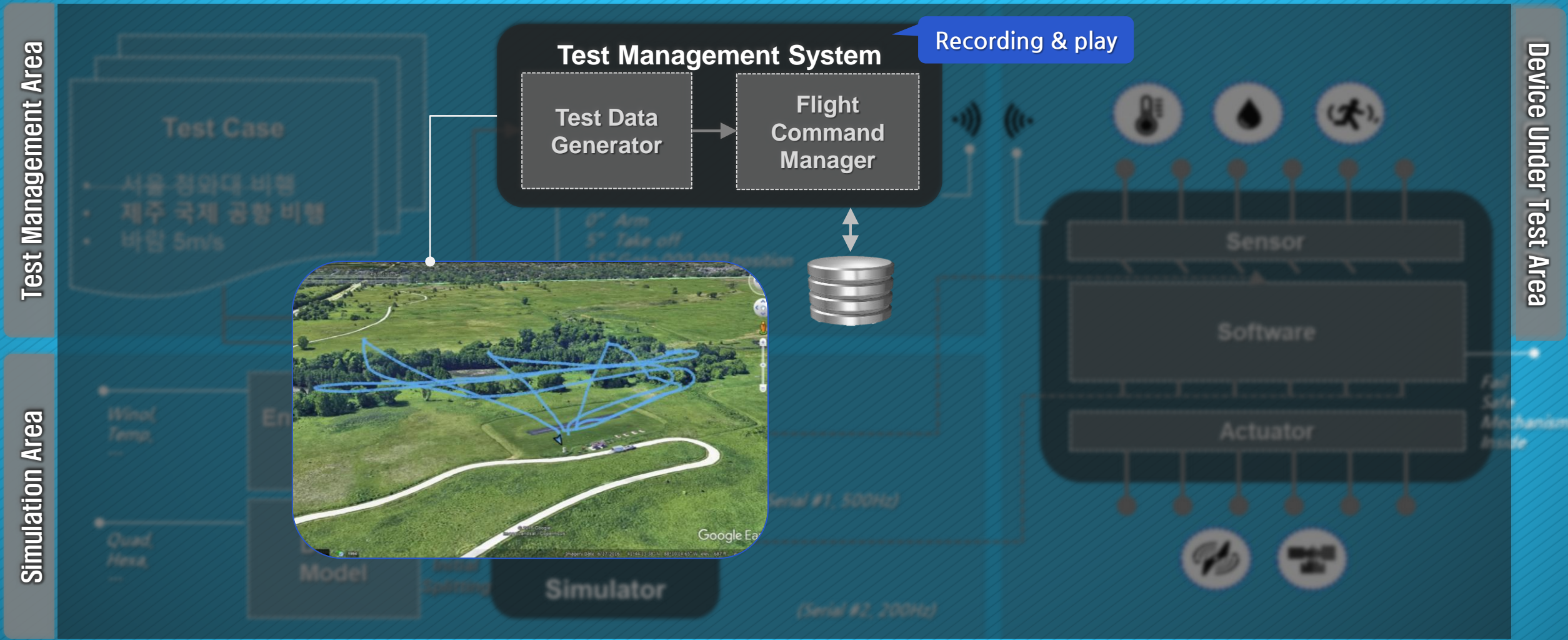
# Req.6 Convert the abstract TC to physical virtual data

Convert abstract TC to physically data that CPS can operate on



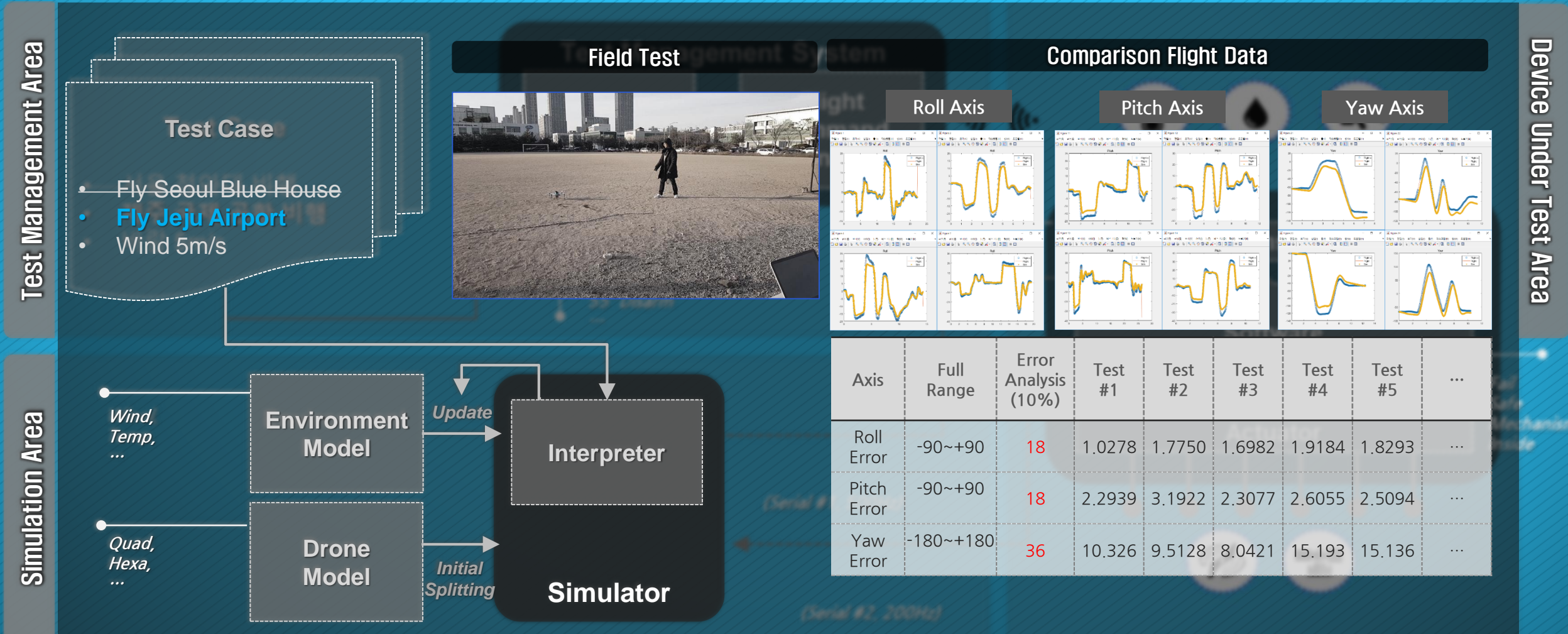
# Req.7 Support Test Recording and Replay

Check the test result is right



# (Const. 3) Test results of real and virtual should be same

Have confidence this CPS works well in real world



Axis	Full Range	Error Analysis (10%)	Test #1	Test #2	Test #3	Test #4	Test #5	...
Roll Error	-90~+90	18	1.0278	1.7750	1.6982	1.9184	1.8293	...
Pitch Error	-90~+90	18	2.2939	3.1922	2.3077	2.6055	2.5094	...
Yaw Error	-180~+180	36	10.326	9.5128	8.0421	15.193	15.136	...



# The importance of testing is increasing According to the increase in CPS with safety Req.



Testing in virtual environment can be useful  
Tests in all environments requires too much time and money

**윈도우 상단**

주요 상태 | 작수명 상태 | 작수종 상태  
비행 상태 | 경로 상태 | 임무 상태  
날씨 상태 | 임무 상태 | 날씨 상태  
모수 상태 | 작수명 상태 | 작수종 상태

**타이머 - 목록**

- 타이머 1: [설정 시간] [시작] [정지] [종료] [재설정]
- 타이머 2: [설정 시간] [시작] [정지] [종료] [재설정]
- 타이머 3: [설정 시간] [시작] [정지] [종료] [재설정]
- 타이머 4: [설정 시간] [시작] [정지] [종료] [재설정]
- 타이머 5: [설정 시간] [시작] [정지] [종료] [재설정]
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- 타이머 8: [설정 시간] [시작] [정지] [종료] [재설정]
- 타이머 9: [설정 시간] [시작] [정지] [종료] [재설정]
- 타이머 10: [설정 시간] [시작] [정지] [종료] [재설정]
- 타이머 11: [설정 시간] [시작] [정지] [종료] [재설정]
- 타이머 12: [설정 시간] [시작] [정지] [종료] [재설정]
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- 타이머 18: [설정 시간] [시작] [정지] [종료] [재설정]
- 타이머 19: [설정 시간] [시작] [정지] [종료] [재설정]
- 타이머 20: [설정 시간] [시작] [정지] [종료] [재설정]

**실시간 데이터**

AIR SPEED: 0.0000 m/s  
GROUND SPEED: 0.0001 m/s  
ALTITUDE: 33.9613 m  
CMB: -0.0236 m/s  
THRUSTLE: 0%

**비행 계획 (Flight Plan)**

Waypoint 1: [Name] [Altitude] [Speed] [Yaw] [Roll] [Pitch] [Action]

Waypoint	Name	Altitude	Speed	Yaw	Roll	Pitch	Action
1	START	30.000	5.000	0.000	0.000	0.000	Takeoff
2	POINT_A	30.000	5.000	0.000	0.000	0.000	Waypoint
3	POINT_B	30.000	5.000	0.000	0.000	0.000	Waypoint
4	POINT_C	30.000	5.000	0.000	0.000	0.000	Waypoint
5	END	30.000	5.000	0.000	0.000	0.000	Landing

**시뮬레이션 모델 (Simulation Model)**

Motor: [Value] [Unit]

Motor	Value	Unit
Motor1	50.000	Motor
Motor2	50.000	Motor
Motor3	50.000	Motor
Motor4	50.000	Motor

**로그 (Log)**

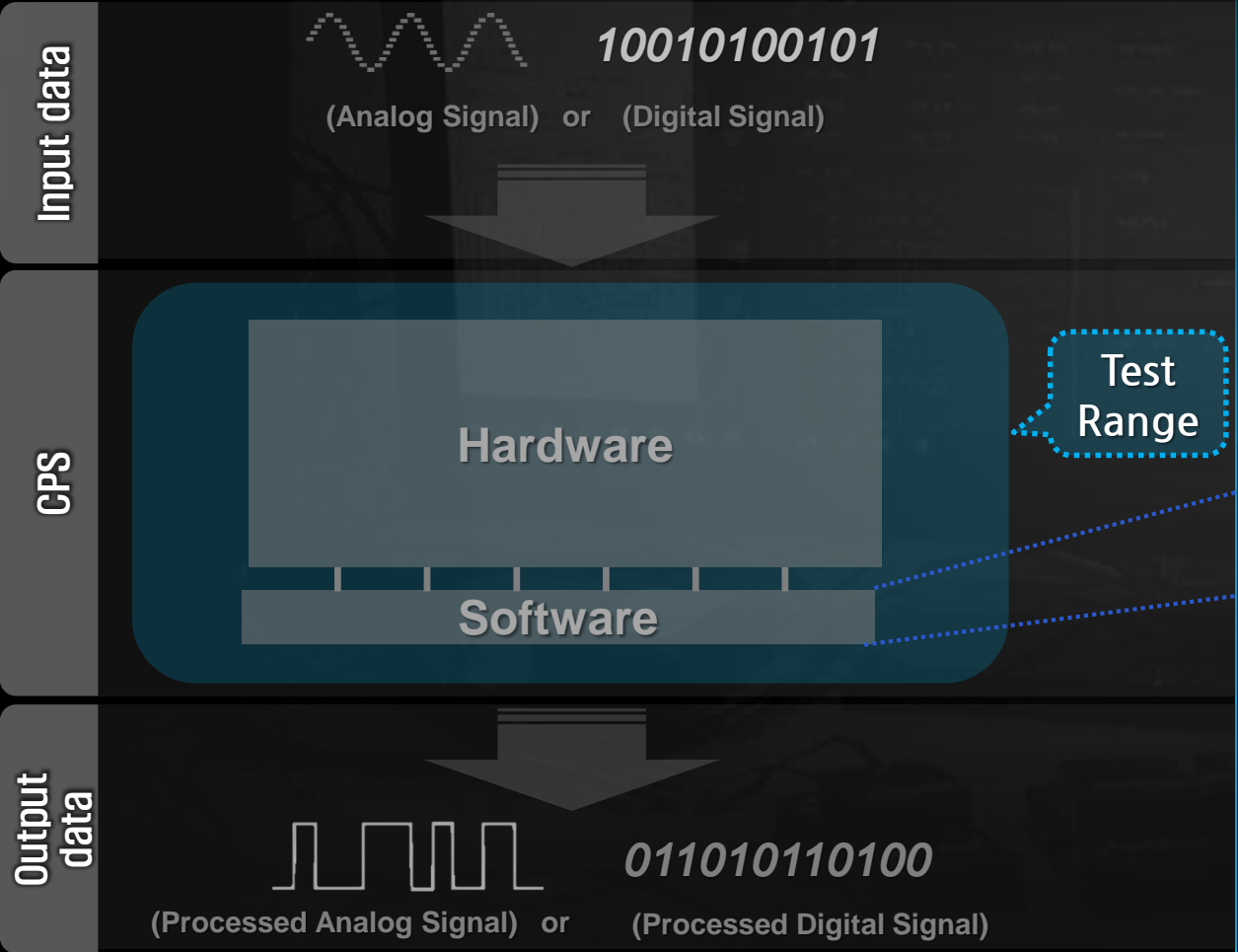
```
INFO: [Time] [Message]  
WARN: [Time] [Message]  
ERROR: [Time] [Message]
```



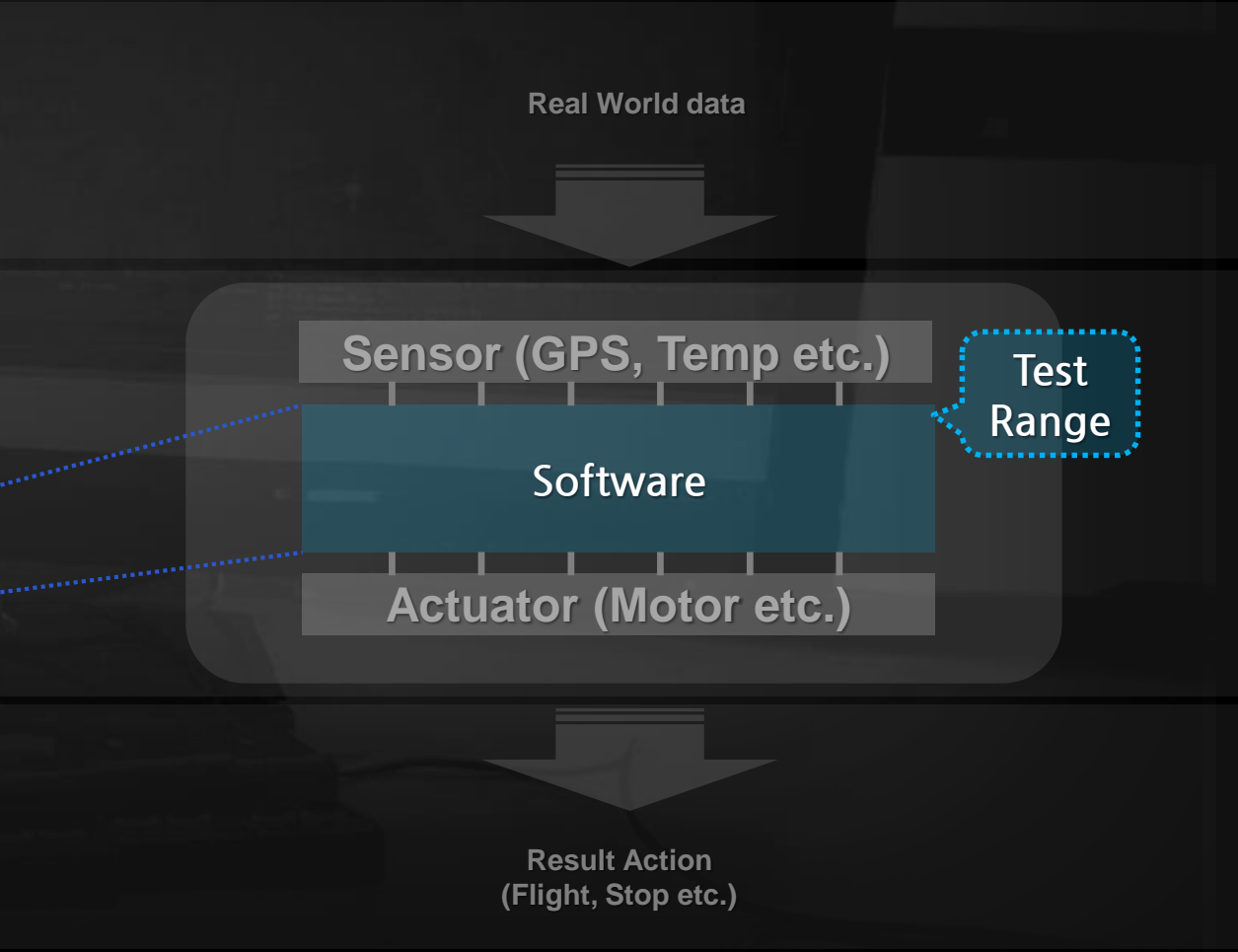
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Each HW and SW part with interface can be testing separately

## Previous HIL Test



## Proposed Modified HIL Test



# We can test SW functions on CPS without real condition.



Test Case



### Test Management System

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Result: Failed      Success Factor: 45.45%      Time Spent: 1 min 4 sec

Test Cases Status

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Execution summary

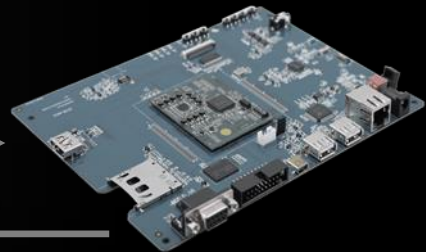
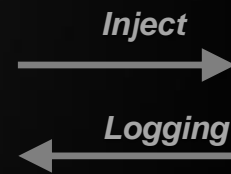
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Defects reported: 1

Created By: Abhimanyu G.

Assigned To: Abhimanyu G. (11 test cases)

Assigned To	Result	Time Spent
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Requirement management feature can be enabled/disabled as per project configu	Abhimanyu G.	Fail 5 sec
Test cases can be linked with one or more requirements	Abhimanyu G.	Skipped 19 sec
Users can use linked issue manager as their requirements management tool	Abhimanyu G.	Skipped 1 sec
Users can use external requirement management tool easily	Abhimanyu G.	Skipped 1 sec
Users can see visual traceability matrix	Abhimanyu G.	Pass 7 sec
Users can filter test cases by requirements on execution page and manage page	Abhimanyu G.	Pass 11 sec
Requirement links should be updated when requirement management source settin	Abhimanyu G.	Fail 5 sec
test case	Abhimanyu G.	Pass 3 sec
Test Execution		
View	Abhimanyu G.	Pass 9 sec
Time tracker	Abhimanyu G.	Pass 2 sec
Add	Abhimanyu G.	Fail 1 sec



CPS

# THANK YOU

CONTACT: [sichon@thinkforbl.com](mailto:sichon@thinkforbl.com)



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*Chon Sunil of ThinkforBL*

*Park Jihwan*