ThinkforBL
CONSULTING GROUP

Suggestion of Testing Method

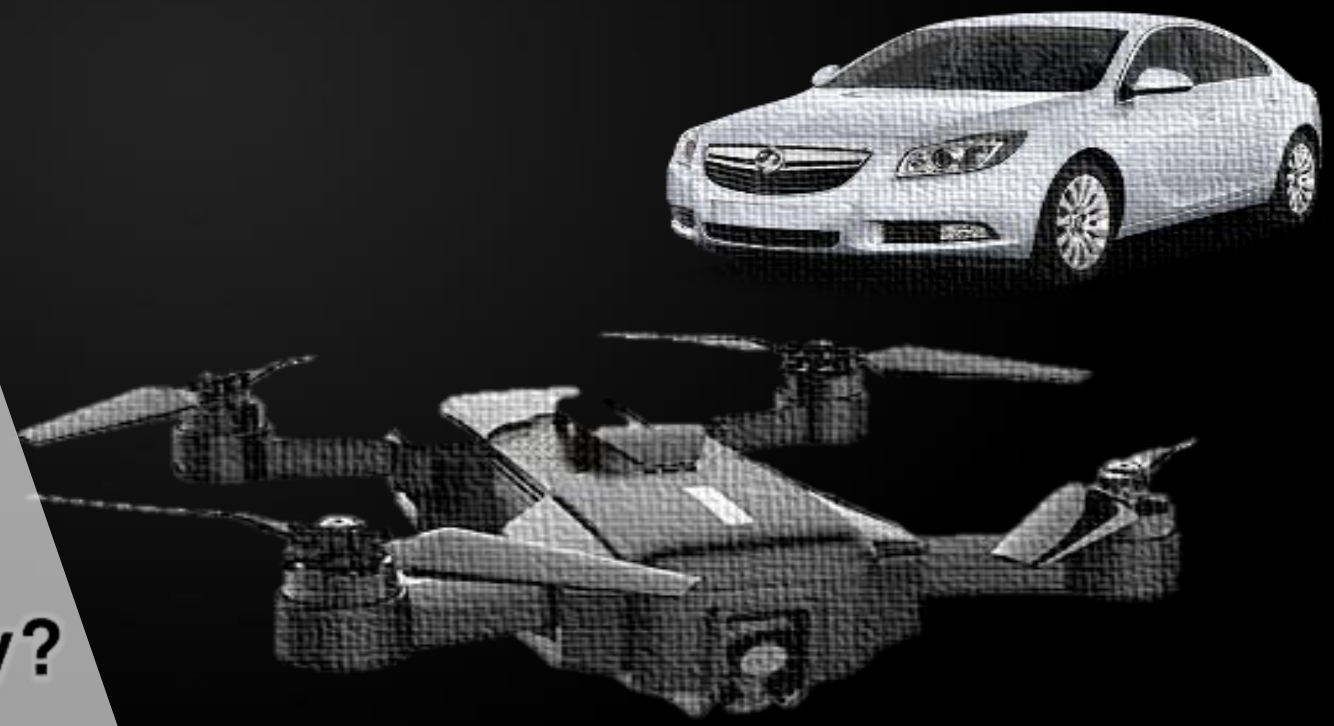
For Industrial Level Cyber-Physical System in Complex Environment

ASQN 2019

CPS are increasing, operate in complex conditions

More advanced testing methods are required.

- Cyber Physical System
- Field Test
- SW Control



TEST is important

However, How can we test everything to reflect reality?

Constraints on drones testing through actual flight

Marine rescue drone

International standard of tube : 3kg
Video transmission and reception : 2km

Air blower

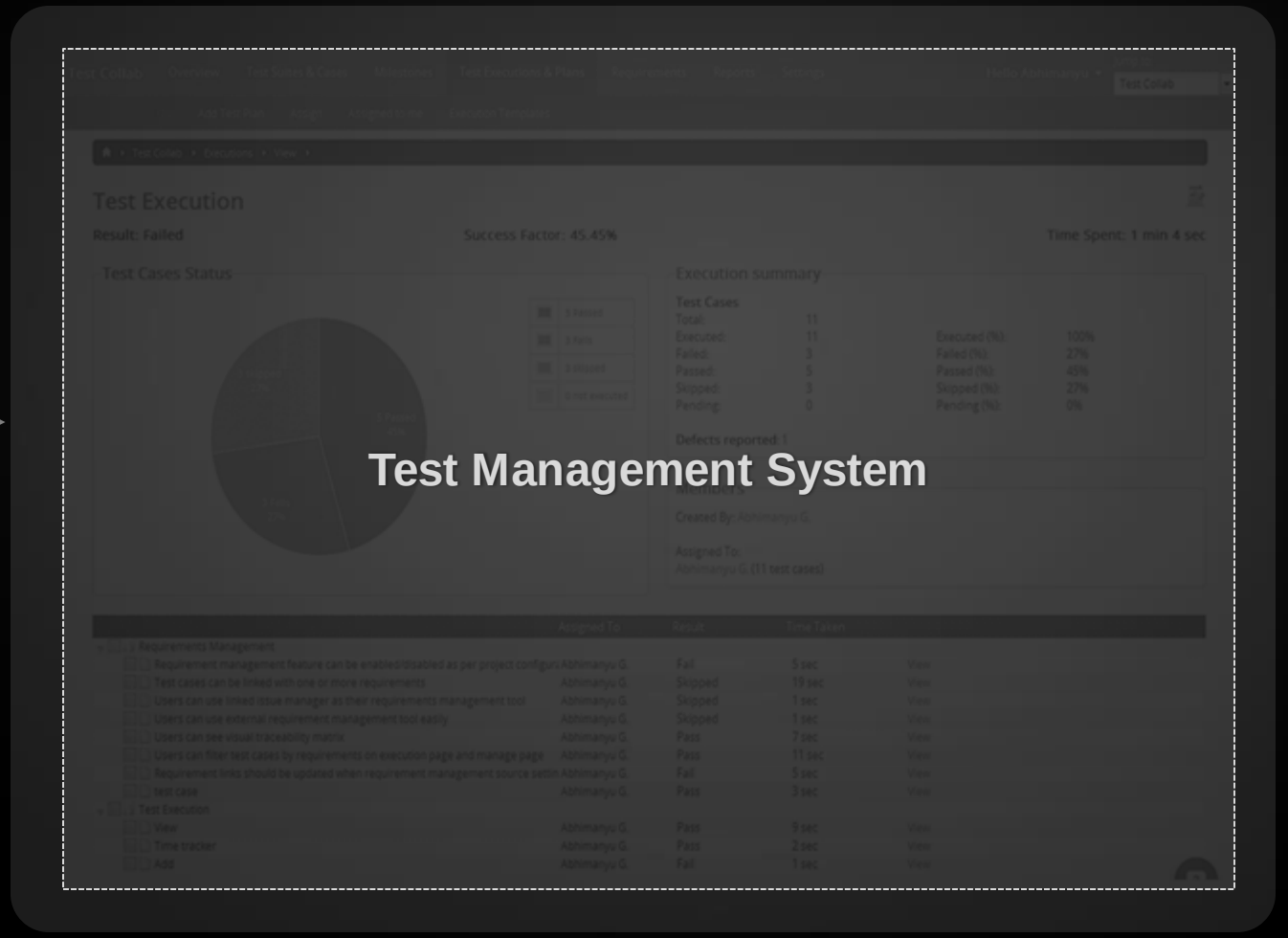
Altitude 150m,
"blower not allowed"

Difficult to verify that
the drones perform their mission
correctly even in strong winds

Possible 2nd Accident in case of failure
in securing position accuracy and drop accuracy

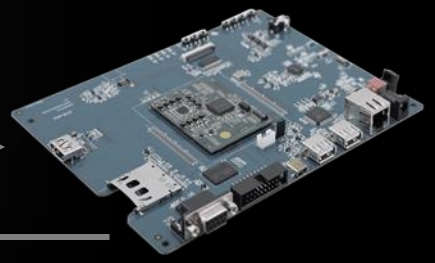
We can test SW functions on CPS without real condition.

Test Case



Inject

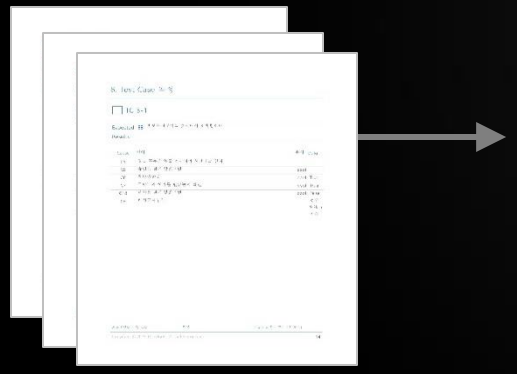
Logging



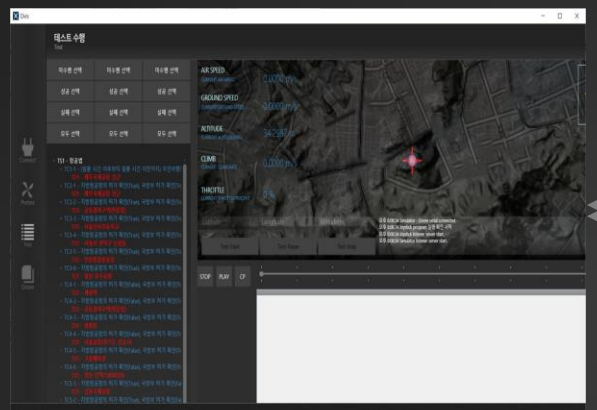
CPS

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

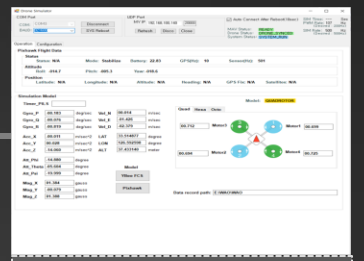
Load test cases, simulator generate sensor data, read motor control data



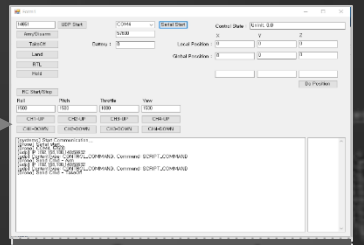
Test Case



Test Management System



Simulator



Command Controller

Virtual Sensor

Value (Serial)

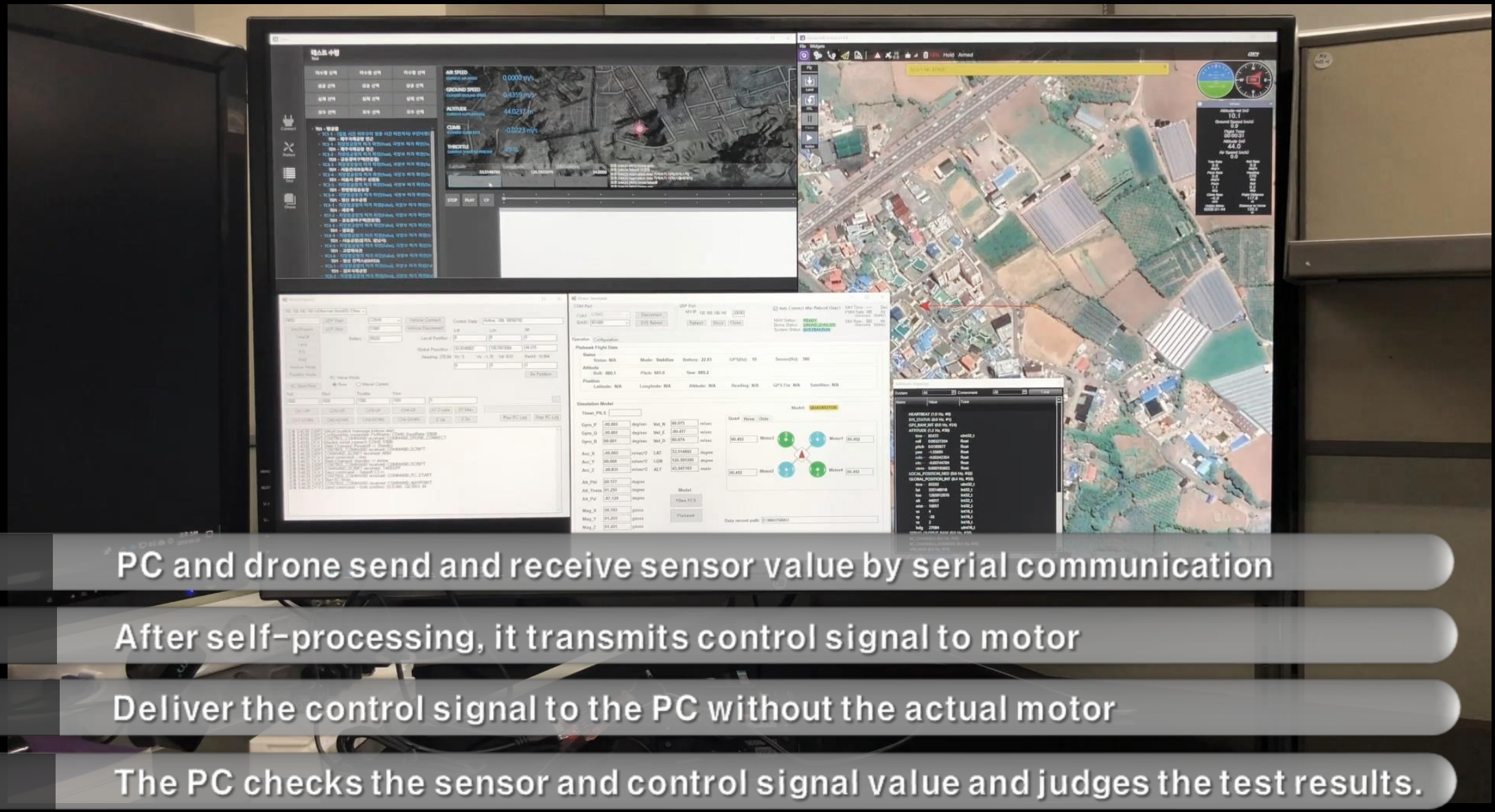
Drone flight Command (Serial)

CPS

Test Target

- Safety of Flight Controller
- Accuracy of Autonomous Flight
- Compliance of Law(Safety)
- Reliability of Mission Execution

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



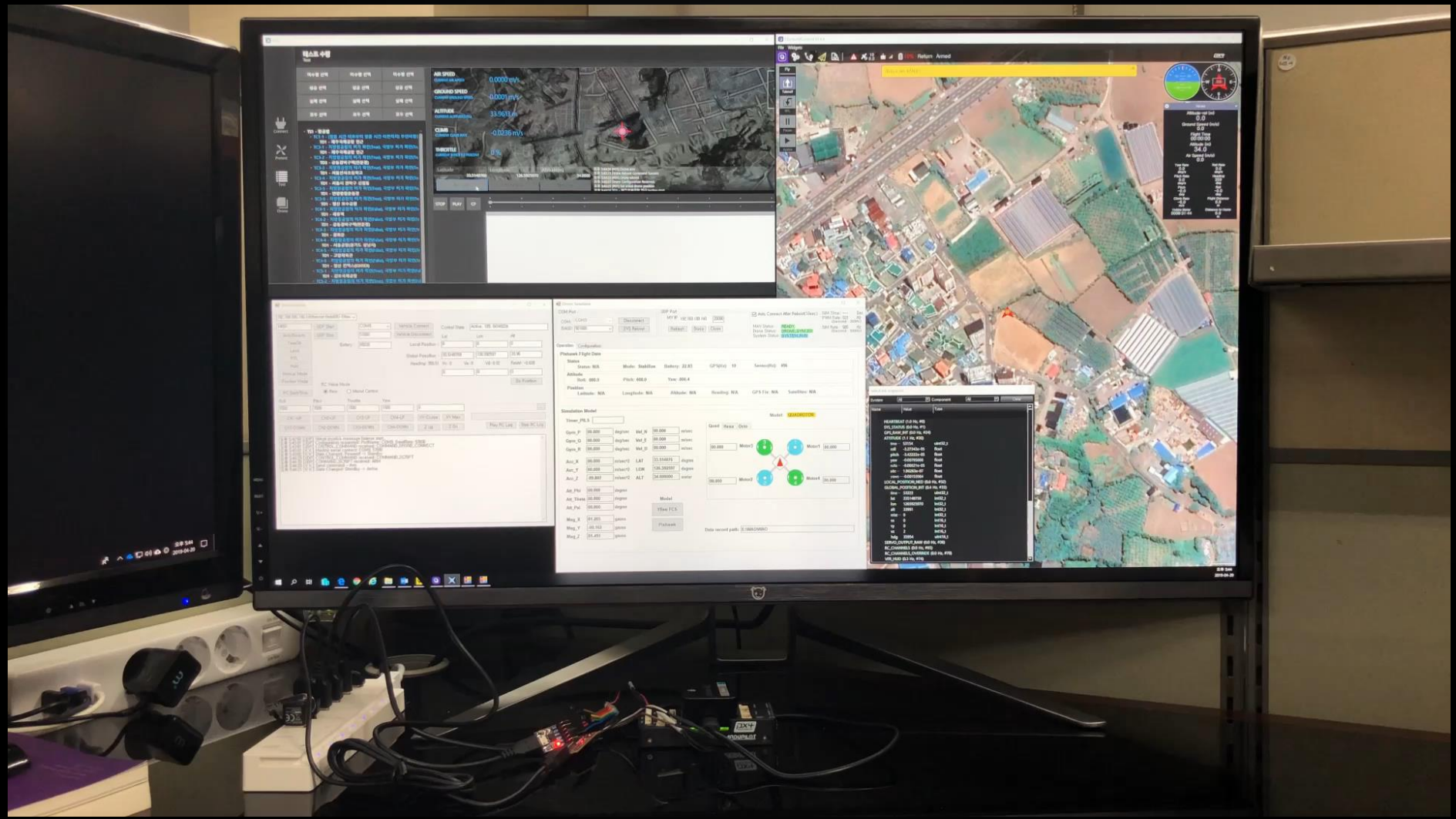
PC and drone send and receive sensor value by serial communication

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 value and judges the test results.

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



Smaller HW, Larger SW, Need way to test complex SW

Each HW and SW part with interface can be testing separately

Previous HIL Test

Input Value

10010100101

(Analog Signal) or (Digital Signal)

CPS

Hardware

Software

Test Range

Output Value

011010110100

(Processed Analog Signal) or (Processed Digital Signal)

Proposed Modified HIL Test

Real World Value

Sensor (GPS, Temp etc.)

Software

Actuator (Motor etc.)

Test Range

Diversity

Safety

Efficiency

Result Action
(Flight, Stop etc.)

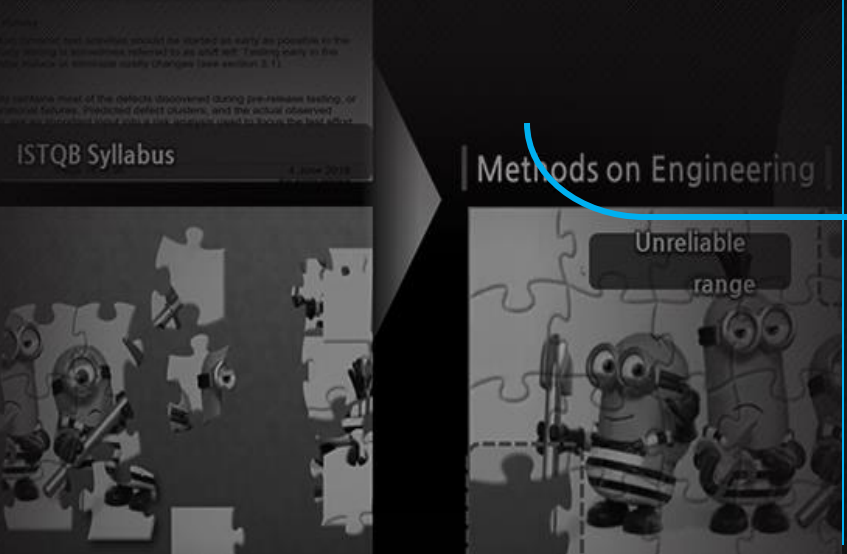
3 constraints should be satisfied to test the SW module in a virtual environment,

1. Test case should be designed as many as sufficient

To have confidence the CPS works safely

Diversity

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



2. Test automation should be possible

Test cases might too many

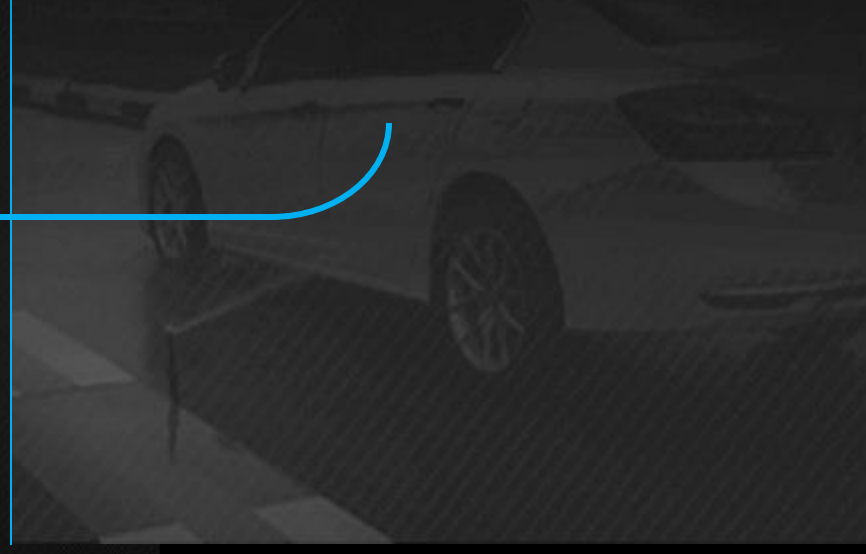
Efficiency

“Safety”

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. 1) Test case should be designed as many as we can think sufficient

Divide the condition into several pieces of data, Logically calculating all combinations

Fault

Function List	
Create the Serial port.	Implemented
Performing the communicate using Serial port.	Implemented
Release the Serial port.	Implemented
Input the message.	Implemented
Change the message.	Implemented
Edit the message.	Implemented
Maintain the compatibility of the message.	Not Implemented
Manage the record of changes of message.	Implemented
Delete the message.	Implemented
Restore the message.	Implemented

SPEC

≠

```
public SerialPort OpenPort2(string portName)
{
    SerialPort tempPort = null;
    SerialPort port = null;
    try
    {
        tempPort = new SerialPort(portName);
        tempPort.Open();
        SomeMethod();
        //Add any other methods above this line
        port = tempPort;
        tempPort = null;

    }
    finally
    {
        if (tempPort != null)
        {
            tempPort.Close();
        }
    }
    return port;
}
```

CODE (Actual result)

Figure out though "Testing"

Related Technology

Specification	$f = ab + cd$
Implemented	$f' = abc + cd$

LIF: 3rd Literal of 1st term fault (Insertion)

$UTP_1(f)$	$\{t1:(TTTF), t2:(TTFT), t3:(TTFF)\}$
when $t1$	$f = T, f' = T$
when $t2$	$f = T, f' = \boldsymbol{F}$
when $t3$	$f = T, f' = \boldsymbol{F}$

$t2, t3$ makes f' $False$, MUTP can detect LIF type

Logic analysis method (MUTP example)

- ENF: Expression Negation Fault
- TNF: Term Negation Fault
- TOF: Term Omission Fault
- LNF: Literal Negation Fault
- LRF: Literal Reference Fault
- LOF: Literal Omission Fault
- LIF: Literal Insertion Fault
- ORF+: Operator Reference Fault
- ORF : Operator Reference Fault

Fault Types based on DNF

Perform DNF-based logic analysis combined with Boolean expressions

(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 value
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

(Const. 2) Example

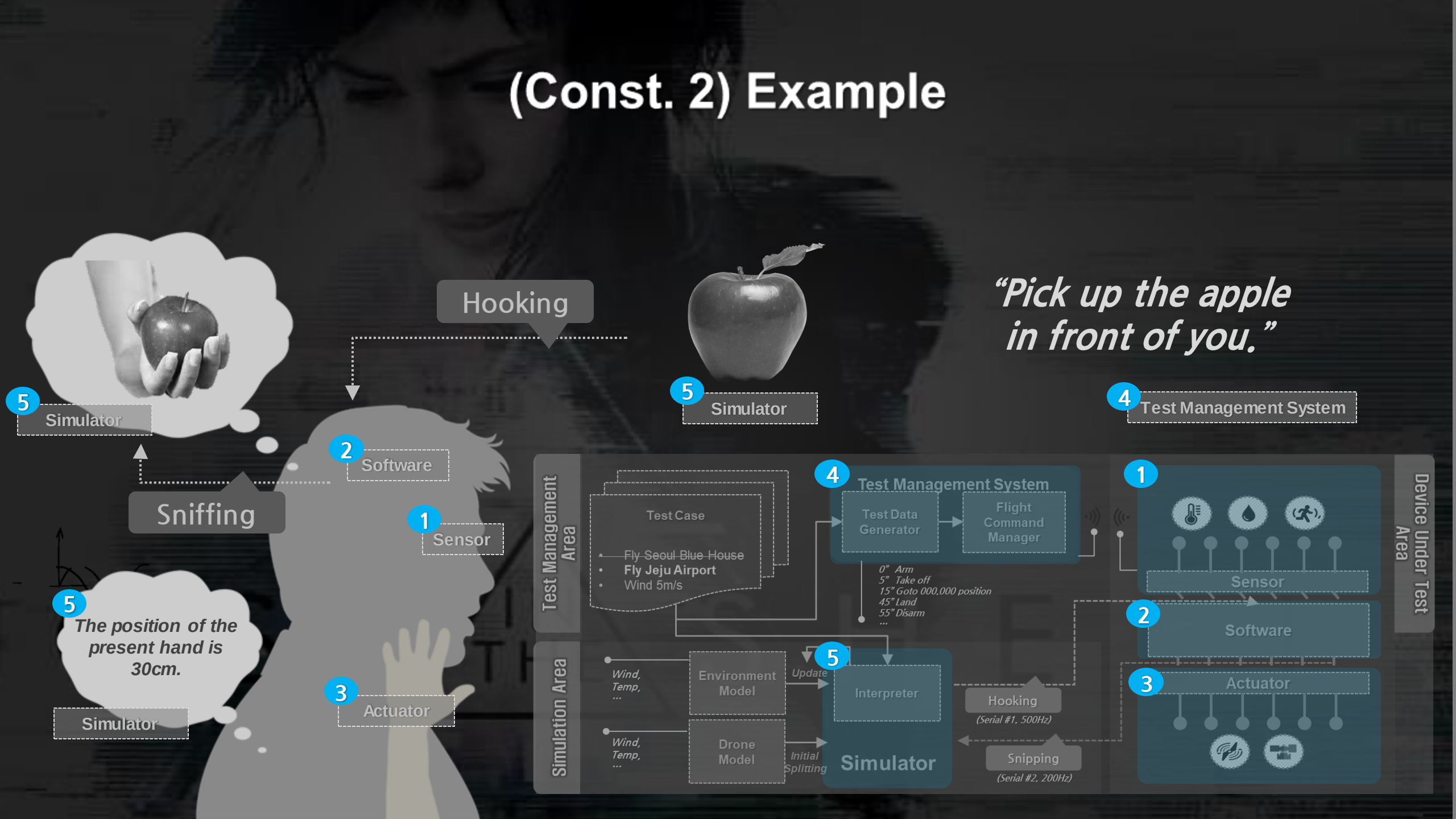
Hooking

"Pick up the apple in front of you."

Sniffing

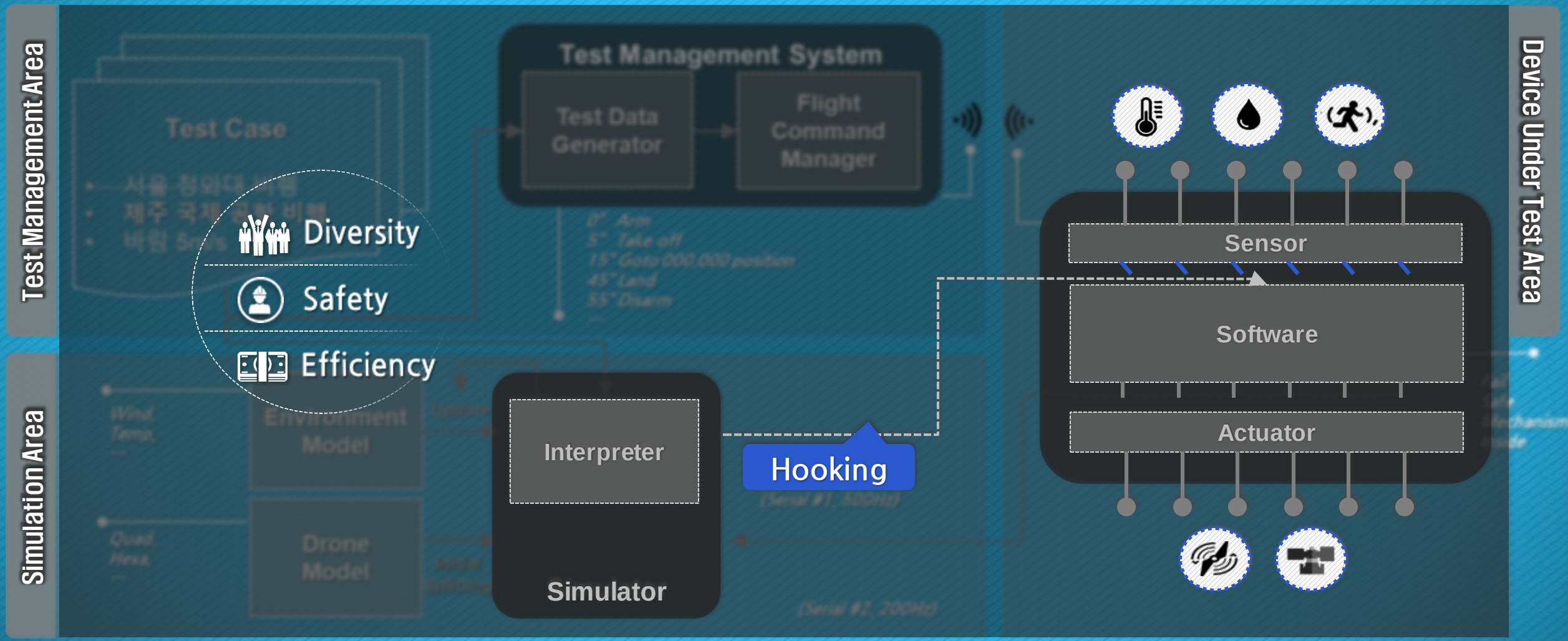
The position of the present hand is 30cm.

(Const. 2) Example



Req.1 Hooking

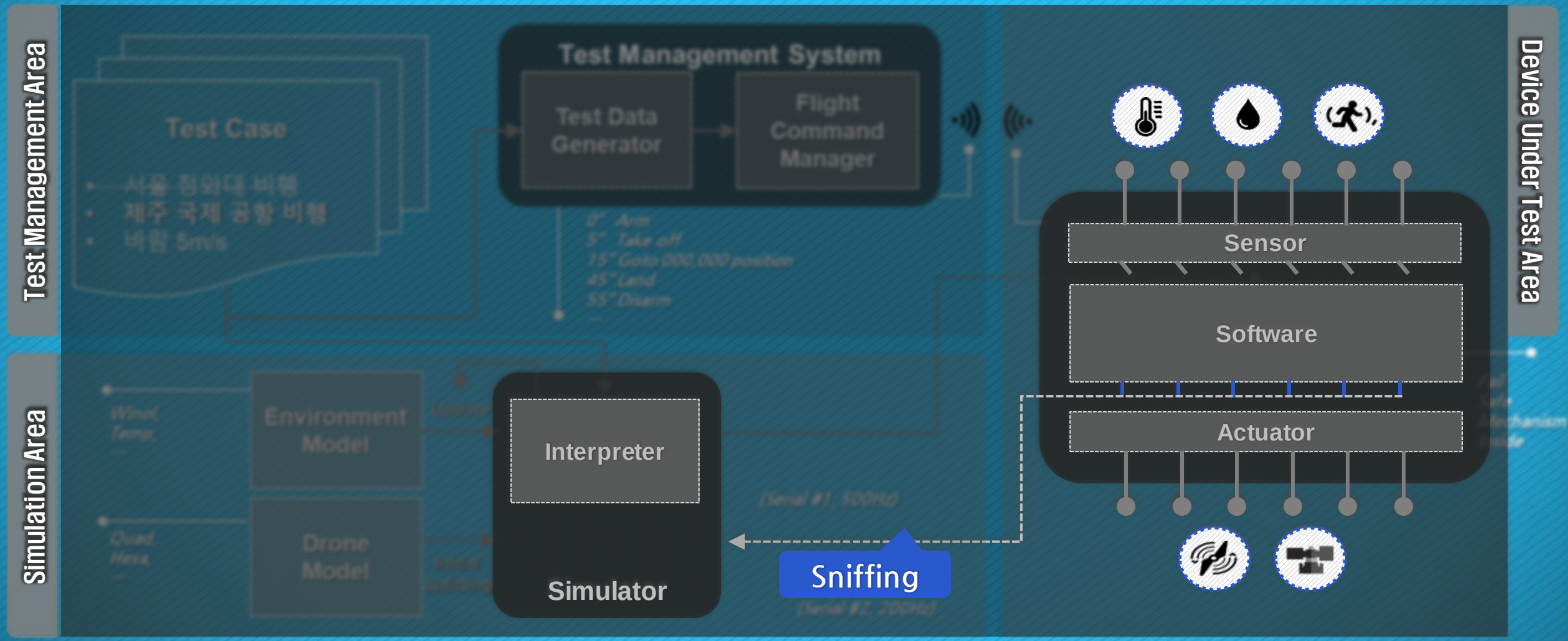
Inject virtual data directly into the SW module of the CPS



Hooking | Sniffing | Interpret the result | Disarming | Avoid Probe Effect | Abstract ➔ Physical | Record & Play

Req.2 Sniffing

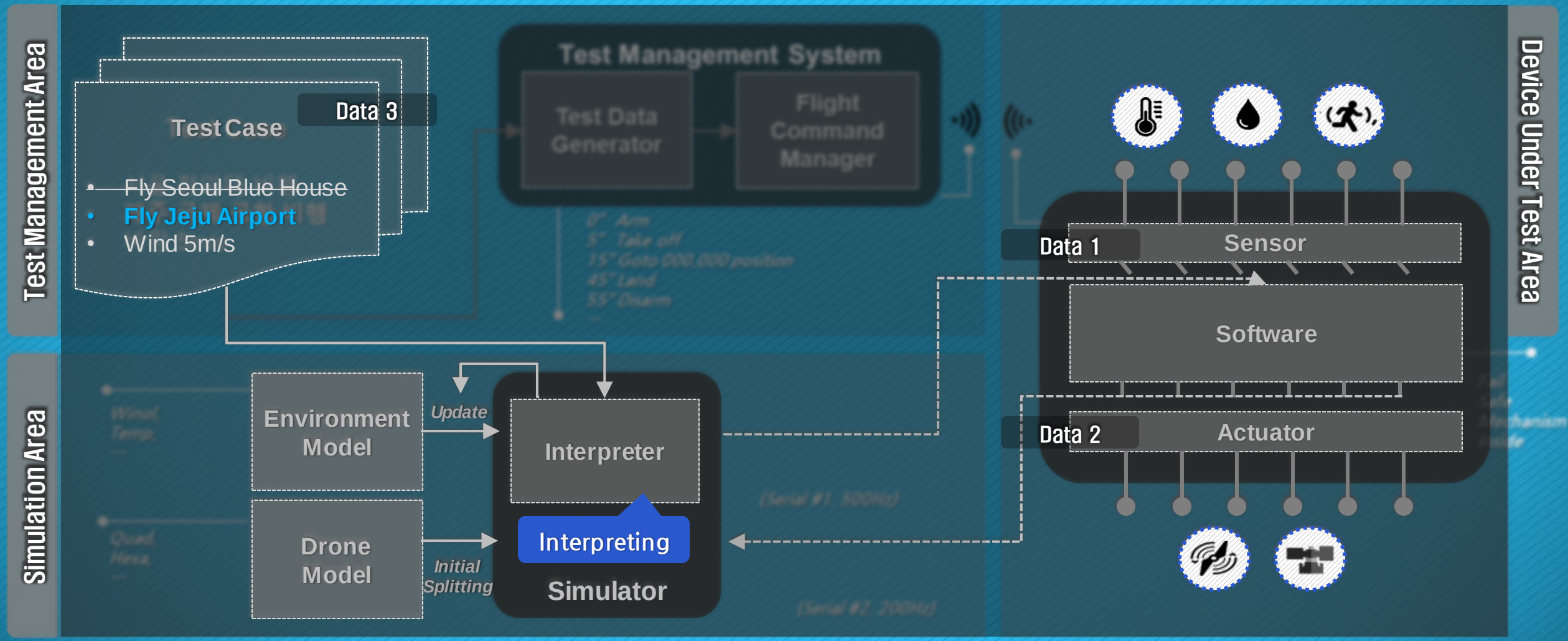
Intercept the actuator data from the SW model



Hooking | Sniffing | Interpret the result | Disarming | Avoid Probe Effect | Abstract ➔ Physical | Record & Play

Req.3 Interpretation of actuator data

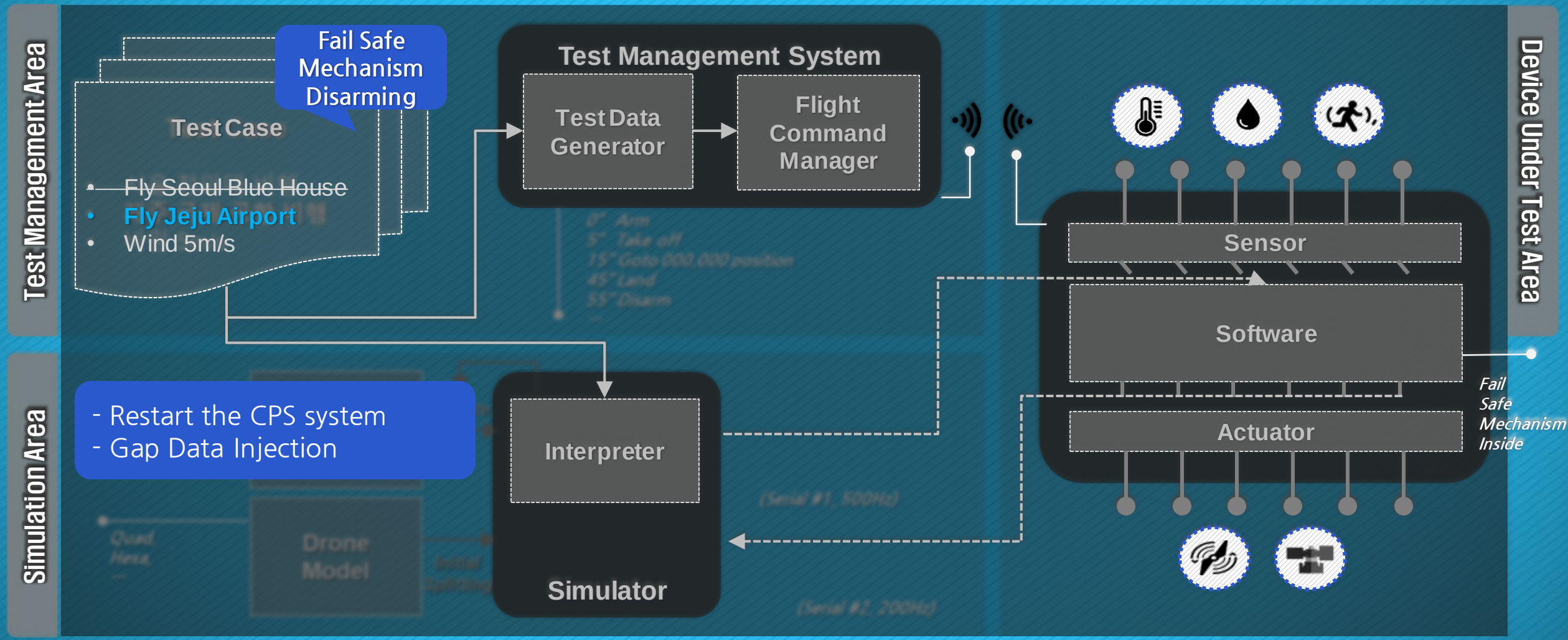
Generate next virtual data using 4 data - TC, curr. Virtual data, curr. Actuator data, Environment Model



Hooking | Sniffing | Interpret the result | Disarming | Avoid Probe Effect | Abstract ➔ Physical | Record & Play

Req.4 Disarm fail-safe mechanism

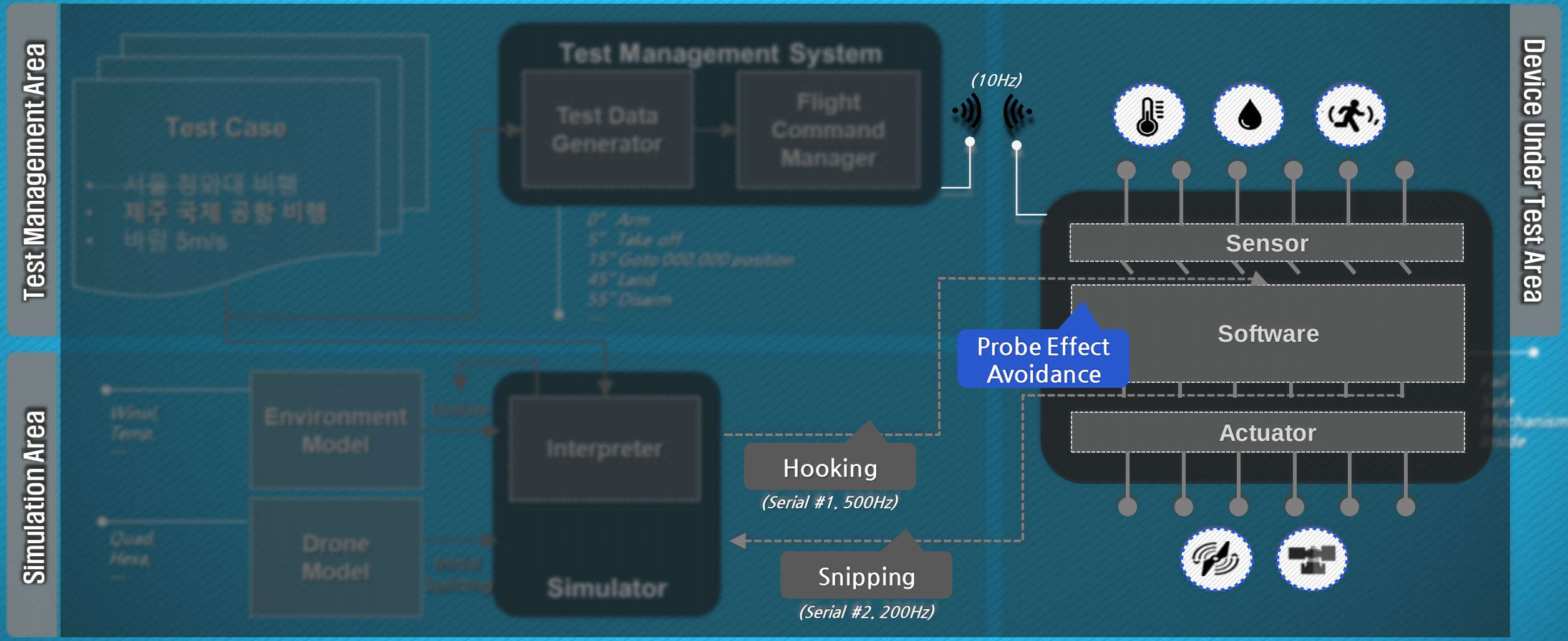
By disarming the fail-safe mechanism, it shortens the time for tests.



Hooking | Sniffing | Interpret the result | Disarming | Avoid Probe Effect | Abstract → Physical | Record & Play

Req.5 Avoid Probe Effect

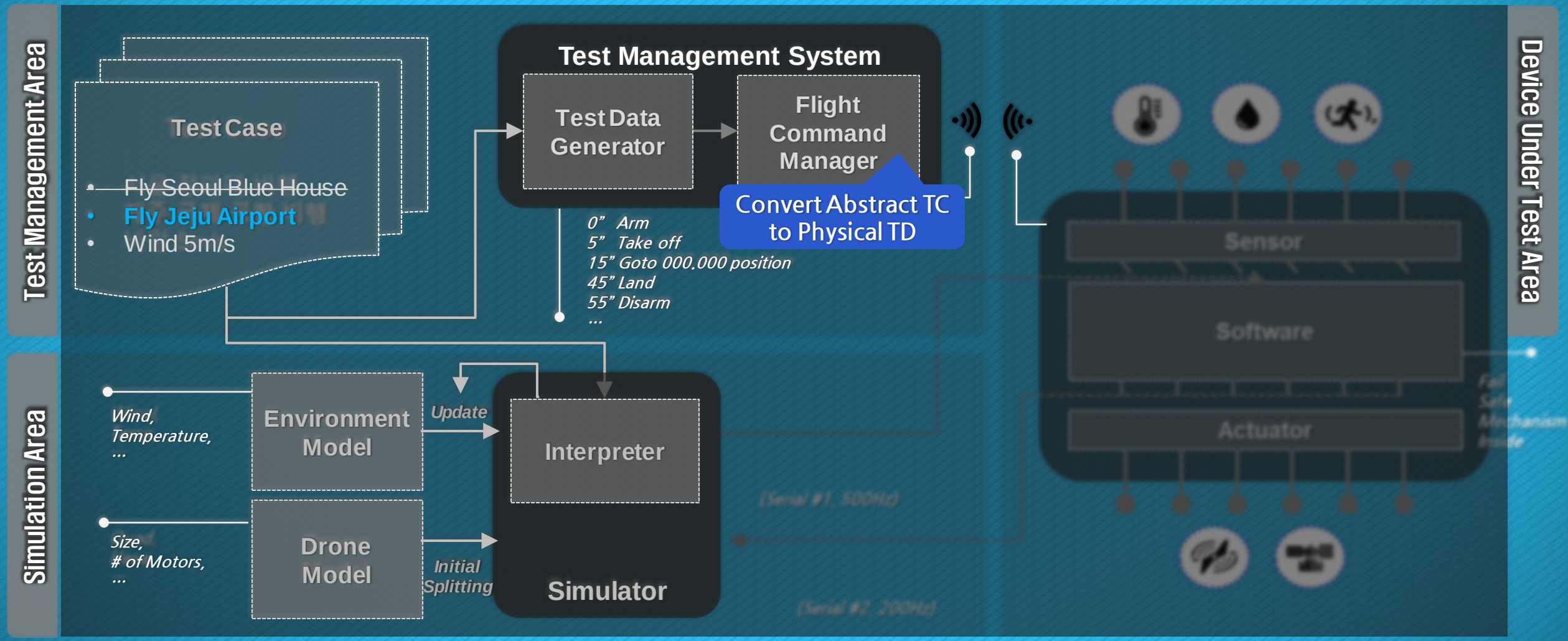
Hooking virtual data & sniffing actuator data without interfere working



Hooking | Sniffing | Interpret the result | Disarming | Avoid Probe Effect | Abstract ➔ Physical | Record & Play

Req.6 Convert the abstract TC to physical virtual data

Convert abstract TC to physically data that CPS can operate on



Hooking | Sniffing | Interpret the result | Disarming | Avoid Probe Effect | Abstract ➔ Physical | Record & Play

Req.7 Support Test Recording and Replay

Check the test result is right

Test Management Area

Simulation Area

Device Under Test Area

Test Management System

Recording & play

Test Data Generator

Flight Command Manager

Simulator

Sensor

Software

Actuator

Hooking | Sniffing | Interpret the result | Disarming | Avoid Probe Effect | Abstract ➔ Physical | Record & Play

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

Have confidence this CPS works well in real world

Test Management Area

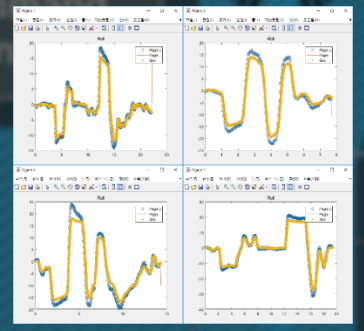
Test Case

- ~~Fly Seoul Blue House~~
- **Fly Jeju Airport**
- Wind 5m/s

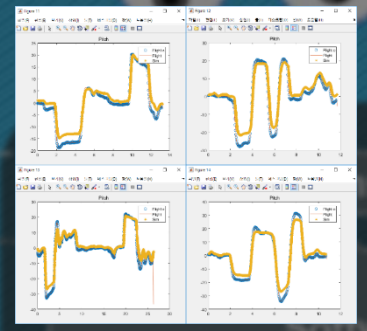
Field Test

Comparison Flight Data

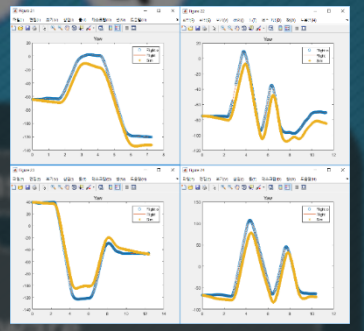
Roll Axis



Pitch Axis



Yaw Axis



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	...

Simulation Area

Wind, Temp, ...

Environment Model

Quad, Hexa, ...

Drone Model

Update

Initial Splitting

Interpreter

Simulator

Device Under Test Area

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

THANK YOU

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