

# An Automated Test System for Flight Simulator Fidelity Evaluation

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**Abstract**— The paper implements an automated test system for evaluating flight simulator fidelity. Flight simulator fidelity is determined by direct comparison to flight test, the detailed design process and arithmetic are given. These problems about how to measure simulator fidelity and about how much fidelity is required to guarantee a certain level of transfer of training is solved. The automated test system consist of testing item file, the file parser ,trim function and the flying part of the test ,evaluation way and transport delay measurement. The design process extends the first phase research results and sums up the two phase results. The test results imply the system structure is reasonable, its performance is effective. The ability to set up and stabilize aircraft model for each test item and act on virtual pilot is the most important contributor to the test efficiencies of the flight simulator automated test system.

**Index Terms**—Fidelity Evaluation; Automated Test; Transport Delay, Flight Simulator,

## I. INTRODUCTION

Pilot training heavily relies on the use of flight simulators, by which expensive flying time is saved. In the future, simulator training will become even more important [1]. Simulator fidelity is closely linked to training effectiveness. It is assumed that the transfer of training from a simulator to a real world task will be greater when the conditions in the simulation better match those in the actual task. Theoretically, the more similar the stimulus and response elements in "A" are to

"B", the more likely positive transfer of training will occur between the two [2]. So high-fidelity simulators are required for good transfer of training. It has been the driving force behind obtaining high fidelity simulators for training purposes. Simulator fidelity can be measured both subjectively and objectively. It is often measured using subjective scales of "presence", or degree of realism felt by the user. Subjective evaluation scales, such as the Cooper-Harper rating [3] has been used to evaluate the fidelity of flight simulation. Although these scales are valuable, they can provide inconsistent results because the individual opinions and biases of the raters make it difficult to generalize across scores. Self-reports can also be used to measure presence, although again, there is likelihood of bias and individual differences. An alternative to subjective evaluation scales is the objectively evaluation. Flight simulation fidelity is best determined by direct comparison to flight test, manual execution of the necessary flight tests in a simulator is a lengthy process involving skilled test pilots and aerospace test engineers [4].Reference [4] has given an automated fidelity test system, but it isn't detailed and arithmetic isn't given. A lot of problems continue to exist about how to measure simulator fidelity and about how much fidelity is required to guarantee a certain level of transfer of training [5].

In this paper, different of the manual test, the automated test system (ATS) is designed to automatically test flight simulator fidelity. The design process extends the first phase research results in reference [6] and sums up the two phase results. A new automated test system is designed to automated test flight simulator fidelity. These concretely design process and detailed arithmetic are given. The ATS includes the instrumentation and

computer controlled test procedures to test statically and dynamically the performance of control loading, and flight aerodynamics. The ATS has an almost completely non-intrusive interface on the Instructor Operator Station (IOS). This gives the test engineer access to all the sensors already incorporated in a flight simulator. Equally important, especially for acceptance testing, the ATS has its own sensors for instrumentation of the simulator cueing systems (visual system, motion system and instrumentation system).

II. FLIGHT TEST SCOPE

A wide range of tests has been developed to support the simulator fidelity evaluation of fixed-wing aircraft. The proper methods are well documented in flight test manuals published by test pilot training facilities and in the aerospace engineering literature [4]. As the capabilities of aircraft have expanded over the years, so has the range and variation of testing. At the current stage of development, the system is being designed to support the airplane flight simulator qualification procedures and standards [7] validation, and therefore the initial test selection is based on those requirements. Test scopes in the fixed wing aircraft are shown in table I.

TABLE I.  
FLIGHT TEST SCOPE

Flight Test Scope	
1	Surface operation performance
2	Ground effect
3	Climb/Descent performance
4	Landing performance
5	Take off performance
6	Approach performance
7	Cruise performance

With the test scope defined, the next critical effort is to define the methods of performing the tests in a manner consistent with the accepted flight test practices [4].

III. AUTOMATED TEST SYSTEM

The automated test system program is composed of models such as test item batch file, batch command file parser, ATS system module, checking force function, transport delay measurement and plotting and analysis capabilities. The function of each model is described as follows. Test item batch file and batch command file parser is analyzed in this section.

3.1. Test Item Batch File

A wide range of tests has been developed to support the performance and flying qualities evaluation of aircraft. The proper methods are well documented in flight test manuals published by test pilot training facilities and in the aerospace engineering literature [3]. According to the flight test manual, every test item batch file is compiled by VC++6.0. The file defines a standard convention for the labeling, unit, and sign convention of

all the flight test parameters that are typically recorded. Standard engineering names are defined for these flight parameters. To provide the control over operation, taking part of the file containing the script for minimum radius turn (MRT) as an example, the following test commands are provided in the batch file.

(1) Initial Condition .

The file provides the cockpit control and default test values for each test item. At the beginning of each in-air test, the aircraft is set to specific flight condition (altitude, airspeed, temperature) with a given configuration (weight, cg, flaps, gear, etc.). For the MRT, some commands are given as follows.

```
dGroundElevReq=8.0;           // Requested Ground
                              // Elevation (Ft)
dPitchAngleExp=1.805;        // Expected Pitch Angle
                              // (Deg)
dPitchRateExp =-0.036;       // Expected Pitch Rate
                              // (Deg/Sec)
```

(2) Trimming Mode.

Trim is accomplished via an internal subroutine in the ATS system module. When the trimming is turned off and the flight is allowed to fly freely, the aircraft will continue to fly at this trim point for an extended period of time. For the MRT, the trim command is given as follows followed by

```
bTrimReq== ON // Flag indicating that trim process
               // is requested
```

until

```
bFlightFreezeReq== ON // Flag indicating that Flight
                       // Freeze process is requested
```

(3) Add Inputs to be Bback Driven and Specify Modes.

These commands do the flying part of the tests when tracking a speed or angle etc is needed. These input commands are inputted by ramp table. For the MRT, some commands are given as follows.

```
nNosewheelMode== CONTROL // Nose wheel steering
                           // mode
```

ramp relative

```
dThrustLeverReq 0 0 3.95 0 4 1.5 40 1.3 end
// Requested Thrust Lever Position (DEG) for engine
```

(4) Set up Output File.

The simulator snapshot or time history data is saved in the output file and the flight test data is saved in another file. This data need to be graded to see if it meets the flight test data.

(5) Test Termination Conditions.

Determining the conditions upon which the test is to be terminated. For the MRT, the requested speed freeze is closed and the 40 second is defined as the total test time for the MRT test.

3.2. Batch Command Files Parser

The file parser makes it possible to add support for batch command file formats to the ATS System module. It is currently available from VC++. The file parser contains information and function telling the ATS System

module how to determine if the parser should be used for a command, how to execute the command, the path pointer, current mode, current state and so on. Through the class, the batch command file is founded.

(1) Implement an Object

Implement an object parses the file format into buffer. The batch command file is stored inside a container. Setup function of class contains the file name.

```
setup (char file name,char Path,double, dTimestep)
```

After the file is founded, the file reads into the buffer through process the function of class. The function verify command if it is command, the command implement function is transferred. For example, if the command is delay input command 8 second. Firstly, the function verify whether the command is delay command, if so, the command delay function is transferred. The code might look like this.

```
if (Command == DELAY)
{ currentstate = Command Delay();
return(OK);}
```

with current state is course variable, the result of the command delay function is inputted into the variable.

(2) Command Implements Function

The command implements function handles each of the callbacks needed by the ATS System. It includes thirty-one functions, such as "RUN","WRITE","READ", "RAMP", "CLEAR" and so on. Each function bears given action. Based on flight test manuals, different test item implements different command function. For example, to the command delay function, firstly, the delay value is judged whether the value is a positive number, secondly, delay value is reduced a time step during each time step iterative process. The process is described as Fig. 1.

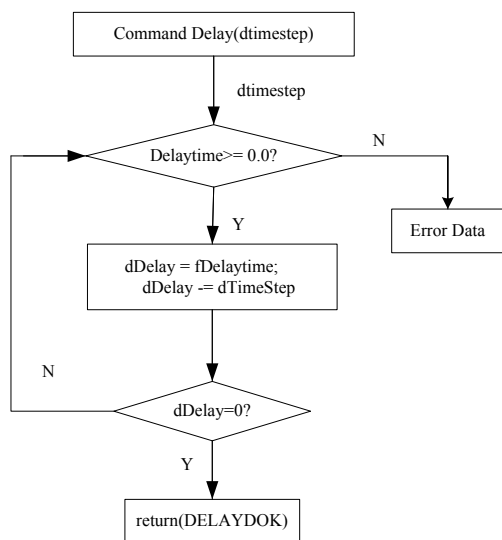


Figure 1. Delay code flow plot

IV. THE ATS SYSTEM MODULE

The ATS system provides an automatic and repeatable means of performing the flight test maneuvers. This requires that the simulated aircraft systems respond to

inputs from the ATS system [3]. In order to support automated fidelity test requirements, the ATS must be able to initialize to any defined condition, automated trimming, do fly part of test, check force and evaluate result.

The Initialize function initializes all the member variables, flight control variables range, input and output file variables from the test item batch file and it copies data from the various model locations to the corresponding ATS variables if the test initialization flag is not set. Otherwise, it will copy data from the necessary ATS variables to the corresponding model location.

4.1. Automated Trimming Function

The function would act just like the real pilot that is being told to perform the same task. The function will back drive the appropriate controls, surfaces and the throttle levers to obtain the desired airspeed with the desired accelerations. Some variables are checked and used to determine if the trim routine can exit and allow the rest of the test to continue. Each variable must be less than a prescribed value in order for the subroutine to determine that the aircraft is properly trimmed. For every test item, this will automatically be set correctly. The trim process is described as Fig. 2.

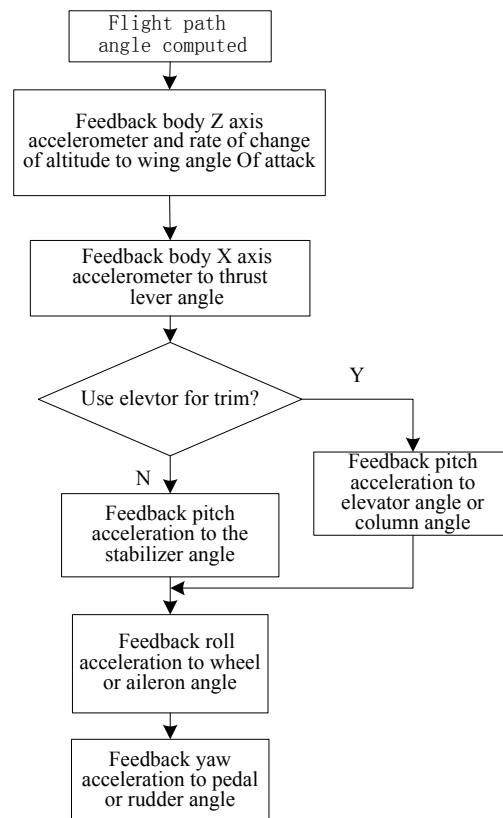


Figure 2 .Trim process flow plot

4.2 Flying Function

This function does the flying part of the test when speed or angle is tracking through pitch control , roll control, yaw control, nose wheel steering control and braking control. For example, to control nose wheel

steering, the control function flow plot is described as Fig. 3.

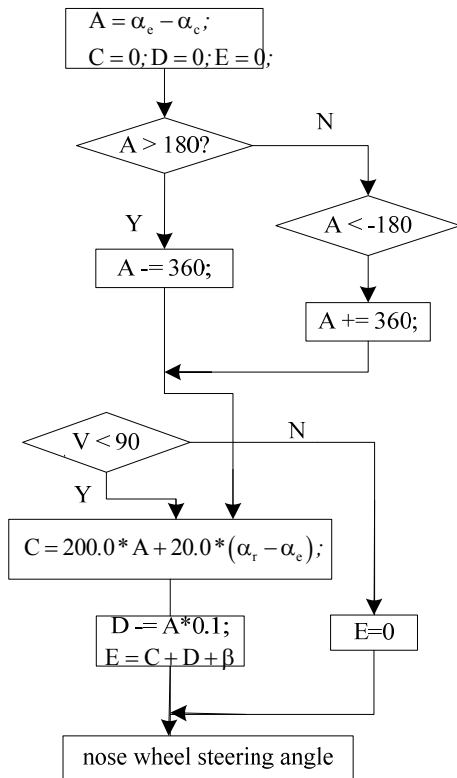


Figure 3 . The control function flow plot

with  $\beta$  is aircraft current nose wheel steering angle,  $\alpha_c$  is expected yaw angle,  $\alpha_c$  is aircraft current yaw angle,  $\alpha_r$  is requested yaw rate,  $\alpha_c$  is body roll rate as reset by the trim algorithm. E is required nose wheel steering angle, V is aircraft current velocity.

The function is computed at each time step until the selected fidelity test item is completed.

4.3. Evaluate Function

During testing, this function will calculate the damping ratio and the time to half the amplitude of each signal in one cycle. The damping ratio and the time to half the amplitude is acted on evaluation measure .The test result is plot with curve. The evaluate function is described as follows.

$$\rho = \sqrt{1.0 / (4.0 \times 3.14^2 / (\ln(a/b)^2 + 1.0))}$$

$$f = 0.693 / (\rho \times 6.28 / T)$$

with  $\rho$  is the damping ratio, f is the time to half the amplitude of the signal, a is the value of first peak value minus first valley value, b is the value of second peak value minus second valley value, T is evaluate period, its value is equal to second peak time minus first peak time.

4.4. Checking Force Function

This function checks the force in column, wheel or pedal during force measurement test to tell examiner where to position control to get the correct force read. For example, to check the column force, firstly, selecting the column force test item in the Instructor Operator Station. Secondly, performing the column sweep using a slow and continuous motion, concretely control course is this. (1)push the column from neutral to full forward position, (2)pull back to full aft position; (3)re-neutralize the column. This test has no time limit and will terminate until the result accords with requested force value.

The process of the check force function is like this. If the current control force is in the range from the value of the required force minus 0.1 to the value of the required force plus 0.1, the force is normal. If the force is larger than the value of the required force plus 0.1, the force evaluation is too large and the force need be decreased. If the force is less than the value of the required force minus 0.1, the force evaluation is too little and the force need be increased. The position and force of column, wheel and pedal are measured by position sensor and force sensor, respectively.

4.5.Delay Test

Time delays are defined as those temporal differences between pilot input and vehicle response, which are not present in the simulator’s real-world counterpart. They can cause the perceived handling qualities of the simulated vehicle to deteriorate, up to the point where the closed-loop system may even become unstable [8].Relative responses of the motion system, visual system, and instrument displays shall be coupled closely to provide integrated sensory cues. This test shall measure all the delays encountered by a pitch step signal migrating from the pilot’s control though the control loading computer and interfacing through all the simulation software modules in the correct order, through the normal output interfaces to the motion system, to the visual system and instrument displays. The test mode shall permit normal computation time to be consumed and shall not alter the flow of information through the hardware/software system. [9].

a. Visual System Delay Measuring

Using a photo sensor measures end-to-end time delay in the beam of the outside-visual projector, from initiation in the control loader, through the simulation software, the image generator and the projection system. Sensor is located on the edge blending mechanism of the central projector, out of view of the pilot [10], it is given as the Fig.4. The photo sensor used is a TOSHIBA TPS603, it detects light with a pull upped by 20 kilo-ohms [11]. For increasing sensitivity, six the same photo sensors are arranged in a circuit board, they consist of the photo sensor. Video signal must be limited to a light-and-dark configuration. A small database consisting of light (white) sky and dark (black) ground will enhance video change detection during the test sequence. During the test, the pitch angle varies between +80°and -80°.

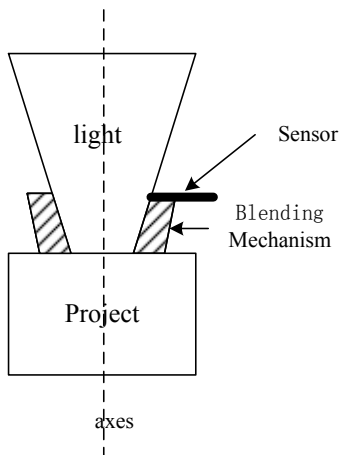


Figure 4. Photo sensor

*b. Motion System Delay Measurement*

The motion system transport delay is also measured from the payload platform sensed by the accelerometer, six accelerometers is mounted on the payload platform as showed in Fig. 5 . Sensed accelerations were transformed to the payload platform accelerations in all six DOF's with kinematic transformation [12] .

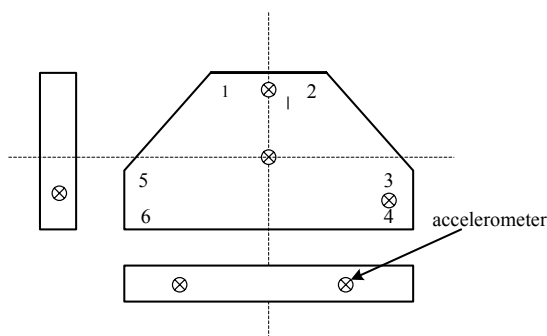


Figure5 .Accelerometer placement

*c. Instrument Displays Delay Measurement*

Attitude Indicator in instrument displays is also measured by the photo sensor. It set up pitch between +30° and -30°.

The resulting change in voltage of the sensor and accelerometer can be measured by a data collection card in the delay measuring computer and the card is controlled by the LABVIEW software. The result is compared to the initial delay test signal switch commanded by the same computer, yielding an end-to-end time delay. The general measuring process is described in Fig. 6.

*4.6. Plotting and Analysis Capabilities*

The final result is the plotted test results. No matter how well the tool works from a test operation and performance standpoint, a poor plotting package will seriously hinder the usefulness of the test system [4]. The main features of the plot capability are described briefly as follows [4].

*(1). Test Parameter Availability .*

Test parameters defined for each test system are recorded for each test. This means that after a test has been run, each parameter can be displayed for analysis and evaluation.

*(2) .Multiple Plots Per page.*

The plot capability will allow the most six parameters to be plotted per page. An option is provided to display the sign convention for any parameter.

*(3).Tolerance Bands and Auto Grading*

The plotted parameter can be displayed with tolerance bands and allow for auto grading of the results.

*4.7.Executive Interface*

The automated fidelity test program is loaded in the flight simulator host computer, the executive interface in the Instructor Operator Station (IOS). The IOS is responsible for test item selection and activation logic (Initialization, Freeze, etc.). The host computer receives and processes mode commands and state changes from the Instructor Operator Station software. The full test system is given by the Fig. 7

V. EXAMPLE RESULT

For verify the automated test system, a minimum radius turn test of the Boeing 737-800 is given as an example. Off-line test is adopted. It is not completed in real flight simulator, but in flight simulator host computer software. It is to demonstrate whether the simulator heading rates of change during ground steering maneuvers conform to the flight test. On the IOS, the test item is selected. The test results of the tiller angle and the nose wheel steering angle among parameters are given by Fig. 8and Fig. 9.The trim data with much bigger error among data are given by table II.

TABLE II. DATA ERROR

Data	Simulator data	Flight test data	Error
Press angle(ft)	9.388	9.180	2.26%
Angle of attack(deg)	-0.707	-0.715	1.12%
Dynamic press	0.084	0.080	5%
Pitch attitude (deg)	-0.707	-0.715	1.12%

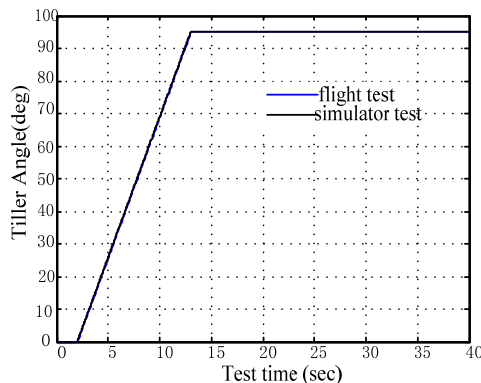


Figure 8.Tiller angle

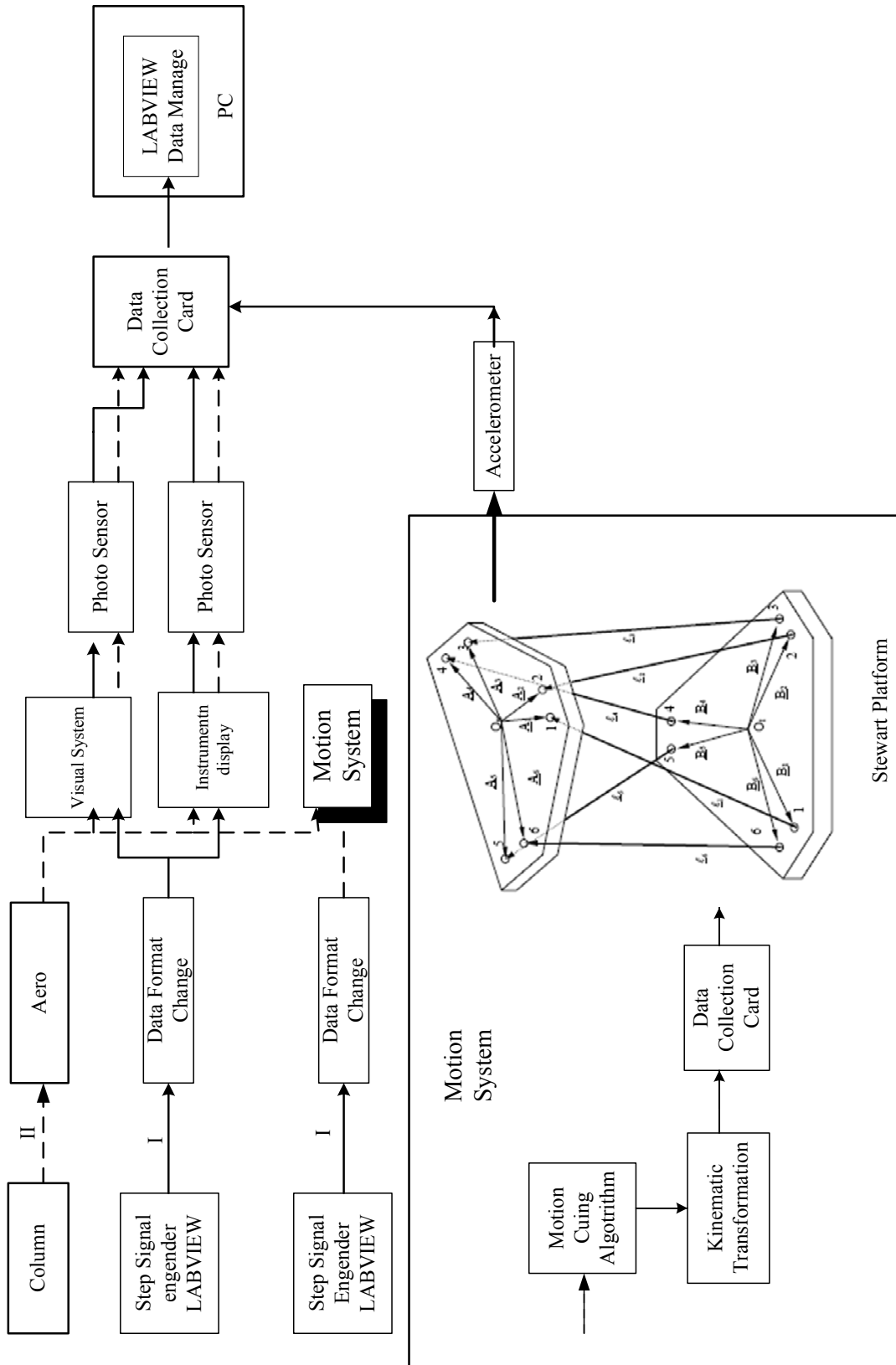


Figure 6 .The general measuring process

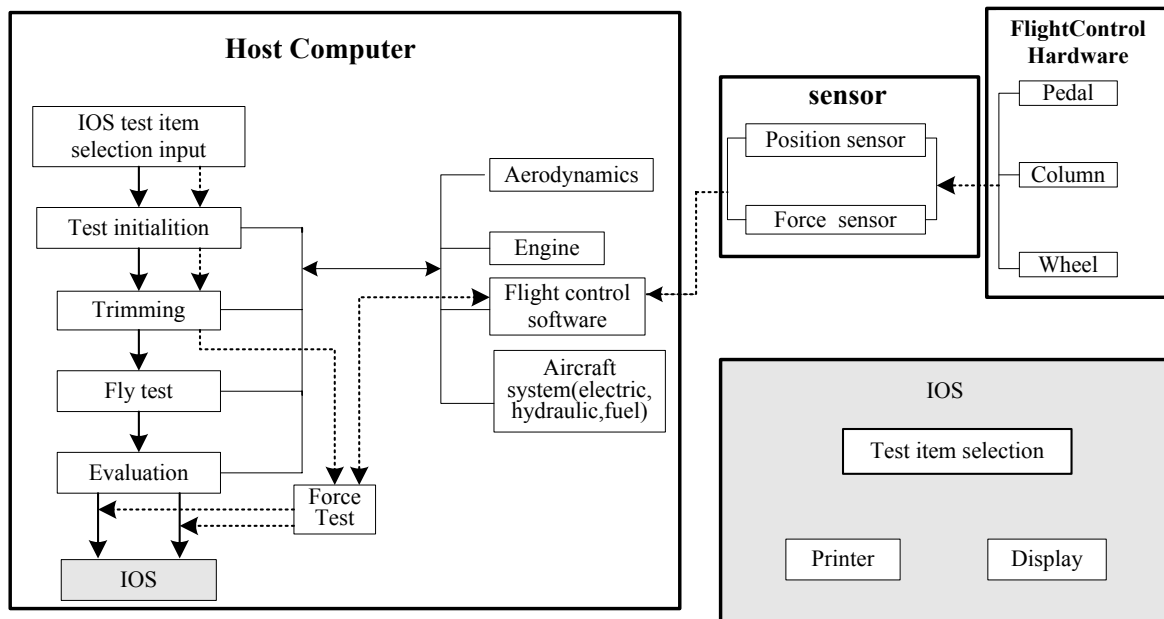


Figure7. The fidelity automated test system

From the Table II, the most error data is the dynamic press with per 5. The most permission error value is 10% in the flight simulation manuals. The most simulator data error is smaller than 10%. So the trim performance is effective.

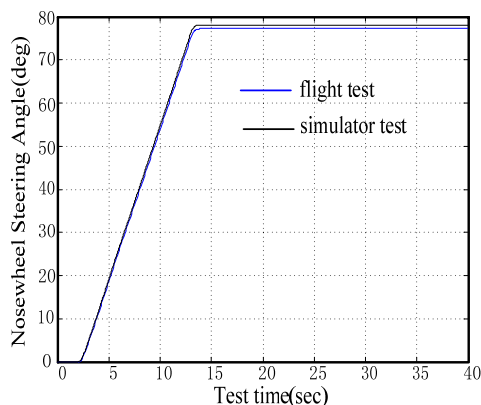


Figure 9. Nose wheel steering angle

From the Fig. 8 and Fig. 9, the flight simulator test results of the two parameters almost conform to the flight test. Because that the aim is to verify the automated test system, the error isn't considered in the two figures. From above the results, it is implied that the automated test system is an effective system, the system structure is reasonable and the performance is effective.

CONCLUSION

Pilot training heavily relies on the use of flight simulators, by which expensive flying time is saved. The

fidelity is best determined by direct comparison to flight test data. The paper describes an automated fidelity test system of flight simulator, the test system consists of fidelity test item batch file based on flight test manuals, batch command file parser, the ATS System module, check force function, evaluation function and transport delay measurement. Concretely design process and detailed arithmetic are given. The test results imply the system structure is reasonable, its performance is effective. The ability to set up and stabilize aircraft model for each test item and act on virtual pilot is the most important contributor to the test efficiencies of the automated test system. A future goal is to expand the test scope to include the visual fidelity test to support the flight test manuals requirement.

ACKNOWLEDGEMENT

This work is supported by the Institute of Electro hydraulic Servo Simulation & Test System in School of Mechatronics Engineering of Harbin Institute of Technology in China.

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