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ADVANCED CALCULATION FOR DETERMINING POSITION AND ANGLE OF UNGUIDED AIRCRAFT-ROCKET BASED ON THE MOTION DETECTION IN AERIAL WEAPON SCORING SYSTEM

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Abstract

Most of all techniques of the Aerial Weapon Scoring System (AWSS) are developed to determine the final position of practice aircraft-rockets in which identified by the impact point coordinates. This paper presents the technique of implementing 3D-view geometry approach to determine all required rocket-parameter results including trajectory, position, and angle in the shooting-target. The developed system generates the resulted rocket-trajectory data which consists of an explosion-image-point and rocket-image-point from the motion detection method used. The aircraft-rocket is observed by the 3CCD-digital video camera where its position should be perpendicular to the position of the-rocket-shot. The transforming view of the Z-axis in the initial video processing are the key point of determining the absolute view of captured-images processed. The calculation used in this research employs the scaling and comparison of pixel coordinates and real-world coordinates. All experimental results in this paper are generated from the real rocket-firing exercise conducted in the Air Weapon Range. The results will be useful to support AWSS in producing advanced analysis of fighter air-to-ground rocket-firing exercise.

Keywords: *3D-view geometry, angle, motion detection, rocket-firing, trajectory, weapon scoring system.*

1. Introduction

The Aerial Weapon Scoring System (AWSS) employs assessment of the air-to-ground aircraft-rocket firing exercise in the special place so called Air Weapon Range (AWR). The firing-exercise uses unguided aircraft-rocket. The common methods of AWSS [1] used refers to the image processing technique by using video cameras where they are put in the certain altitude of different towers, and away from the shooting-target area. The resulted image processing is generated to obtain the rocket impact-point in the shooting-target. This result is informed to the pilot by the special-qualified personnel called Range Safety Officer (RSO).

The scoring results will be sent in a real time to the pilot so he can learn from this. If the results inform any unpredicted error or mistake during the shooting, then the pilot can use this information to do correction for his next shot. These create problem and difficulty to the pilot since he cannot learn anything from these unpredicted errors and mistakes.

The current AWSS unable to satisfy these requirements due some following aspects : (1) the high-speed motion of the aircraft - rocket, (2) the safety procedure based on the AWR situation, and (3) the installed infrastructures, such as a tower. It is associated with efforts to address the risk factors for the RSO and the scoring system. Observation can only be made from the limited places. Moreover, the assessment of a rocket firing scoring system like this can only give a chance to pilot to use only maximum two heading sources directly to the target.

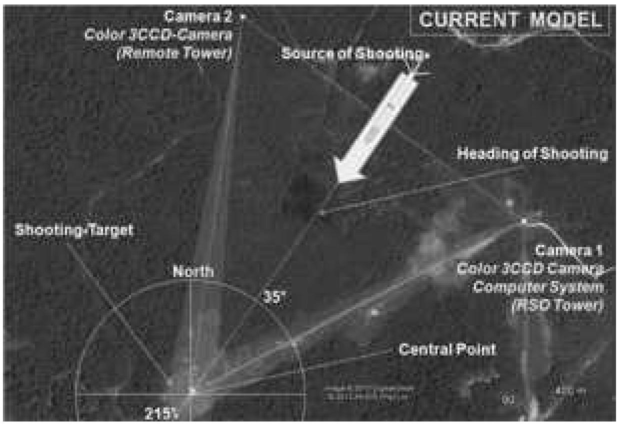

Figure 1. *The Layout of The Current Model (Picture is modified from Google Earth)*

This paper presents the resulted research of computed calculation in determining not only position, but also the angle of the unguided aircraft - rocket in the shooting-target. Determining the rocket-trajectory angle is very important in order to make analysis for answering the unpredicted errors and mistakes during the shooting. The proposed system generates important variables of resulted trajectory from motion detection based on explosion-image-point and captured-rocket-image-point. The results are projected to become the important information which is useful for a thorough evaluation of the exercise.

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2. Literature Review

Some existing techniques of moving object detection results the capturing system by using the surveillance camera from some different images. There are some researches of moving object detection have been proposed such as the research that detect the moving object by using strip frame images [2]. The other researchers such as [3][4][5][6] and [7] have released some methods of moving object detection by different images.

The research about determining the object position and its coordinates is related to the transformation of the object from 3D to 2D. The refered system of implementing the moving detection in the current AWSS (see Figure 1) released by Stratech Technology [1] employs the result of rocket-impact-point in 2D space. Because of that illustrated technique in Figure 1, this technique could only determine the rocket-impact position.

Some previous researches have presented the 3D system for geometry approach. The previous research about the multi-view object class detection with a 3D geometric model [8] and the viewpoint invariant features from single images using 3D geometry [9] have been proposed. The other research about 3D approach to process the motion class [10] also has been introduced which made the significant value of transforming the slow object motion in the surface. Most all of those implementing 3D based researches have contributed in the development of 2D to 3D transformation in single images. Those findings may be developed to illustrate the object found in several point of views.

3. Proposed System

3.1. The Approach

The model is proposed to achieve the best image capturing process of the aircraft-rocket motion detection. Layout of the proposed model is illustrated in Figure 2. To support the model, there are three approaches generates the introduced system as follow :

(1) The rocket-image capturing process is possible done by positioning camera more closer to the shooting-target.

(2) The optimum position of the camera is perpendicular to the source-of-shooting

(3) The same perception between camera and computer screen will result the exact image transformation of 2D to 3D.

The preliminary research of the motion detection technique to improve quality of capturing the unguided-aircraft-rocket is done. The research consists of two big parts : (1) the image-processing based motion detection and (2) the calculation of trajectory and angle based on the resulted part 1. In this paper, we introduce the advanced technique of calculating the trajectory and angle by using the approach of 3D-view geometry. The proposed computation generates the resulted image processing data in order to produce the aircraft-rocket trajectory and angle.

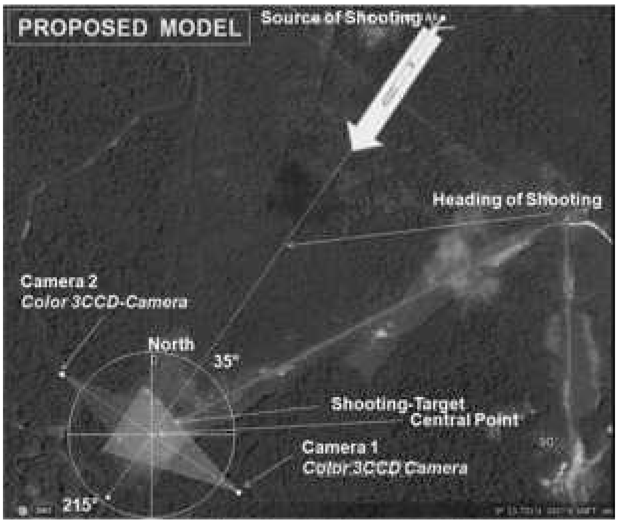


Figure 2. *The Layout of Proposed Model (Picture is modified from Google Earth)*

3.2. The Proposed Block Diagram

In the proposed model, there is a key point based on the position of the camera used. The camera is always perpendicular to the central-point and the source of shooting. Figure 3 illustrates the block diagram of the global system designed in the weapon scoring system and shows where the 3D-view geometry computation is implemented and influenced the calculation. The coordinates of the rocket and the angle of the rocket are the projected results of the proposed system.

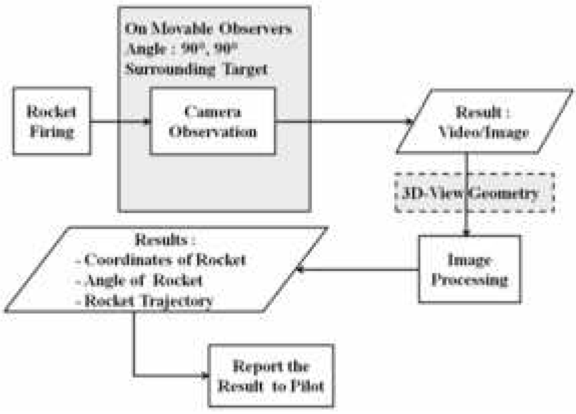


Figure 3. *Global System Design of Proposed System of the Fighter Aircraft Rocket-Image Motion Detection.*

The visualization of implementing 3D-view geometry approach in the computer system is shown in Figure 4. The following equations generate the rotation matrices for X, Y, and Z-axis. The transforming view of camera vision on the computer screen by the rotation of X-axis uses the following Equation (1). And also about transforming view of camera vision on the computer screen by using the rotation of Y-axis and Z-axis uses the following Equation (2) and (3).

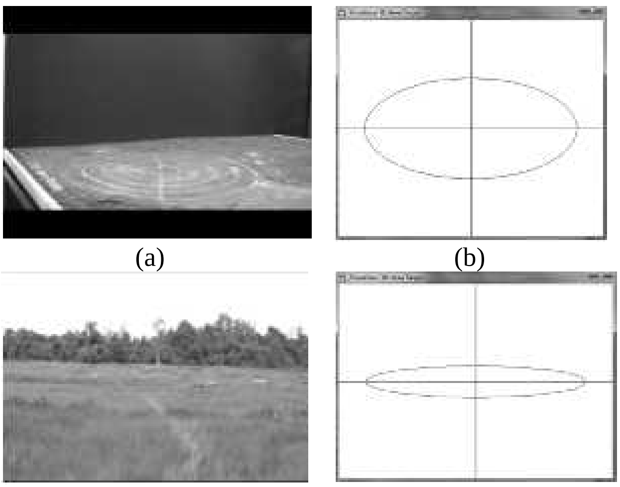
$$\begin{pmatrix} \cos\theta & 0 & \sin\theta \\ 0 & 1 & 0 \\ -\sin\theta & 0 & \cos\theta \end{pmatrix}\begin{pmatrix} x \\ y \\ z \end{pmatrix} = \begin{pmatrix} x\cos\theta + z\sin\theta \\ y \\ -x\sin\theta + z\cos\theta \end{pmatrix} \quad ...(1)$$

$$\begin{pmatrix} \cos\theta & 0 & \sin\theta \\ 0 & 1 & 0 \\ -\sin\theta & 0 & \cos\theta \end{pmatrix}\begin{pmatrix} x \\ y \\ z \end{pmatrix} = \begin{pmatrix} x\cos\theta + z\sin\theta \\ y \\ -x\sin\theta + z\cos\theta \end{pmatrix} \quad ...(2)$$

$$\begin{pmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{pmatrix}\begin{pmatrix} x \\ y \\ z \end{pmatrix} = \begin{pmatrix} x\cos\theta - y\sin\theta \\ x\sin\theta + y\sin\theta \\ z \end{pmatrix} \quad ...(3)$$

The same perception between camera-perspective and computer-screen is then achieved. This enables the view of the shooting-target is similar to the computer screen when the conditions initializing is performed.

Figure 4 (a) shows the image of shooting target in the experiment, and Fig. 4 (b) visualizes it. Figure 4 (c) shows the image of real shooting-target in AWR, and Figure 4 (d) visualizes the view of computer-screen about it. This illustrates the same perception between camera perspective and computer screen by implementing the 3D-view geometry system. In this paper, we only present the viewing camera region as Z-axis using only one camera where its position is placed in the explained Camera 1 of illustrated Figure 2.



(a) (b) (c) (d)

Figure 4. *Visualization of 3D-view Geometry Generates the similar Point of View Between The Initialized Shooting-Target and Computer Screen.*

3.3. Determine Angle and Position

The following equations are used to calculate the position and angle of the fighter aircraft-rocket. They generate two coordinates of the resulted rocket-trajectories. The position means how far is the distance between the rocket-explosion coordinates ($X_1;Y_1;\ Z_1$) from the central point ($X_0;\ Y_0;\ Z_0$). The angle is determined by calculating the translation between the coordinates in the rocket trajectory. When ($X_2;Y_2;\ Z_2$) represent the captured rocket-image coordinates, the calculation of the angle and position may implement the following Equation (4) and (5).

$$\text{Distance} = \sqrt{(X_0 - X_1)^2 + (Y_0 - Y_1)^2 + (Z_0 - Z_1)^2} \quad ...(4)$$

$$\text{Angle of Rocket} = \arctan\left[\frac{(X_2 - X_1)}{(Y_2 - Y_1)}\right] \quad ...(5)$$

The previous Equation (3) is very important in handling the perspective of the computer screen, in order to transform the position of all captured region by rotating the Z-axis. If the exact Z-axis is rotated by angle of 90°, it will result the correct calculation of the distance. Implementing this will affect the Equation (4) which becomes faster in computation time by using the following Equation (6).

$$\text{Distance} = \sqrt{(X_0 - X_1)^2 + (Y_0 - Y_1)^2} \quad ...(6)$$

The rocket-trajectory is visualized by using the function of drawing a line in the software used. Drawing a line includes the coordinates subtraction between the explosion-image position ($X_E,\ Y_E$) and rocket-image position ($X_R,\ Y_R$).

4. Experimental Results and Discussion

A. Experiment in Preliminary Research

The following paragraphs explain the experiment in the preliminary research which results the aircraft-trajectory components. Some important parameters were firstly initialized and set up i.e. :

(1) The coordinates of the central point was North 00°13.542'-East 101°06.102'.

(2) The shooting-target radius was 75 m.

(3) The camera was put 1.75 meter height from the ground.

(4) The camera was placed 90 m from central point.

(5) The fighter aircraft shot the target by the heading of 215°.

(6) The fighter aircraft dive-angle of 15°, and it became the designated angle.

(7) The experiment used the observing camera which its specification was decribed as follow : Type of SONY DSC-T90 digital CCD-video-camera, effective resolution of 12 MP, use the lens of Carl Zeiss Vario-Tessar 3.5-4.6/6.18-24.7 Optical 4X Steady Shot. The camera was connected to the computer system by performing the mode of FINE 720 pixel without zooming.

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B. The Rocket-Trajectory Components

The following Figure 5 shows the results of image-processing implementing the 3D-view geometry system in the preliminary research to obtain the rocket-trajectory components (i.e. Explosion-image and captured rocket-image).

The following Figure 5 shows the example of the resulted rocket-image trajectory from the preliminary research, presented in the artificial and scalable shooting-target of AWR by performing the scale of 1 : 460. The circled object in Figure 5 (a) represents the explosion-image, and Figure 5 (b) represents the captured rocket image.

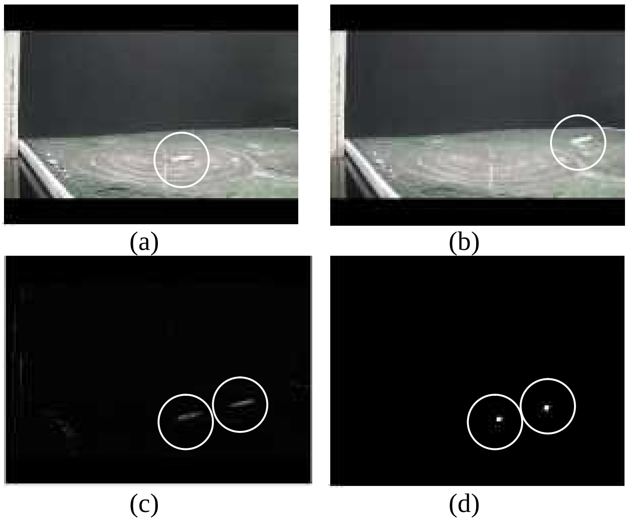

Figure 5. *The sequence of results on image processing to determine rocket-point.*

Figure 5 (d) shows the most important marks that produce the rocket-trajectory. By implementing Equation (3), the presented marks are generated to the fixed calculation to draw the trajectory and determine the angle.

C. The Results of Determining Position and Angle

By implementing all presented formulas from Equation 1 to 6, the data of resulted rocket-trajectory where generated from the pixel coordinates, the angle and position of the rocket are then computed. of generates the results of determining the position and angle of unguided aircraft-rocket firing exercise. The accuracy of the resulted angles can be obtained by using the formula (11) and (12). The results of the computed angles are tabulated in Table 1.

$$Error = \frac{(Computed\ Angle) - (Aircraft\ DiveAngle)}{Aircraft\ DiveAngle} \quad ...(7)$$

$$Accuracy = (1 - Error)100\% \quad ...(8)$$

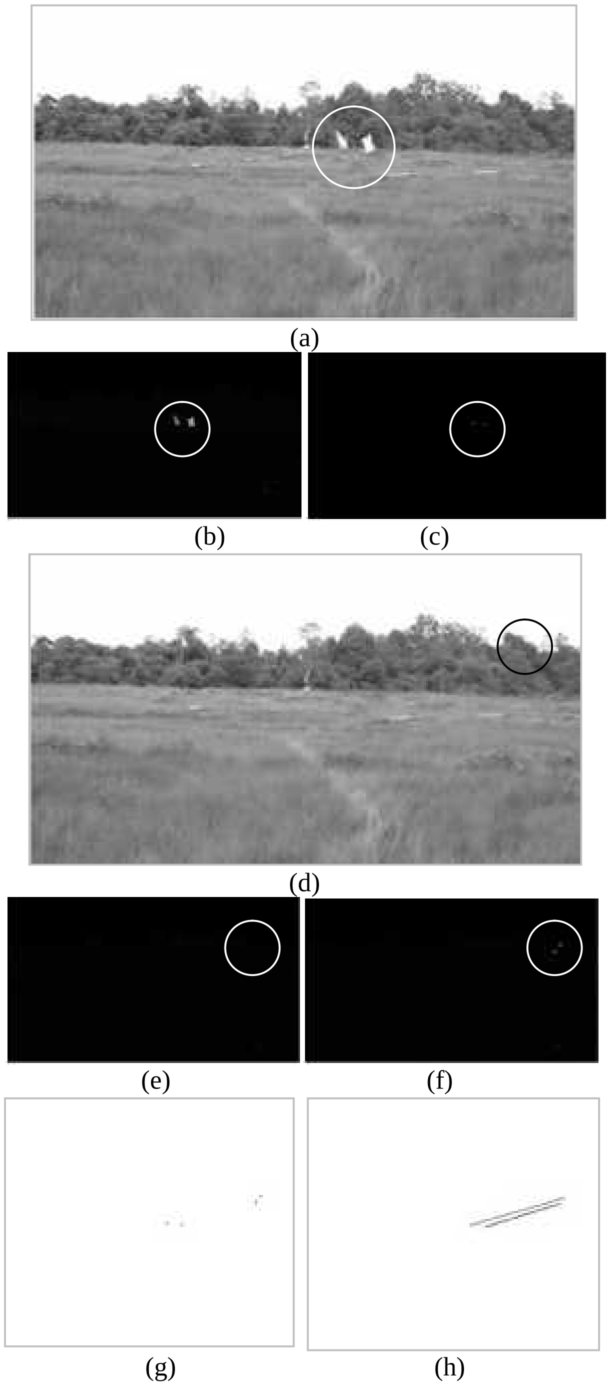

Figure 6. *The Process of Preliminary 3D-View Geometry Based Motion Detection Resulted Aircraft-Rocket Trajectory, (a) The Explosion-Image, (b, c, e, f, g, h) The Image Processing Based Motion Detection, (d) The Captured Rocket-Image (in the Circle), (g and h) The Required Components To Determine Aircraft-Rocket Trajectory and Angle.*

The experimental result is shown in Table 1. There are seven calculated data of the aircraft rocket firing exercise. All data are presented from the real aircraft rocket firing conducted in AWR Siabu. The next paragraphs explain some discussion according to the calculated results.

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Table 1. *The Results of Calculating Position and Angle of Unguided Aircraft-Rocket Firing Exercise.*

The Actual Rocket-Firing		Pixel Coordinates On Screen					Computed Calculation (Distance from CP)			
No.	Time of Explosion	Explosion-Image		Rocket-Image		Central-Point	Distance (pixel)	Angle (°)	Error Rate	Accuracy (%)
		X_1	Y_1	X_2	Y_2	(X_0,Y_0)				
1	0:10:50.2	553	174	608	159	(322,164)	231.21634	15.25511	0.017	98.299
2	0:13:00.3	87	160	150	140	(322,164)	235.03404	17.61257	0.174	82.583
3	0:15:14.4	479	164	541	148	(322,164)	157	14.47029	0.035	96.468
4	0:15:15.7	8	160	111	122	(322,164)	314.02547	20.25063	0.350	64.995
5	0:17:28.6	101	158	235	120	(322,164)	221.08143	15.83238	0.055	94.451
6	0:17:30.8	44	157	153	126	(322,164)	278.08811	15.87594	0.058	94.160
7	0:17:36.1	357	161	528	110	(322,164)	35.12833	16.60698	0.107	89.287

The discussion based analysis according to the results will be explained as follows. Based on the results in Table 1, the positional distribution of the rocket impact-points are illustrated in the following Figure 7. Visualization of the rocket-trajectories and angles is shown in Figure 8.

The positions of number 2,4,5, and 6 are mostly in the left side of Central Point while number 1,3, and 7 are in the right side. The best rocket-shot is number 7 (35.12833 pixels) where the rocket impact point is closer to the Central Point. Two more best rocket-shots are number 3 (157 pixels) and 5 (221.08143 pixels).

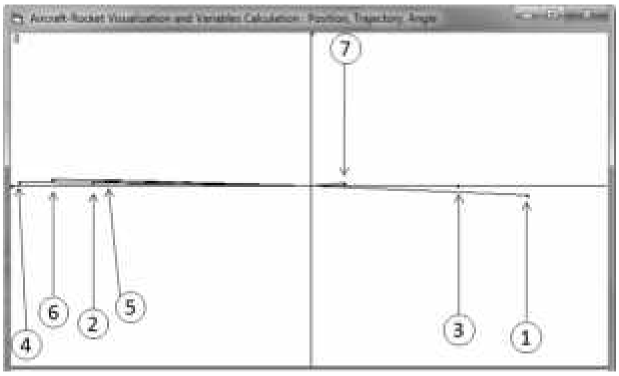

Figure 7. *The Position Distribution of the Rocket-Impact-Points Based On Table 1.*

By using Equation (5), the rocket trajectory can be drawn. Figure 8 shows the drawing of the trajectory of each rocket. Each trajectory may show different size of length, because it is generated by two parts of calculation components (i.e. the explosion-image mark and captured rocket-image mark) which depends on the process in the motion detection system used.

The drawing of each trajectory may imagine angle of the rocket itself. According to the column of Accuracy presented in Table 1, the best three of firing performance based on the rocket angle quality is the rocket-firing number 1 (98.299%), number 3 (96.468%), and number 5 (94.451%).

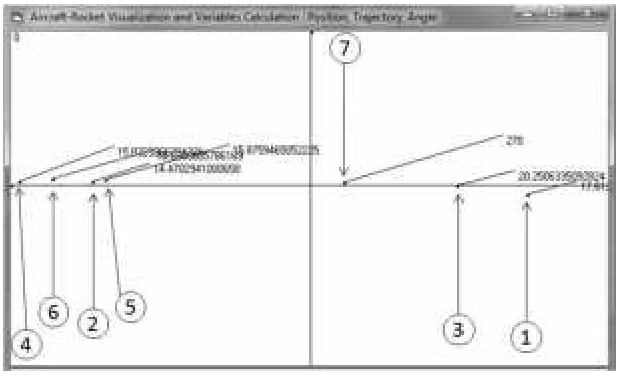

Figure 8. *Visualization of the Rocket-Trajectories and Angles Based On Table 1.*

The advanced analysis may be performed by comparing between two 'best three' results based on the explanation of Figure 7 and 8. The following Table 2 is the comparison of both results.

Table 2. *Comparison of The Best Three results.*

Variable	Rank #1	Rank #2	Rank #3
Position	7	3	5
Angle	1	3	5

By performing the temporary analysis according to Table 2, the rocket-shot of number 3 shows the best performance among all results based on combination of the position and angle variables. By the way, the real expected result of the exercise is the rocket impact-point which is hopefully closer to the Central Point like the rocket-shot of number 1.

5. Conclusion and Future Works

This paper presents the part of the 3D-view geometry based motion detection system to determine the required aircraft-rocket parameters in the shooting-target. This proposed method succeeds in determining the aircraft-rocket trajectory, position, and angle. The results support the advanced analysis of the aircraft-rocket firing exercise, and the development of the weapon scoring system. Future works include : (1) make the analysis

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based on the results and (2) compare the results to the real condition of aircraft parameters after flying.

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