Positioning Accuracy of the Laser Tracking System for ALFLEX

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ABSTRACT

A Laser Tracker(L/T) was in charge of automatic tracking and three-dimensional positioning of ALFLEX. Data obtained by the L/T was treated as the reference position of ALFLEX,then applied to estimate the characteristics of both onboard and ground navigation instruments. Real-time data obtained by the L/T was also applied to indicate the position and to support the decision on the release point of ALFLEX.

This paper describes positioning accuracy of the L/T in the landing experiments.

1. Introduction

In March 1995, an L/T had been developed as a Laser tracking system for aircraft tracking system. Since then, automatic tracking and three-dimensional positioning were completely performed during the Hanging Flight Phase and Free Flight Phase in the ALFLEX automatic landing experiments. As a result of the data evaluation for the all experiments, it is confirmed that the L/T was completely operating on the performance without problems.

The following is description on the L/T outlines and the positioning accuracy based upon the data obtained by the L/T during the automatic landing experiments.

2. L/T Equipment Outline

2.1 L/T Configuration

The L/T is an equipment to measure Slant Range (SR), Azimuth (Az), Elevation (El) to an aircraft using laser and TV image while performing automatic tracking. The L/T is composed of a Laser transmitter, a Receiving telescope , an Image receiver , a GPS receiver and a monitor for the safety surveillance.Figure 1 and 2 show the appearance of the Optics Shelter and the Electronics Shelter , respectively.

2.2 L/T Function

The L/T features the following function.

a. Three-dimensional position ranging and goniometric function
b. Automatic tracking function
c. UTC time providing function
d. Radar slave function
e. Laser irradiation level adjustment function
f. Various calibration function
g. Various compensation processing function

No additional function was required for the ALFLEX experiments except the function above.

2.3 L/T Equipment Specifications

Table 1 shows the specifications of the L/T equipment.

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Figure1. Optics Shelter

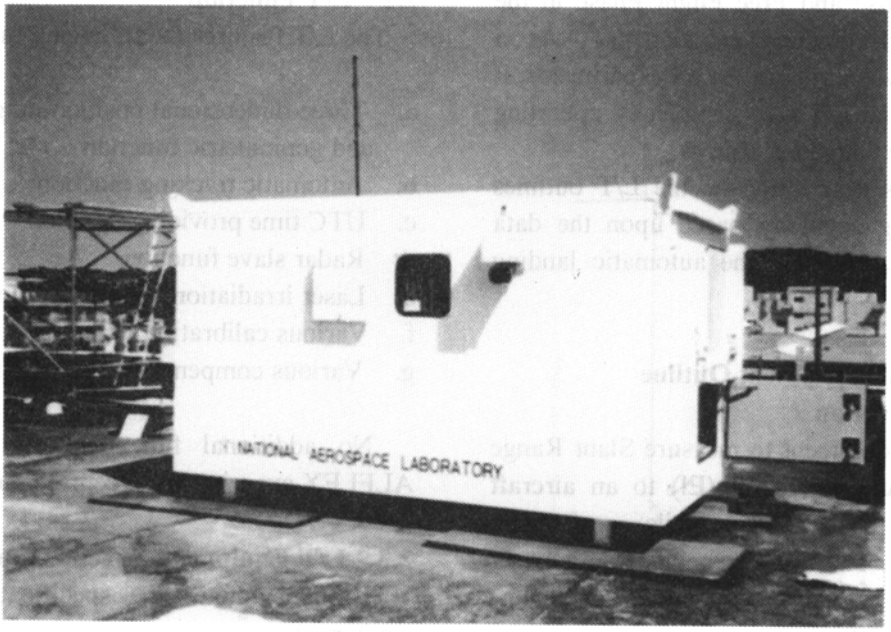

Figure2. Electronics Shelter

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Table1. L/T Specifications

No	Item	Specification
1	Range Accuracy	0.3m (1 σ)
2	Azimuth Accuracy	0.1m rad (1 σ)
3	Elevation Accuracy	0.1m rad (1 σ)

3. L/T Measurement Procedure

The reference position of the L/T is the invariant point of the telescope. The coordinates of the invariant point were defined by actual measurement and calculation of the installation position , based upon the coordinates of the existing surveying points in Woomera Airfield.
The defined coordinates (WGS-84) are as follows;

Longitude : 136.80956027647° E
Latitude : 31.14722694923° S
Altitude : 171.757m

Since the obtained data by the L/T were data of SR , Az and El to the airplane , it is necessary to define the true north and true leveling. To determine the true north and Z axis direction , it is implemented them using the Star calibration function , and set them as the reference of the angle data. In order to get the accuracy improvement for each flight experiment , as an Preflight Inspection item , the L/T obtained range and angle compensation parameter using the calibration reflectors installed on the Hangar , the Control Tower , and the Water Tank. Figure 3 shows the arrangement of the calibration reflectors.

Compensation was done to the obtained raw data after each flight experiment , then data was output as "formal data". This compensated data was treated as "reference data" to evaluate the ground and onboard navigation equipments. Also , simplified compensation expressions for real-time data were completed and added to the software of Flight Control Facility to support the decision on the release point during each flight.

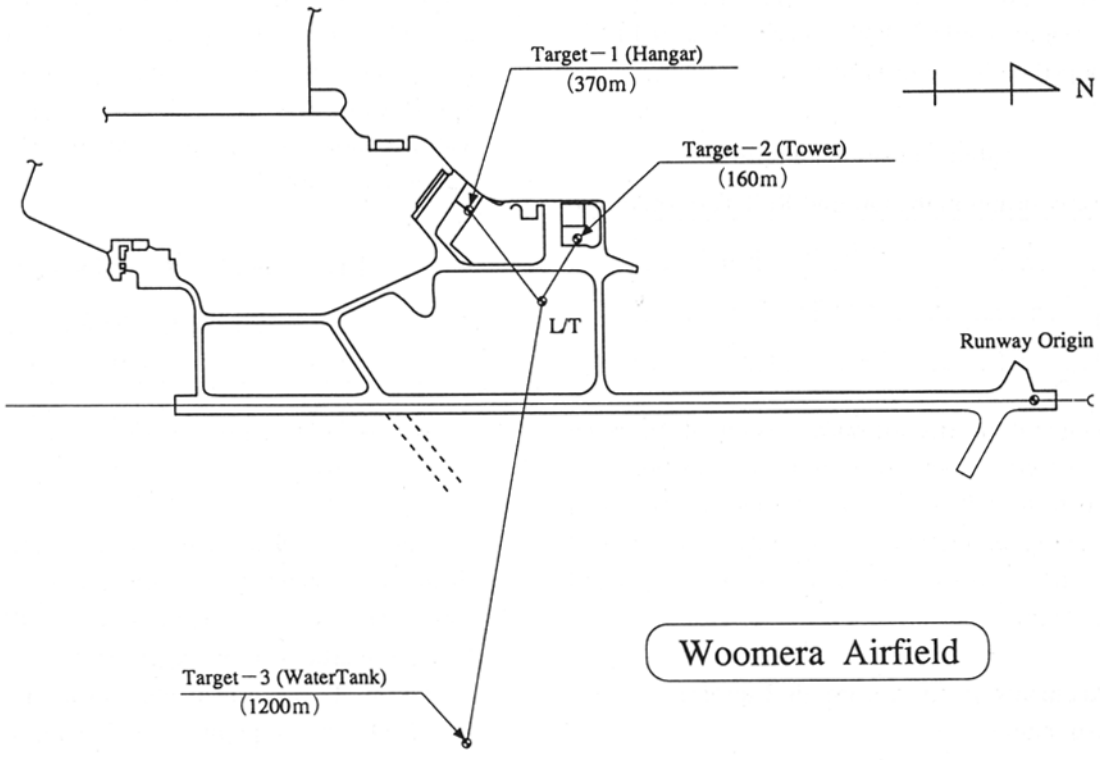

Figure 3 .Terrestrial Targets

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4. Accuracy during the Automatic Landing Experiments

4.1 Runway Origin Ranging

To prepare for the automatic landing experiments , the accuracy of the L/T was confirmed in comparison with the Transit , the L/T and the existing surveying values , by using the reflector set on the runway origin . Figure 4 shows errors in the runway coordinates , which shows the errors of X , Y and Z directions were approx. 30cm.

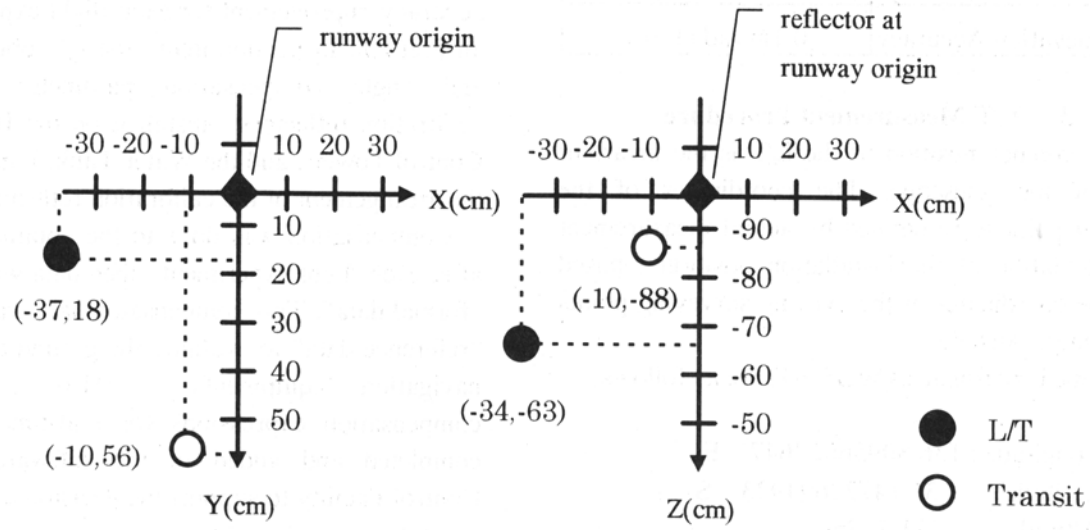

Figure 4 .Positioning error at Runway origin

4.2 Positioning error at the Ground Roll Test

At the starting point of the Ground Roll Test , errors were obtained when ALFLEX was put at the 10m offset position in Y-axis direction from the runway origin. Table 2 shows errors when ALFLEX was stopped on the runway origin.

Table2. positioning error

(at runway origin in the Ground Roll Test, 90km/h)

Δ X	0.36 m (mean)
Δ Y	0.35 m (mean)
Δ Z	0.33 m (mean)

Assuming that the aircraft body was put along to the X axis direction , the laser reflector position was obtained from calculation based upon the positions of the centre of gravity of the body. As table 2 shows , the errors of X, Y,and Z axes were all approx. 35cm.

4.3 Accuracy at the Automatic Landing Experiments

Figure 5 shows the predictions of the L/T measurement errors in the Free-Flight Phase , lead based upon the terrestrial targets described above , the runway origin ranging and the flight test results [1] in Japan. For 2.5km far or more from the runway origin , the results of Flight Test in Japan was applied. For on the runway , the runway ranging data was applied. Then , both data was approximated by 1st-order approximation. Table 3 shows the L/T predicted positioning error at the release point.

Table3. predicted positioning error

(at release point)

Δ X	±1.0 m (3 σ)
Δ Y	±0.6 m (3 σ)
Δ Z	±1.3 m (3 σ)

Next , the observation data at the Free-Flight Phase were evaluated. Figure 6 shows the flight trajectories measured by the L/T at F101 , that is the first automatic landing experiment.

The L/T performed the positioning from the ALFLEX release point to the landing point and the stop point completely. Although laser beam interruption by pitot boom occurred several times

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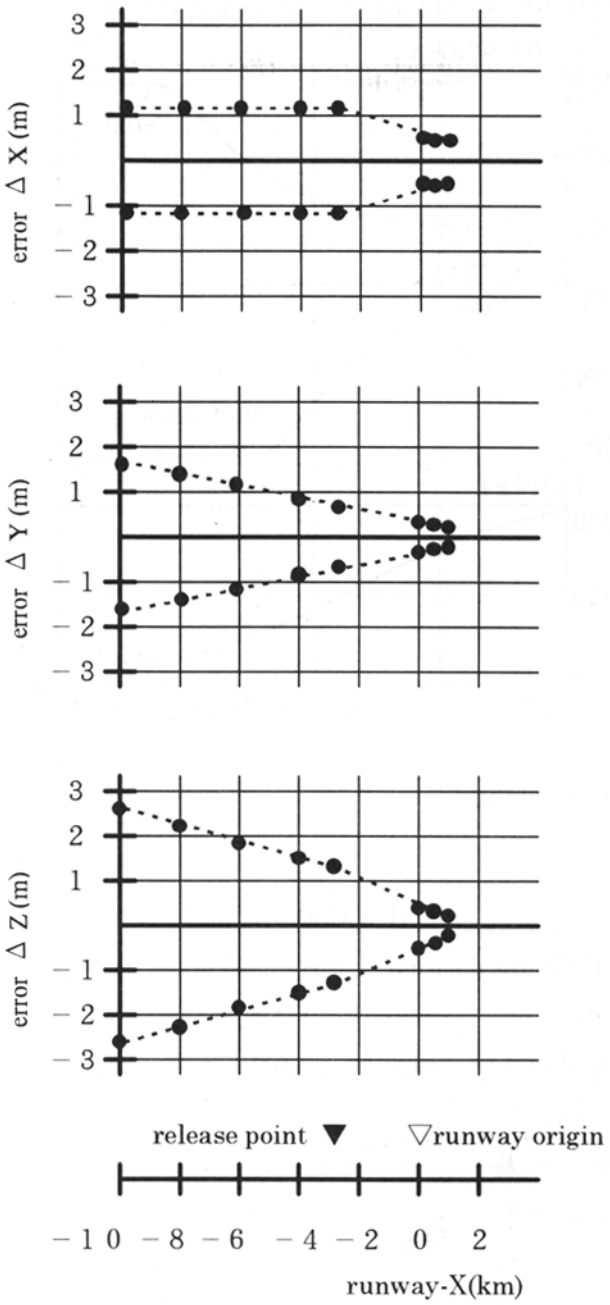

Figure 5 .Prediction Error in Free Flight

during 13 times of free flight, the positioning could be done for all 13 flights with full automatic tracking. For the accuracy of the L/T data during the Hanging Flight Phase and the Free Flight Phase , it occurred no problem on the accuracy in comparison with the Hybrid Navigation results. Figure 7 shows the comparison between real position of aircraft body and the position determined by L/T. Aircraft body was drawn at the stop position measured with measuring tape on the runway in F101. By deriving errors of the runway coordinates from Figure 7 , the results of Table 4 were obtained.

Table4. positioning error

(at stop position in F101)

Δ X	0．07 m(mean)
Δ Y	0．12 m(mean)
Δ Z	0．25 m(mean)

The results above show that the L/T accuracy during the automatic landing experiments is approx. 15 cm for X and Y directions , and approx. 30 cm for Z direction from the positioning results at the stop position. Since it is within the prediction error range shown in Figure 5 , it is possible to say that the positioning with sufficient accuracy was performed. The errors varied in each experiment seems to be caused by the atmospheric fluctuations on the runway due to the high temperature.

5. Conclusion

Aircraft tracking system with laser was developed and applied to determine the precise positioning of ALFLEX. System calibration was performed by the star calibration and the terrestrial targetting.

Because of strong atmospheric fluctuation in Woomera Airfield , positioning accuracy was confirmed with various kinds of method. In the runway origin ranging and the Ground Roll Test, approx.30 to 35 cm of accuracy was obtained. In the Free-Flight, the accuracy was improved to be 15 cm for X and Y direction and 30 cm for Z direction.

Also, the simplified expression on atmospheric compensation was developed and showed the operational effective method to determine the release point of ALFLEX.

Reference

[1]Takatsugu ONO,et al.:Development of the Laser Tracker and its Flight Evaluation Test, Proceedings of the 34th Aircraft Symposium 1996(in Japanese).

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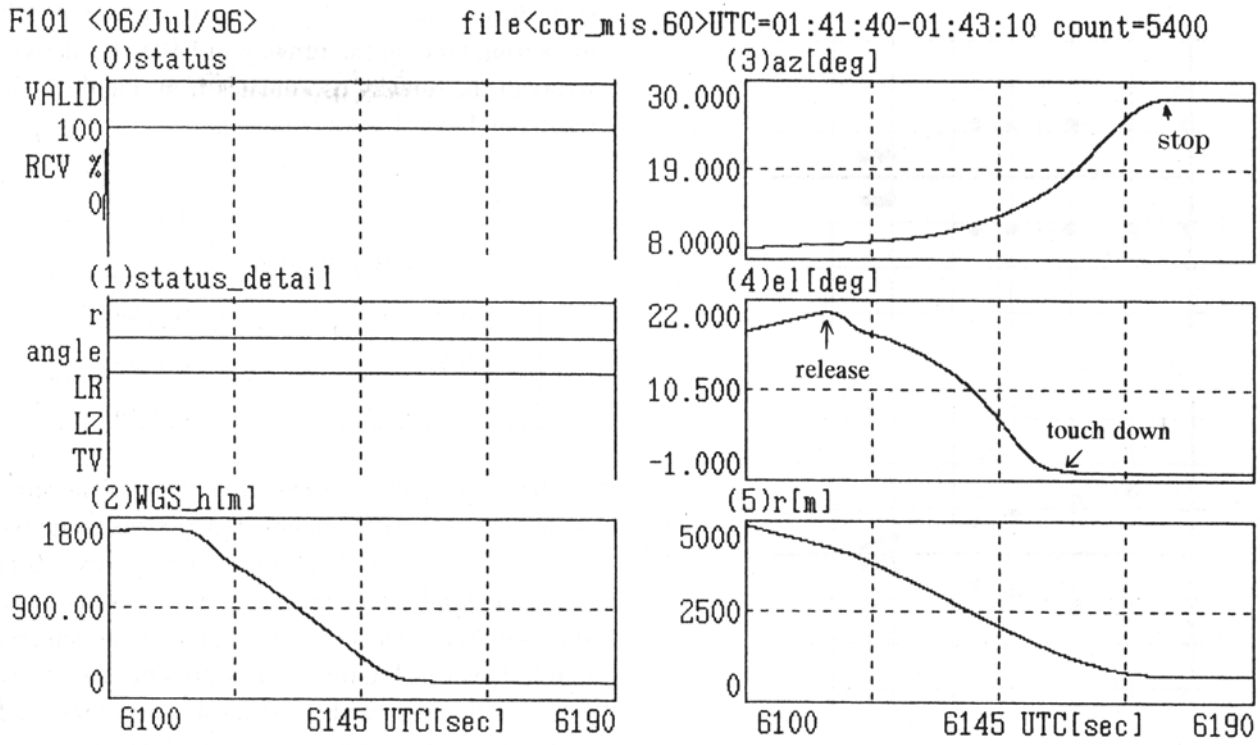

Figure6. Time History in Free Flight F101

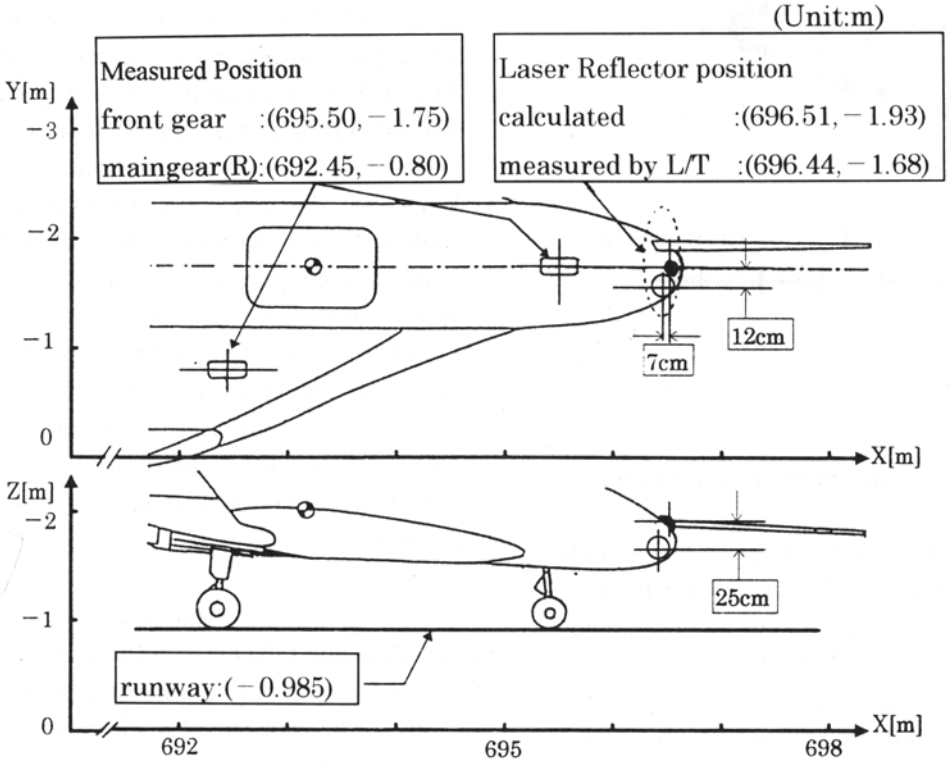

Figure7. Positioning error by L/T(F101)

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