# THE SIMULATION RESEARCH OF THE LOW ALTITUDE PENETRATION FLIGHT TESTING TECHNOLOGY

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## Abstract

*Several key technologies of the Low Altitude Penetration were discussed in this paper, such as digital map, trajectory optimization, trajectory tracking, etc. and a series of ground simulation was carried out to discover the characteristics of the flight testing, finally the flight testing methods and the flight test support technology were discussed.*

## 1 General Description

Low altitude penetration(LAP) flight testing need to be carried out, based on the knowledge of aircraft related systems, the safe and effective performance testing of all system components, a comprehensive assessment of low altitude penetration mission capability, safety and effectiveness checkout every quality identification of an aircraft at low altitude penetration. The test items include: to verify the effectiveness of aircraft radar / navigation / flight control equipment, identify the aircraft performance of low altitude penetration, verify the low altitude penetration driving skills and operational methods, and explore practical low altitude penetration tactics and methods. The difficulty mainly comes from the risk of collision with complex terrain, bad weather conditions make the low-altitude penetration tactics difficult to carry out, and it's hard to train a test pilot to be an expert.

Simulation is the key to solve the high-risk, high-tech features in the Low Altitude Penetration Flight Testing (LAPFT), through the ground flight testing tasks demonstration, study the test methods and test pilot training techniques, and eventually provide the necessary technical support for the future low penetration flight testing, and then the flight safety and efficiency can be improved greatly. Such as the European "Tornado" fighter, it was used 6 years to finish the flight testing of automatic terrain following system, more than 600 hours flights and over 3000 hours simulation tests [1].

To resolve several key problems of LAPFT, the mechanism, features and phenomena of the LAP study deeply in this paper based on modeling and simulation, and then the flight test programs and methods of test security were explored.

## 2 Key Technologies of LAPFT Simulation

In order to establish the LAP ground simulation platform, several key technologies such as the equations of 6-DOF motion, digital maps, terrain height real-time detection, route planning and optimization were discussed as follows.

### 2.1 Dynamic Modeling of 6-DOF

Large maneuvering is necessary in aircraft LAP to achieve terrain following and threats avoidances, and then there are seriously couplings in vertical and lateral control channels, the movement of aircraft presented strong nonlinearities. Small disturbance linear model is no longer suitable, so the six degrees of freedom motion flight equations were adapted in this flight software, including the real atmospheric models, aerodynamic models, flight control system model, engine / fuel model, gear model and the aircraft physical state model, etc. .

### 2.2 Digital Map Technology

The digital map accuracy and the fidelity of the environment affect the reliability of flight

simulation results directly, this paper uses real satellite photos and terrain elevation data to construct visual environment, this will give pilots the most realistic visual experience in LAP tests, which provides a strong support for manual terrain following (TF)/ terrain avoidance (TA) test simulation demonstration [2].

### 2.3 Terrain Height Real-Time Detection

The radio altitude is the most important source data of aircraft collision avoidance system, when the real-time radio altitude is less than the setting value, a pull up command was given out by the automatic flight control system, and the aircraft will flight up in default mode until the pilot interferes. In this paper, the collision detection method used in a virtual three-dimensional terrain to get radio altitude in real-time, then the data source problem of automatic flight up controllers was solved.

### 2.4 Route Planning Technology

It include a threat model (such as radar, surface-to-air missiles, artillery) and threat / terrain information fusion and the overall route planning technology. Based on the pilot test scheme, the route planning model was established for flat terrain, rugged terrain and rough terrain with threat areas, and the improved ant colony algorithm was used to achieve the overall trajectory planning and optimization [3].

## 3 LAP Ground Simulation Test

By reference to the principles of real test which was carried out from a high ground clearance to the low ground clearance, from flat terrain to rugged terrain, from the partial security to the risk increased dramatic task, series of simulation tests were done in the simulation platform to study the LAPFT characteristics. Three sets of terrain (flat terrain, rugged terrain and the tough terrain with threat area) were selected to execute the simulation test in manual mode. Figure 1 describes the pilot-in-the-loop manual TF / TA experimentation in the environment with threat zone. Figure 2 show the pilot manually flies a airplane through the threatened area following the setting path.

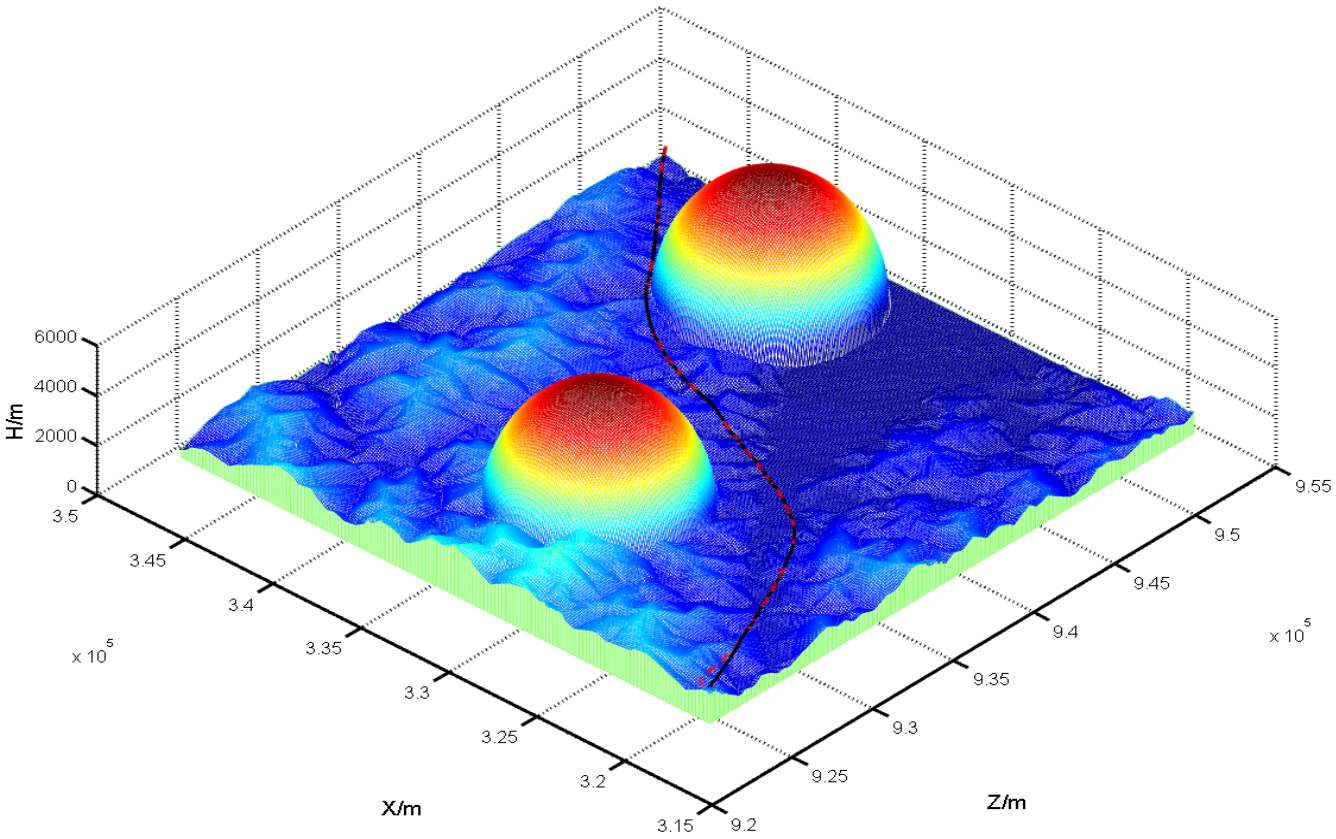
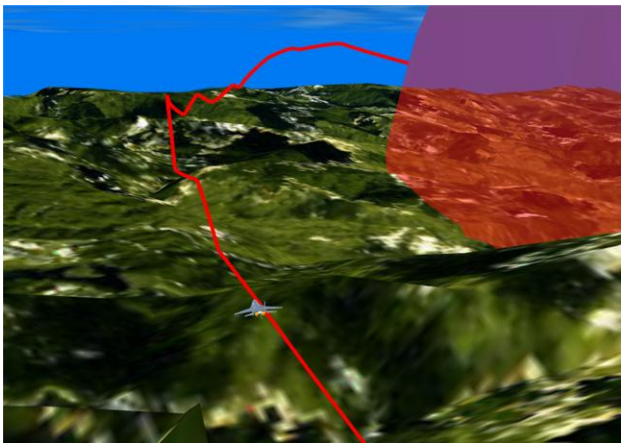



Fig. 1. Manual TF

Fig.2. Terrain / Threat Avoidance



After the ground simulation test of manual LAP through flat terrain, rough terrain and terrain with a threat zone, then some conclusions were drawn as follows based on the analysis and statistics of test data:

- For the lower ground clearance, all kinds of alarms (e.g., "fly up", "G limit", etc.) increased dramatically, the psychological pressure on pilots increased as the ride quality is lower;
- The threat area makes pilot psychological burden increased, but because of good planning track, it avoids some of the threats and rough sections, so the number of warning was reduced by contrast it to the test in rough terrain;
- With the increase of pilot proficiency, the number of various alarms decreased;
- Automatic pull up control law can reduce the risk of aircraft crash hill greatly.

## 4 LAPFT Method Research

The main purpose of low altitude penetration flight test is to evaluate the security of on-board LAP system, assess the adaptability of aircraft at LAP mission, verify and confirm the control procedures of LAP, also to explore the flight test methods, driving technology and constraints for the flight test characteristics of LAP. The test contents include cabin adaptability tests, pilot workload during TF, MTF warning and caution, and the working conditions of automatic fly-up system, from simple to difficult, step by step for the LAP test, and check the navigation screen figure during the TF.

### 4.1 Air-Ground Integration Flight Test Method

To ensure a high degree of experimental reproducibility, the flight test has to be carried out following in the specified path. The terrain contour lines were reconstructed by simulation technology in the terrain following system flight test, and a large number of ground simulation experiments were done on this basis, the differences between the actual terrain following and the simulation trajectory were obtained after the simulation data and actual flight test curves compared with. The low altitude penetration test using the air-ground integrated flight test methods includes the following main items:

- Ground Simulation Test And Training

Including ground demonstration experimental task card and their selection, the pilot simulated training and emergency training, etc.

- Adaptability Training

Include the aircraft adaptive training and various devices operation training for the LAP.

- Air-Ground Integration Flight Test

Air-ground integration flight test methods were adapted for flight tests; the experimental data send to the ground station through the telemetry equipment when the test tasks were carried out by test pilots. The ground control center and simulator get the data after the signal processed with modulation and demodulation. The flight simulator repeats the maneuver simultaneously, and compares the data curves with previous simulation data; monitors the telemetry data in real-time, checks the parameters of the aircraft equipment, and gives advice to test pilots.

### 4.1 Flight Security Measures

The key security measures of LAP test list as follows:

- The Digital Map Of Test Field

To ensure the consistency of visual information between the ground simulation / training and the real flight, the selected test field needs to build a three-dimensional digital map, so that the test pilot training of ground simulation can get the

highest possible fidelity, and also the digital map is the important data source to a navigation system.

- Ground Simulator

The test pilot skill level and response capacity can be improved effectively in the simulator; it's also to be a powerful study tool for the LAPFT, and plays an important role in an air-ground integration flight test.

- Real-Time Track Measurement

Flight path measurement at LAPFT is an important task of evaluating the terrain following and terrain avoidance. The aircraft track can be obtained by GPS or telemetry, or ground-based measurements in real-time.

- Real-Time Weather Forecast

The weather (wind direction and wind speed) which affects the LAPFT mission was forecasted to support the flight test mission decision-making.

- Real-time Command System

All data and information has been monitored in real-time, cooperation with the pilots, and supervision and command of the whole flight test mission, are the core of the air and ground flight test. It includes the ground control system, engineers and senior test pilots.

## 5 Conclusions

This article briefly describes the research of the LAPFT with ground simulation in recent years, the LAPFT characteristics were researched by means of the simulation methods, the air-ground integration flight test concepts were proposed for LAP, and the key technologies and security measures have been pointed out. The LAPFT demonstration was carried out based on real terrain data after the simulation model has been established, that will play an important role in the future LAPFT supporting.

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