AUTOMATIC TAKE-OFF AND LANDING SYSTEM FOR FIXED WING SMALL AIRCRAFT

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Abstract

Fuji Heavy Industries Ltd., Aerospace Company has developed an experimental aircraft for automatic takeoff and landing. An automatic take-off and landing system, based on flight control technologies from various UAVs, was added on to a powered glider, and we successfully substantiated by several times of flight tests. From this results, we confirmed that this system can be applied to UAVs, and also to manned aircrafts for future automatic transportation system. This report describes the outline of our experiments of automatic take-off and landing.

1 General Introduction

In recent years, UAV(Unmanned Aerial Vehicle) applications are spreading to various fields such as agricultural spraying, surveillance and observation, and more complicate missions. To simplify and to rationalize its operation, it is wanted for UAVs to have the ability of take-off and landing on runway, like conventional aircraft. Fuji Heavy Industries Ltd.(FHI) have been promoting the research and development of automatic take-off and landing system for various UAVs. At the High Speed Flight Demonstration (HSFD), an experimental program of JAPAN Aerospace Exploration Agency (JAXA), we established the automatic take-off and landing technology of a high speed fixed wing UAV with a jet engine. And, for rotary winged UAVs, we succeeded automatic take-off and landing experiments with RPH 2, an unmanned helicopter for civil uses such as observation and agricultural spraying.

Based on such autonomous flight control technologies for various UAVs, we started FABOT (Fuji Aerial roBOT) experiment program, which aimed to demonstrate automatic take off and landing by a low-speed, low wing loading and small-size aircraft. In this report describes the overview of the FABOT system.

2 System Components

2.1 Vehicle Specifications

For experiment system, we decided to add an Automatic Flight Control System (AFCS) on an existing aircraft to reduce the costs and term. For the platform, we selected a powered glider HK36-TTC115 Super Dimona, production of Diamond Aircraft, which has low wing loading, and ordinary tricycle system.
The aircraft outlook is shown in Fig.1 and the vehicle's major specifications shown in Table 1.

Fig.1 Outlook of the Experimental Aircraft

Table 1 Vehicle Specifications

Length	7.28	[m]
Span	16.33	[m]
Height	1.78	[m]
Maximum Weight	770	[kg]
Wing Area	15.30	[m^2]
Maximum Power	73.5	[kw]

2.2 Automatic Flight Control System(AFCS)

Fig.2 shows the block diagram of the Automatic Flight Control System (AFCS). The remarkable characteristics of this system are that ; It has sufficiently precise, but low-cost Navigation system integrated from various sensors, such as GPS, IMU, air data sensor, etc. Each sensor data is processed in the flight computer and provided to guidance law as hybrid navigation data.

As the position sensor, we adopted an RTK-GPS system, which makes it possible to detect position and ground speed with enough accuracy for take-off and landing. The differential information is send to the vehicle from the portable ground equipment shown in Fig.3, which consists of a GPS receiver, a laptop PC, and a wireless modem. Thus, the on-board system is truly compact to be boarded on a small aircraft, while the ground equipment is portable enough to realize easy operation.

The flight computer processes the input from the navigation system, according to fully automatic guidance and flight control algorithm from take off to landing, then outputs control commands to actuator controller, which drives the control surfaces and throttle. Actuators are installed under the co-pilot seat.(see Fig.4)

In this experiment, the AFCS controls only elevator, aileron, rudder, throttle. Other effecters such as foot brake, spoiler, and other isolated operation such as starting engine, are pilot controlled, for the purpose of simplifying the system.

For safety, the system has a disengage device in the linkage, which enables to switch the authority from autopilot to human pilot in case of unexpected trouble. The action to disengage is only to grip the lever attached to the control stick. It enables quick disengage in critical situations, especially in low altitude.

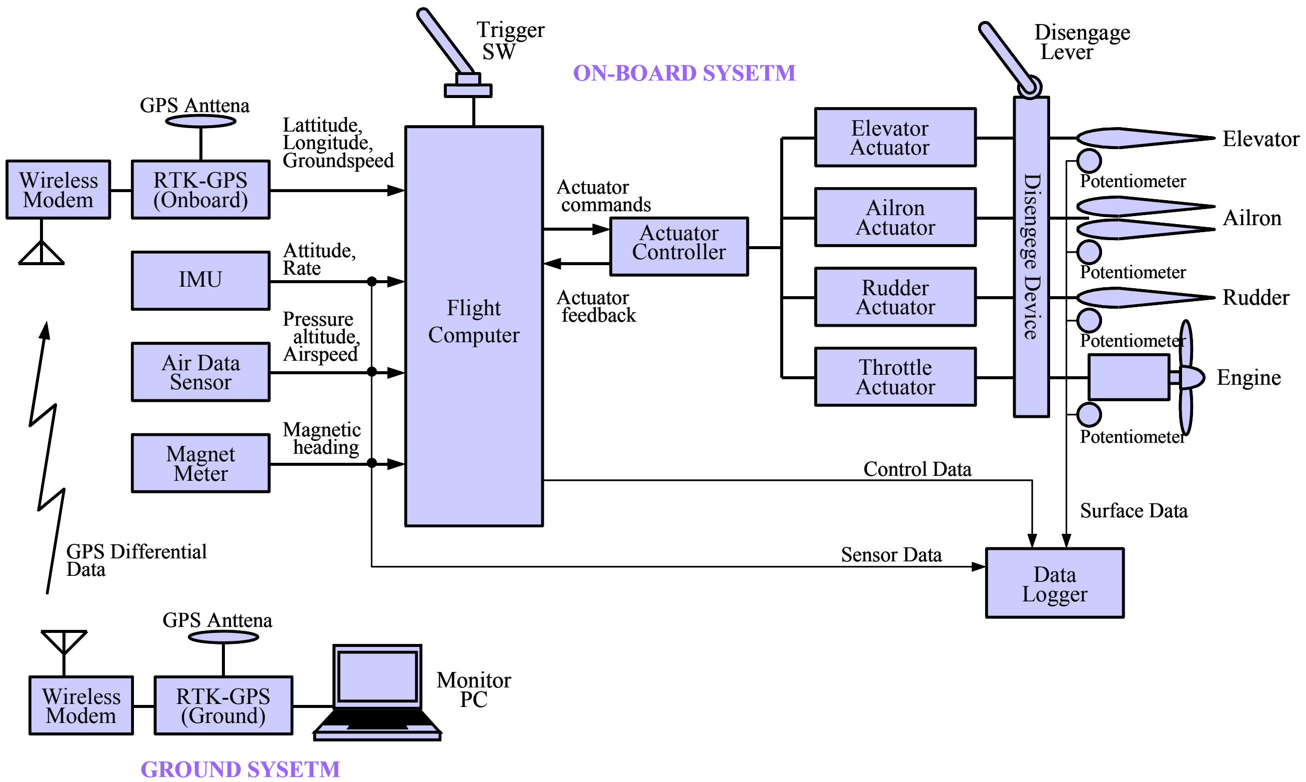

Fig.2 System Block Diagram of AFCS

Furthermore, we designed it possible to disengage without the lever action, by pushing or pulling the control stick with a certain strength.
Fig.5 shows the outlook of the control stick equipped with the disengage lever, and the engage indicators on the consol panel.

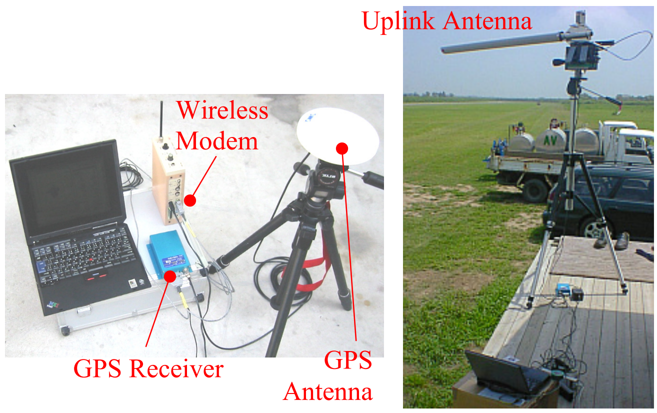

Fig.3 Portable Ground Equipment

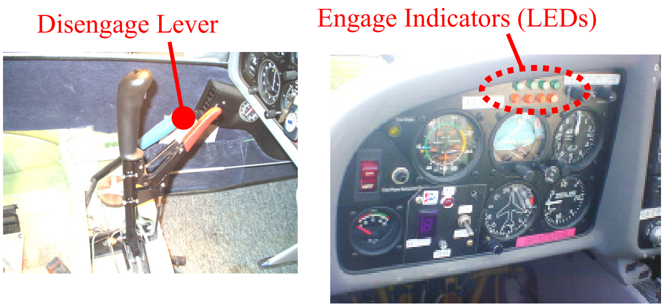

Fig.5 Control Stick & Console Panel

3 Features of Automatic Take-off and Landing

The AFCS makes the aircraft fly automatically according to pre-programmed flight plans. In this experiment, we set the waypoints as a track pattern around the airport, shown in Fig.6.

3.1 Automatic Take-off

When the pilot turns on the trigger switch on the console panel, the AFCS starts the take-off phase, shown in Fig.7.
After starting take-off phase, it controls the throttle to hold maximum power, and each effecter moves to keep the taxing attitude of the vehicle. When reached to the rotation speed, elevator control pulls up to make airborne, which

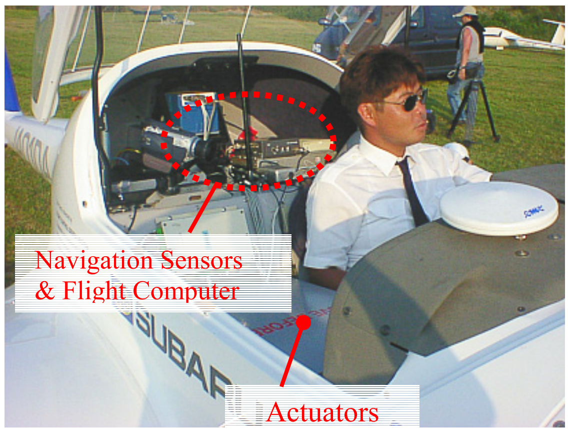

Fig.4 Installation of AFCS

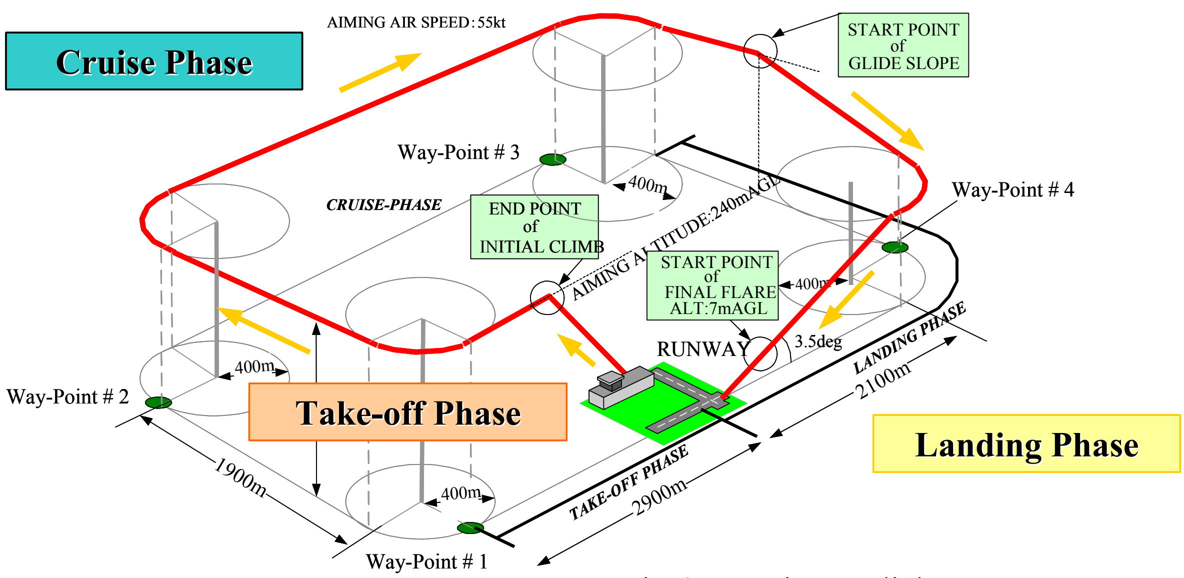

Fig.6 Experiment Flight Pattern

is the rotation mode, and next, passing certain altitude, it transits to climb mode.
In the climb mode, the throttle control maintains max power, while the elevator keeps the target airspeed. The take-off phase is completed after reaching the first waypoint, and then the AFCS starts the cruise phase.
Before rotation, course tracing is achieved by rudder control so that the aileron control is used to hold the bank angle horizontally. After airborne, course tracing is switched to the aileron control.

3.2 Automatic Landing

When completed all the cruise waypoints scheduled in the flight plan, it starts the landing phase, shown in Fig.8.
In the first step of the landing phase, it is programmed to keep 3.5 degree of flight path angle and 60 kts of approach speed. When it pass certain flare altitude, it starts flare mode. Elevator starts pull up to the flare pitch angle, and throttle decelerate to the idle speed, then touch down. After touch down, it transits to taxi mode by reduction of the airspeed
Course tracing is achieved by aileron control in the approach, and it switches to the rudder control after starting flare.

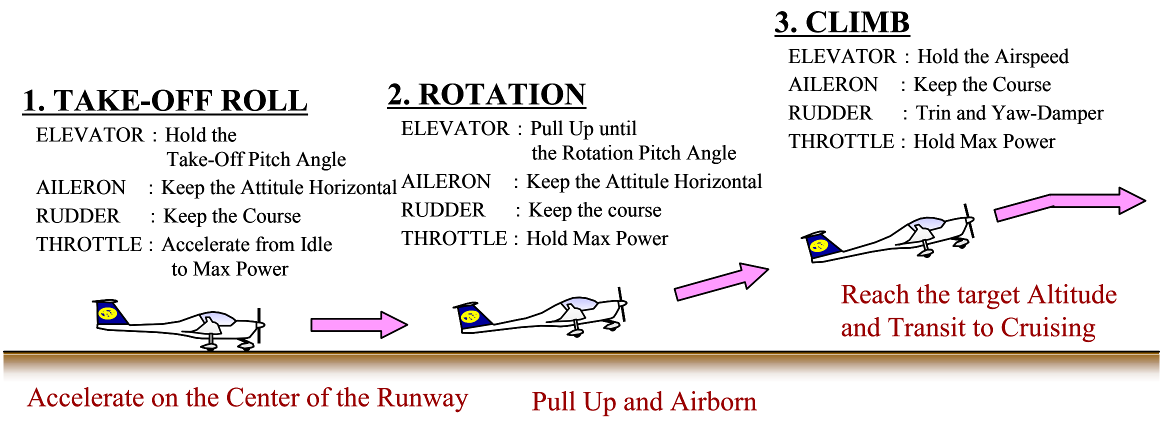

Fig.7 Automatic Take-Off

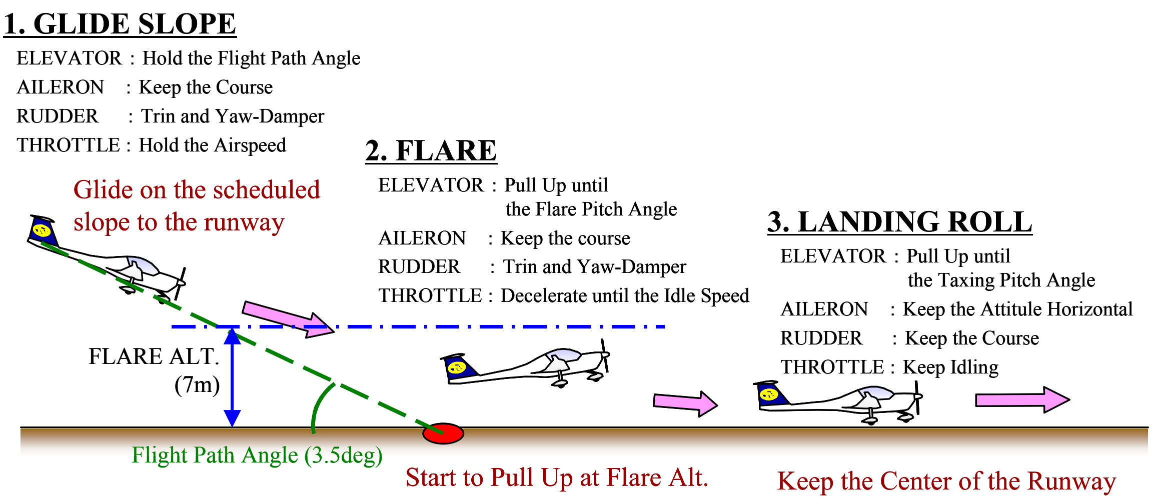

Fig.8 Automatic Landing

4 Results of Flight Tests

An example of flight path in flight tests is shown in Fig.9.
It shows that the aircraft traced the scheduled flight pattern precisely.

4.1 Take-off Results

Fig.10 is the time histories in the automatic take-off phase. From the beginning of taxing to the end of climbing, the course error was less than 1 meter, which is accurate enough for take-off from a 20-meter wide runway.
After airborne, the climb rate and the airspeed was kept approximately same to the targeted values. And, after reaching the target cruise altitude, 240 meters, the transition to the cruise phase was achieved smoothly.

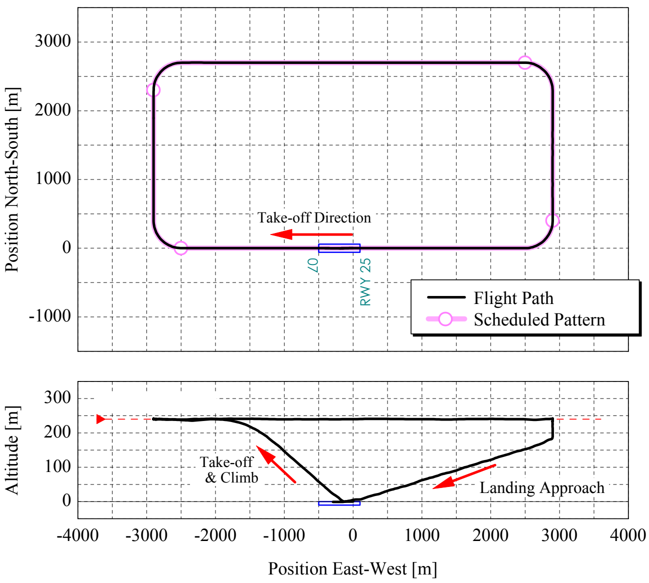

Fig.9 Result of Test Flight - Flight Path

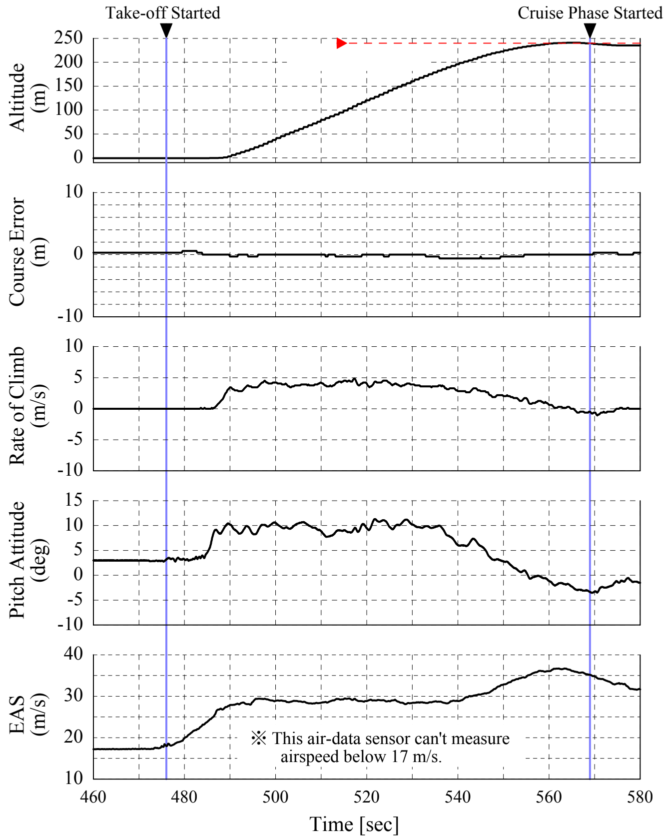

Fig.10 Result of Test Flight - Automatic Take-off

4.1 Landing Results

Fig.11 is the scene of automatic landing. The time histories in the landing phase is shown in Fig.12. The course error was about 2 to 3 meters, also enough accuracy for landing to a 20-meter wide runway.
After started the flare mode, the rate of decent reduced smoothly, and just before touch down, the rate of decent was 0.3 m/s, which means very soft landing.
As is shown above, we confirmed the ability of our automatic take-off and landing system. The AFCS could keep the vehicle so stable that the test pilot could hold his hands up during the landing approach, shown in Fig.11 and Fig.13.

Fig.11 Automatic Landing

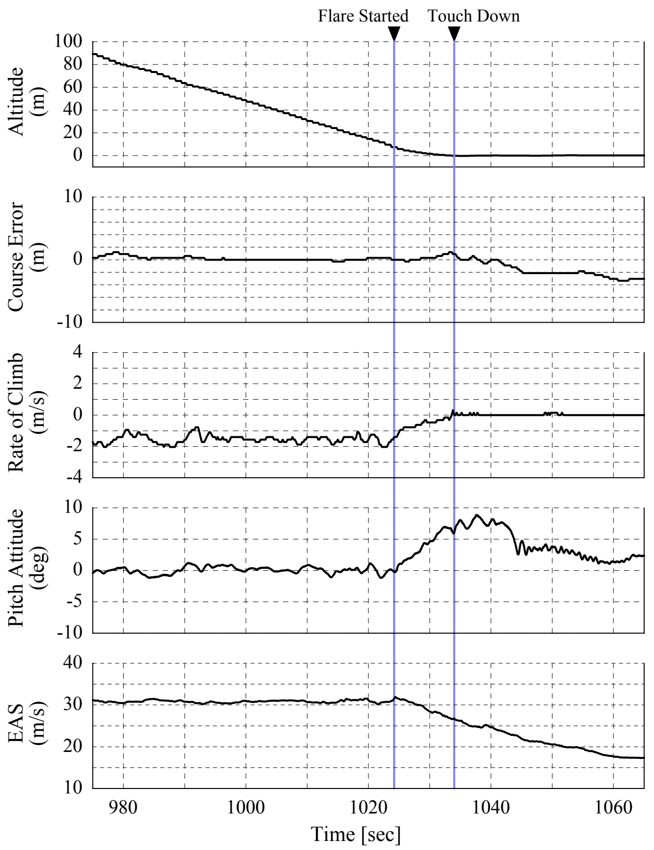

Fig.10 Result of Test Flight - Automatic Landing

5 Conclusion

We integrated an automatic flight control system to an existing small aircraft with minimum modification, and the automatic take-off and landing experiment has completed successfully for the first time in Japan.

This is very important result which leads to the expansion of the freedom of UAV operations.

On the other hand, this result we achieved will be applicable to future small aircraft, which will be needed for the next generation aircraft transportation system. On the basis of the success of FABOT experiment, we are going to respond to as many requests from various fields.

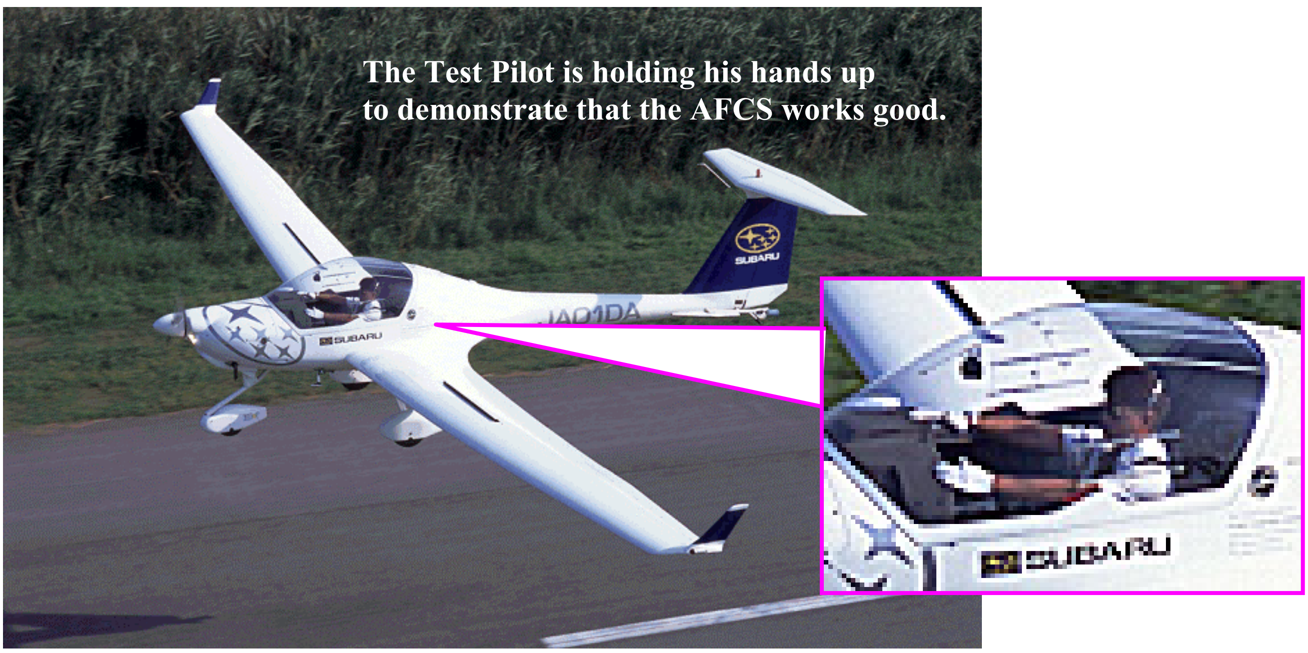

Fig.13 A Scene Just Before Touch Down