DESIGN AND EVALUATION OF TACOM CONTROL LOGICS

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Abstract

*This paper describes the overview of the control logics of TACOM (Multi-role small UAV, **TA**-youto K(**C**)**O**gata **M**ujinki in Japanese) . It is intended to describe key technologies including those related to guidance and control. The evaluation flight test of the TACOM system was completely successful in 2001.*

Introduction

TACOM is a UAV system developed by Technical Research & Development Institute (TRDI) of Japan Defense Agency (JDA). The program was intended to describe key technologies including those related to guidance and control as follows: (Figure 1)

(1) Wing expansion control,
(2) GPS/ADS (Air Data System) hybrid navigation,
(3) Autonomous target tracking.

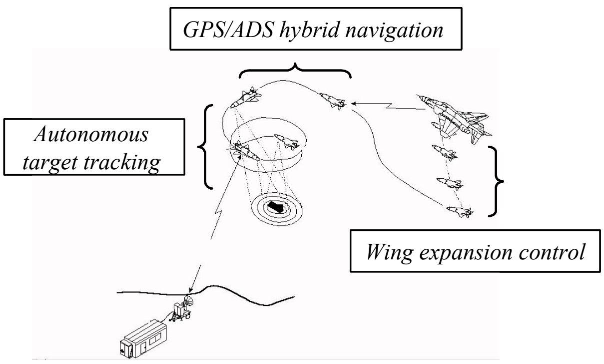

Figure 1 Key Technologies

1 Navigation and control system overview

In a usual navigation mode, the outputs of GPS, Attitude and Heading Reference System (AHRS) and air data sensors are processed to provide positions and velocities. In addition, the angles of InfraRed (IR) sensor gimbals are processed for positions during the target tracking mode.

With a pre-programmed flight plan, commands are created in a flight control computer so that the position and velocity of the UAV would comply with a suggested flight path, altitude and velocity given by the flight plan on memory. Manual commands are also possible.

The flight control law includes longitudinal control for static pitch stability using stabilators, lateral control for static roll stability using stabiliators, directional control for yaw-damper and yaw-trim using rudders, and engine rotation speed control to set velocity and altitude at low altitude.

The Block diagram of the navigation and control system is shown in Figure 2.

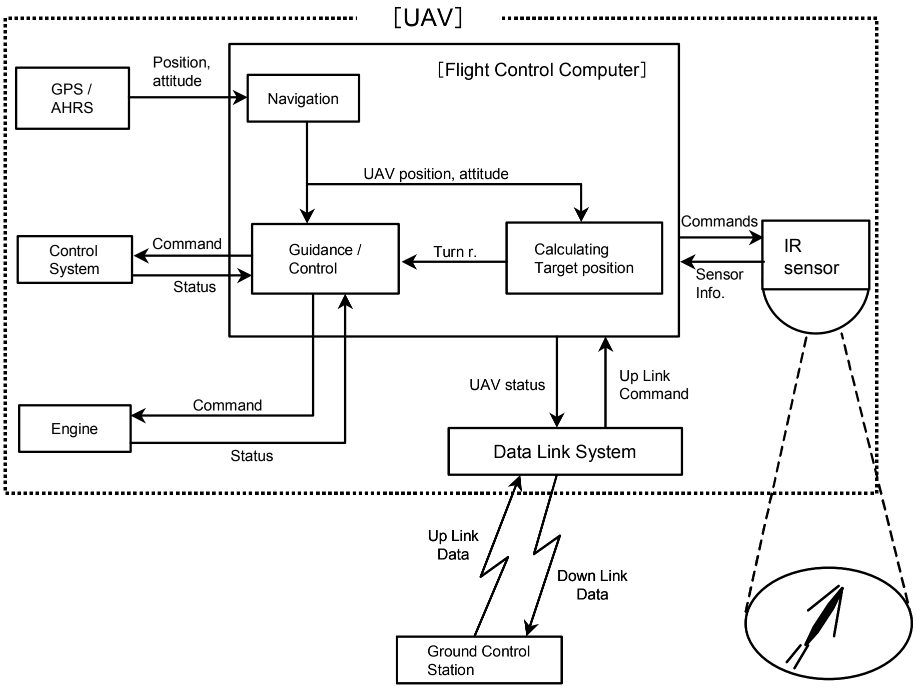

Figure 2 The Block diagram of the navigation and control system

2 Wing expansion control

The wing expansion is performed by wing expansion actuators following an air-launch procedure illustrated in Figure 3. In order to keep the carrier safe at the separation, the UAV is controlled not to ascend due to the abrupt increase of the pitch angle. Since the influence of the flow around the carrier is quite large and the folded wings make the UAV less stable, an attitude control starts immediately after the launch. When the wings expand, it works so that lift due to the increase of the wing area will be not be generated to keep the load on the actuators as small as possible. In addition, two sets of control gains, i.e., gain for the folded wing configuration and that for the expanded wing configuration, are memorized and mixed properly for a smooth transition between the two configurations.

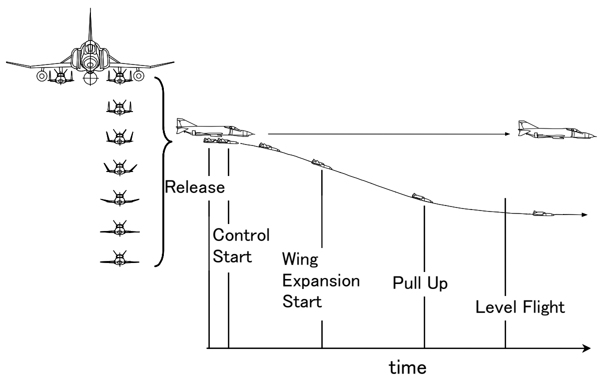

Figure 3 Wing Expansion Control

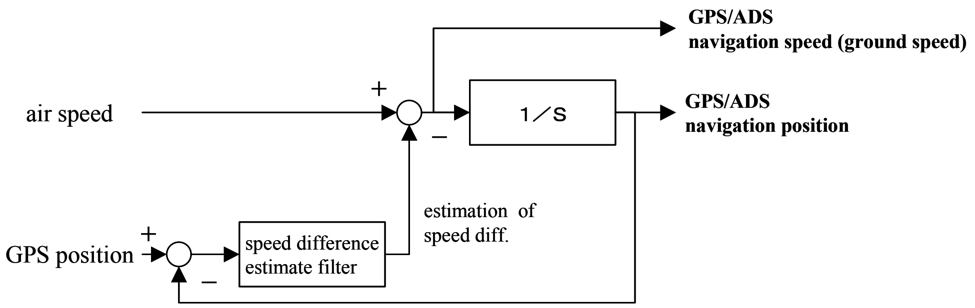

Figure 4 GPS/ADS hybrid navigation block diagram

3 GPS/ADS hybrid navigation

The GPS/ADS hybrid navigation is essentially an automated dead-reckoning. Dead-reckoned position is computed by true airspeed integrations with the elimination of estimated wind components, which are periodically updated by being referred to GPS positions. The GPS/ADS hybrid navigation block diagram is shown in figure 4. If the GPS was temporarily unavailable, the positions would be continuously calculated using the previously estimated winds and the current airspeed.

4 autonomous target tracking

A sensor integrated guidance and control enables autonomous target tracking. This is called Target Management System (TMS) (Figure 5), which proceeds as follows:

(1) Target positions are continuously calculated once the target is specified in the Ground Control Station (GCS).
(2) The orbit pattern of a descending spiral turn about the target is automatically created a TMS command
(3) The UAV start descending along the pattern by a DESCNEDING TURN command.
(4) The UAV reaches a pre-set lowest allowable altitude and maintain the altitude.
(5) The UAV returns to the pre-programmed flight path by a RESUME command.

TACOM is equipped with a buried sensor to reduce drag, because it is a high-speed airplane. The field of view of the sensor, therefore, is restricted by the area of windows. The TMS also takes this into considerations to perform continuous target tracking.

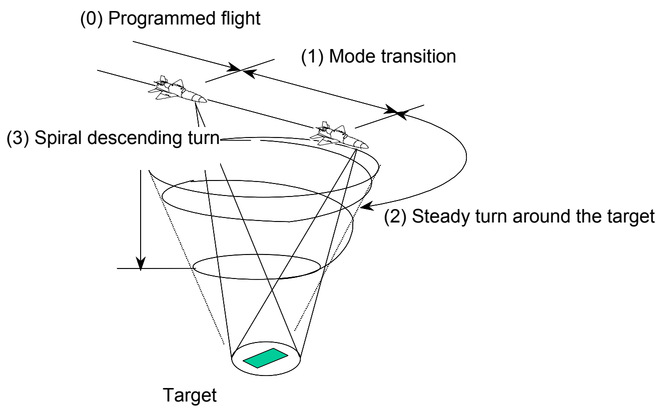

Figure 5 TMS

5 ground test

In the design stage, accurate aerodynamic models were required to simulate the wing expansion control and the TMS. In order to understand these aerodynamic interactions between the carrier and the UAV, a set of wind tunnel tests were performed. A wind tunnel test with a carrier model carrying UAVs provided the carrier's aerodynamic influence on the UAVs. A drop test provided the trajectories of the UAV under the aerodynamic interactions. Another wind tunnel test was also done using Captive Trajectory System (CTS:ref. Figure 6) that periodically calculates separation trajectories based on measured aerodynamic forces on the UAV model. Thus, the aerodynamic models in the simulation were improved with these results to predict actual flights as much as possible.

In ground functional tests, a full scale UAV and the GCS were used to simulate flights, validate system functions and the responses to commands from the GCS, and train operators.

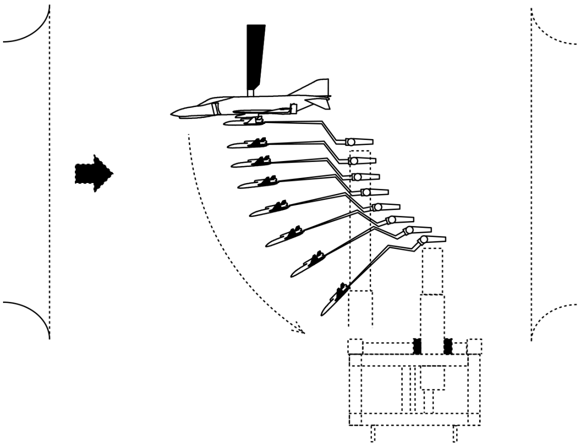

Figure 6 CTS (Captive Trajectory System)

6 Captive Flight Test

Prior to UAV independent flights, all the procedure and datalink qualities were previewed by Captive Flight Tests (CFT: ref. Figure 7) in which the carrier flew the UAV flight patterns carrying the UAV with its power on. In the CFT, the UAV was also able to take images of targets and transmit them to GCS. Operators were, thus, able to monitor the sensor images and command the UAV to track the target.

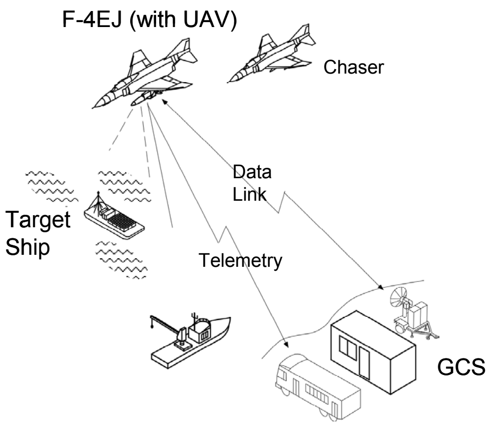

Figure 7 CFT (Captive Flight Test)

7 flight test

All the flight tests had successful air-launches as shown in Figure 8. While a major part of the flights was performed with the GPS/AHRS navigation, it was proved that the GPS/ADS hybrid navigation was accurate enough to navigate the UAV in the second flight. The TMS was also demonstrated successfully in the flight tests. The UAV equipped with a sensor continuously took images of a target boat, transmit them, and kept pointing the sensor to the target through the windows.

Figure 8 Air –Launch

8 conclusion

Through the program, fundamental guidance and control logics for an air-launched UAV were established. These logics could be applied to a future UAV development of this kind that could be used for reconnaissance or other various missions.