Development of Small and Smart Target Drone: Cost Reduction Success with Proprietary Technologies

The aerial target drone systems are operated by the Japan Ministry of Defense for live fire training to protect our country from enemy threats. We developed the Small & Smart Target Drone Systems for simplifying and integrating its sub-system / structure / components due to the requirement of significant cost reduction.

Introduction

The Ministry of Defense is conducting firing training with autonomously flying aerial target drones as part of training to protect the country from aerial threats.

1 Background

The numerous aerial target drones developed inside and outside Japan so far are large and expensive. As it has not been possible to purchase a sufficient number of aerial target drones due to budget reductions for annual unit training, securing enough opportunities for firing training has been difficult.

2 Overview of small and smart target drones

(1) Operation overview

We have developed two types of small and smart target drones: the air-launched small aerial target for Japan Air Self-Defense Force (JASDF), and the ground-launched aerial target for the Japan Ground Self-Defense Force (JGSDF).

The air-launched small aerial target is used for air-to-air missile firing training by training aircraft. The drone is air-launched from F-15DJ mother ship in the JASDF training area, and it flies autonomously along the flight pattern set previously by the ground control equipment. The Operation is shown in **Fig. 1**.

In contrast, the ground-launched aerial target is used for firing training with ground-based antiaircraft weapons (such as missiles and automatic cannons), in which the target drone is launched from a launcher on the ground by a rocket motor.

(2) Drone overview

The air-launched small aerial target is one type a drone. As **Fig. 2** shows, the drone comprises a nose unit, a control and communication unit, a main wing unit, an engine unit, a steering unit and a tail unit. The nose and tail units are the same part.

(i) Aircraft structure

The fuselage is a monocoque structure comprising a metal tube, and the fins of the main wing unit and steering unit are solid structures.

(ii) Nose unit and tail unit

The nose unit and tail unit are equipped with Luneberg lenses to produce radar reflectivity close to that of a fighter, allowing the drone to be a target for a radar-guided missile. The lenses are covered by fairings to reduce aerodynamic drag.

(iii) Control and communication unit

The control and communication unit is a module functioning as the brain of the system. It consists of a GPS/INS navigation sensor that detects the drone's position, speed, attitude and so on, a computation circuit that performs flight-control and power-source management, an ATC transponder necessary for airspace safety, a signal transmitter and receiver to communicate

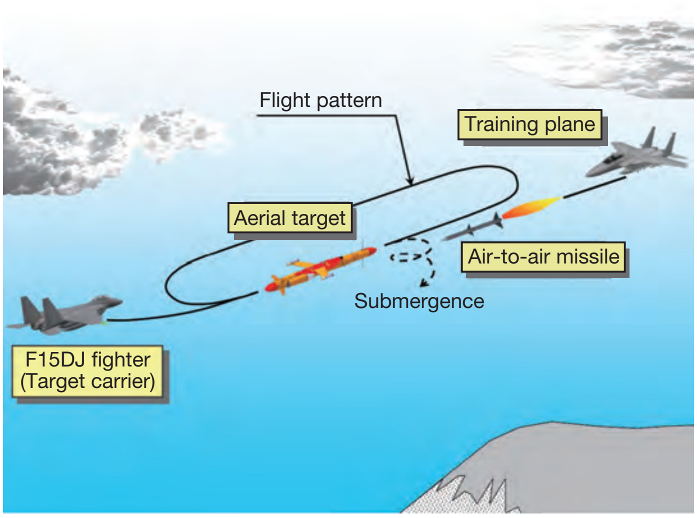


Fig. 1 Overview of operation air-launched small aerial target

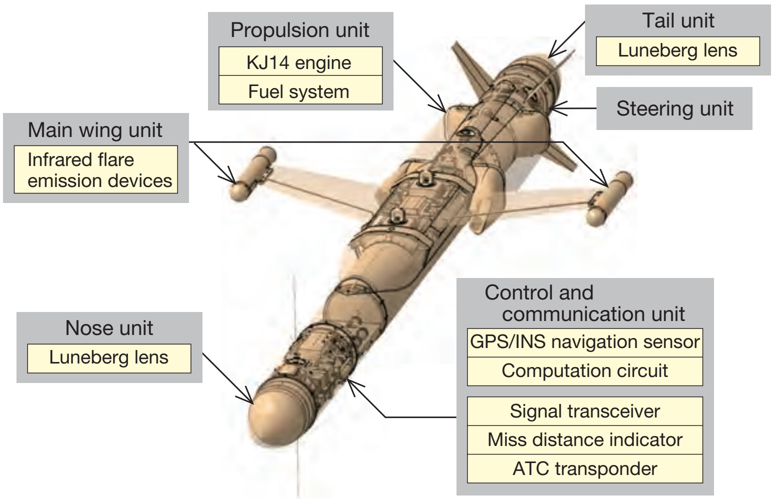


Fig. 2 Overview of drawing of air-launched small aerial target

with the F-15DJ mother ship or others, and a miss distance indicator that analyzes the distance to the passing missile.

(iv) Main wing unit

The main wing unit consists of the main wing structure and infrared flare emission devices attached to the main wing tips. The infrared flare emission devices ignite flares according to a command from the mother ship to allow firing training with infrared guided missiles.

(v) Propulsion unit

The propulsion unit comprises a fuel system and KJ14 engine. The propulsion unit uses the KJ14[1)] turbojet engine developed by us.

(vi) Steering unit

The steering unit consists of four all-flying fins. The drone is controlled by moving them in various combinations.

3 Policy of reducing cost

To develop small and smart target drones, the Ministry of Defense required us to drastically reduce cost compared with conventional target drones while maintaining the functionality and performance required for their firing training. To address this requirement, we decided to adopt the approaches of "simplification" and "integration," taking advantage of our proprietary technologies, considering that aerial target drones are unmanned aircraft and throwaways used only for a short time.

4 Cost reduction with our proprietary technologies

(1) Cost reduction by simplification

(i) Small engine

The KJ14 shown in **Fig. 3** is a single-spool turbojet engine designed for propelling a small unmanned aircraft.

Its compressor rotor and turbine rotor are integrated into a monorotor (an integrated structure made by precision casting) as shown in **Fig. 4**, and it uses a cantilever structure supporting only the low-temperature side at the front of the engine for simplification and lighter weight. This differs from support structures at both ends.

Furthermore, placing its bearings in the low-temperature part provides the additional advantage of allowing easier lubrication and cooling. To lubricate the bearings, considering that the engine is used only for a short time, a grease-filled bearing system is used to avoid the maintenance task of oil filling, which would be required for a separate lubrication system. Windmilling (rotation of a rotor by air flowing into the engine) starts the engine used together with a simple ignition cartridge. This design has not only reduced the cost, but has also made the engine smaller and lighter.

(ii) Fueling system

When starting the engine, fueling uses initial pressurization on the bladder tank, the shut-off valve and

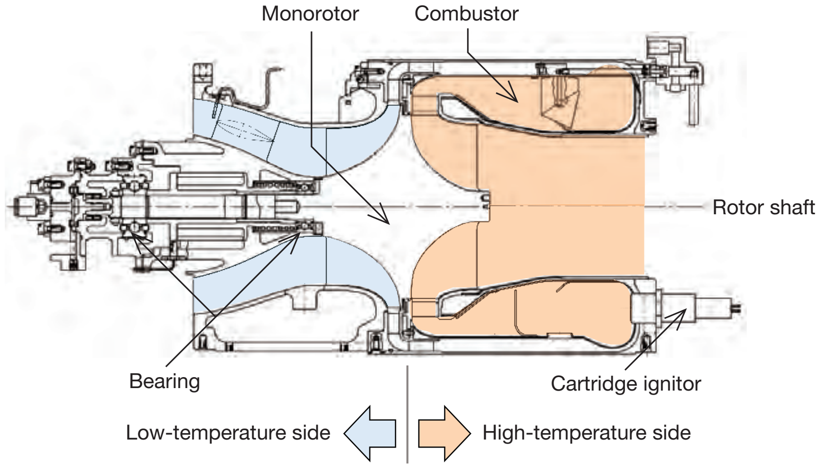


Fig. 3 Overview of drawing of KJ14 turbojet engine

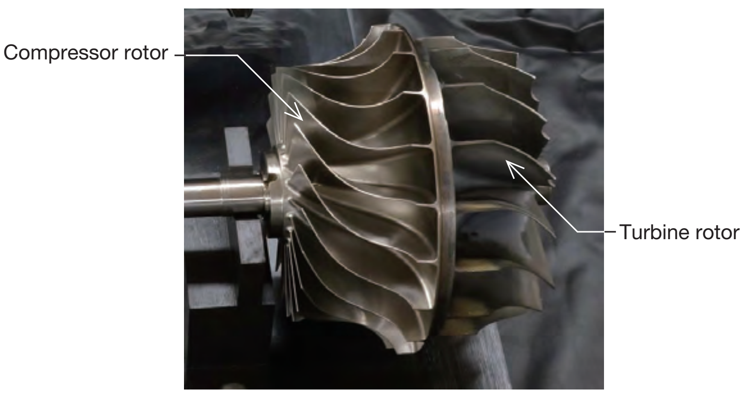


Fig. 4 External view of monorotor

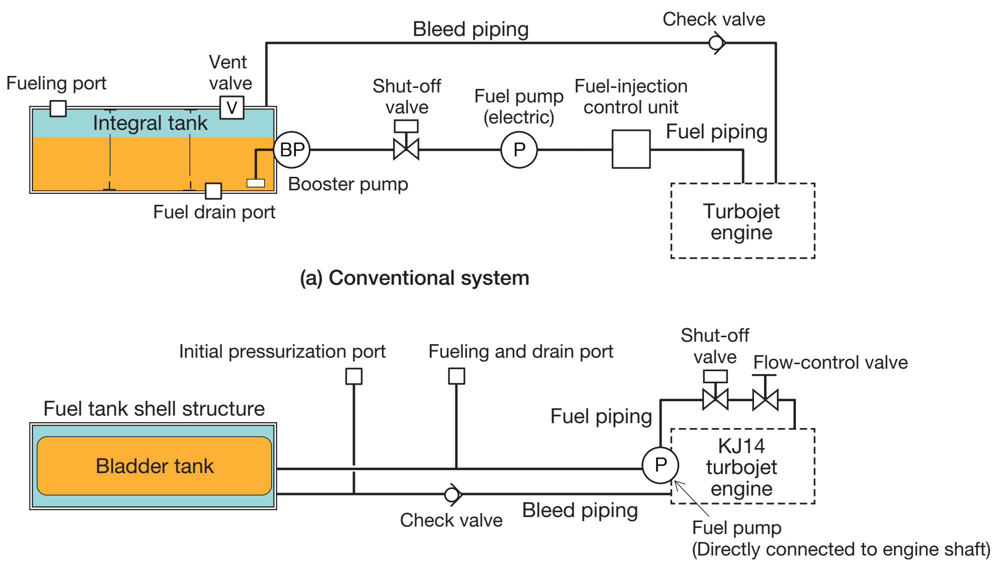
the flow-control valve. Once the engine starts, it relies on the engine exhaust pressure, the fuel pump placed coaxially with the engine, and the flow-control valve for stable fueling. As **Fig. 5** shows, this design has produced a simple and highly reliable fueling system with a small number of parts without needing an expensive booster pump, fuel pump, and valves.

Although the bladder tank system used in this drone is inferior to an integral tank system in terms of space optimization, it is an outstanding system that eliminates two problems: that of irregular impact loads caused by fuel sloshing around; and a poor fuel supply due to air getting into the fuel piping.

(iii) Flight control system

Since there was no maneuverability requirement involving ascending and descending while flying, and to reduce cost, we decided not to use a pitot tube (which needs precision machining and precise instrument calibration) as shown in **Fig. 6**. Instead, this drone employs a GPS/INS navigation sensor alone for the flight control system and to estimate airspeed and altitude essential for flight control calculations.

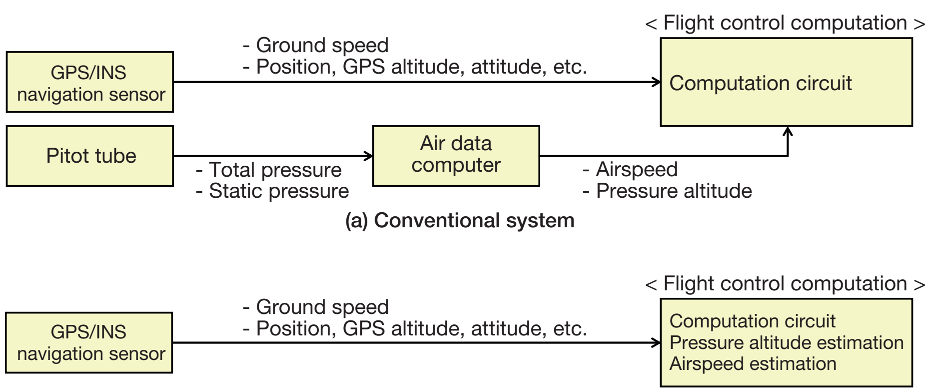
The flight control system estimates airspeed based on the attitude measurements sent from the GPS/INS navigation sensor and a database of speed and attitude obtained from wind-tunnel tests. Altitude is estimated by



(a) Conventional system

(b) This system

Fig. 5 Simplification of fuel supply system



(a) Conventional system

(b) This system

Fig. 6 Simplification of flight control system

comparing the drone's GPS altitude and the flying altitude of the carrier plane at the time the drone is launched. We have confirmed that this calculations works correctly comparing the estimated values with measured values obtained from calibrated instruments installed on manned aircraft.

(2) Cost reduction by integration

(i) Aircraft control — engine control

Since the aircraft body manufacturer has to date been different from the engine manufacturer in aircraft development, much effort goes toward interface adjustment. With this drone, however, as both the airframe and the engine were developed by us, it was relatively easy to integrate the aircraft control and engine control, and the size of the control circuit unit was reduced by half as shown in **Fig. 7**.

(ii) Engine mounting

To minimize the number of parts and reduce the assembly and machining workloads, the engine is mounted in a unique way whereby it is directly connected to the aircraft as a primary structure of the body as shown in **Fig. 8**, instead of being mounted as a pod in conventional drones.

(iii) System integration

Electromagnetic compatibility testing is a test to check whether the level of generated emissions does not exceed the specifications and the irradiated noise does not cause malfunctions. This is to prevent electromagnetic interference on the drone itself and the F-15DJ fighter by unnecessary electric noise emitted from the electric devices (emission).

We achieved cost reductions when developing this drone by fulfilling the requirement for an integrated aircraft system as shown in **Fig. 9**, instead of needing electromagnetic compatibility testing for individual devices. In addition, we applied ready-made products such as Commercial Off-The-Shelf (COTS) products, mainly for electronic components such as the computation circuit, communication equipment, and GPS/INS navigation

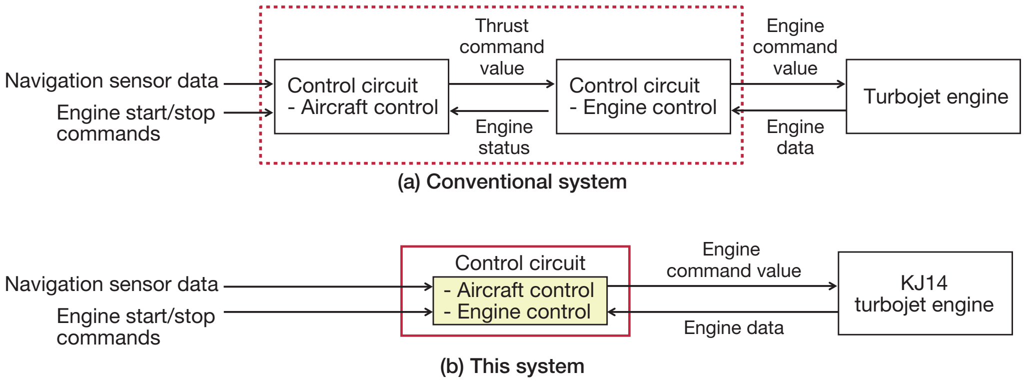


Fig. 7 Flight Control system incorporated with engine control system

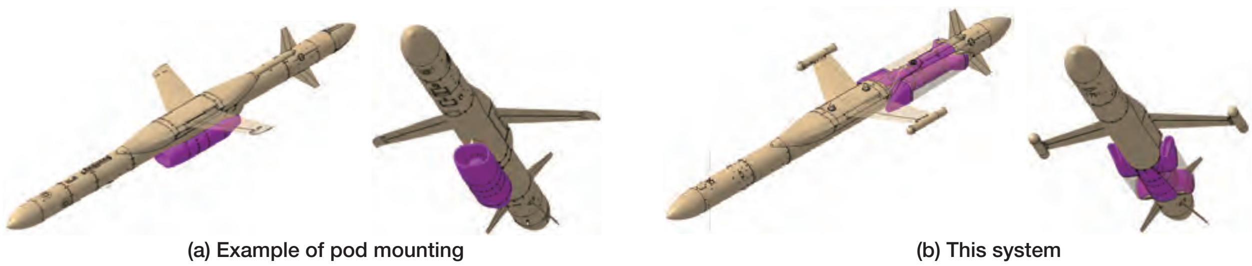


Fig. 8 Overview of engine installation

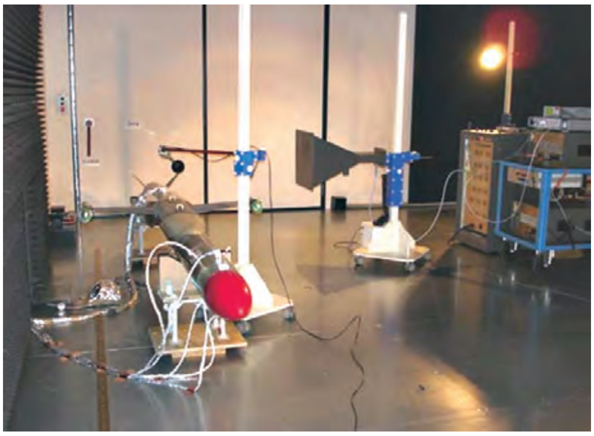


Fig. 9 Electromagnetic compatibility testing of whole aircraft

sensor. However, we have been able to keep costs low by modularizing the components and guaranteeing environmental durability for factors such as temperature, humidity and vibration required for military products instead of dealing with each part individually.

Conclusion

In developing this air-launched small aerial target, we have significantly reduced costs compared with conventional aerial targets. The small and smart target drones, including the ground-launched aerial targets for the JGSDF, are rated highly in terms of price and performance by the customer, the Ministry of Defense. This is due to the synergy effect in our company, which develops both the aircraft body and engine.

Pursuing further synergy, we will continue to provide defense-related instruments and equipment that has outstanding cost performance.

Reference

1) Nagata, Satake, Maeda, Kaneda, Ichimura: "Development of KJ14 Small Jet Engine," Kawasaki Technical Review No. 161 pp. 12-15 (2006)

Eiji Ida
Defense Aircraft Project Engineering Department,
Defense and Aerospace Project Division,
Aerospace Systems Company

Tomohiro Horii
Defense Systems Engineering Department,
Defense and Aerospace Project Division,
Aerospace Systems Company

Masayuki Ochiai
Defense Systems Engineering Department,
Defense and Aerospace Project Division,
Aerospace Systems Company

Wataru Morita
Defense Systems Engineering Department,
Defense and Aerospace Project Division,
Aerospace Systems Company

Takayuki Aiura
Defense & Space Systems Department,
Marketing & Sales Division,
Aerospace Systems Company

Yasuhide Satake
Aero Engine Department,
Marketing & Sales Division,
Aerospace Systems Company

Shutaro Ichimura
Defense Engine Engineering Department,
Defense Engine Project Division,
Aerospace Systems Company

Hideki Shimpo
Defense Engine Engineering Department,
Defense Engine Project Division,
Aerospace Systems Company