TILT ROTOR DEVELOPMENT STATUS IN KOREA AS SMART UAV PLATFORM

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OVERVIEW

The conceptual, preliminary and detailed design of the Smart Unmanned Aircraft System(UAS) were performed till the early of 2006 and its parts and subsystems are being purchased or manufactured nowadays. After a tiltrotor-typed vehicle was selected as the Smart Unmanned Air Vehicle(UAV) platform among several candidates, the design of the platform was begun in the early of 2003. A turbo-shaft engine was selected to drive two side-by-side rotors, and the rotor system was designed to utilize a constant-velocity joint gimbaled hub. Lots of wind tunnel tests were performed in 2005, and several 40%-scaled vehicles were fabricated and being tested in Korea Aerospace Research Institute (KARI) Flight Test Center. A small flight control computer was installed on the 40%-scaled vehicle and autonomous flight test are under way to verify full scale flight control program. The flight control computer, data link system and ground control system were developed and are under testing. The iron-bird which is composed of rotor-drive-engine systems has been developed and are utilized in the subsystem ground test, and the full-scale UAS flight test is scheduled in 2009. Total 24 domestic and international organizations and 90 full time research engineers have been involved in the Smart UAS development program, in which the head quarter is located in KARI. The overview and recent status of the Smart UAV Program was included in this presentation.

Terminology

SUDC : Smart UAV Development Center

MOST : Ministry of Science and Technology

MOCIE : Ministry of Commerce, Industry, and Energy

1. 21C FRONTIER PROGRAM SUPPORTED BY KOREAN GOVERNMENT

Smart Unmanned Aerial Vehicle program is one of the 21st Century Frontier R&D Program initiated and sponsored by Korean MOST (Ministry of Science and Technology). From 2005 MOCIE took over the sponsorship for this program. The goal of the SUAV program is to develop Smart UAV with innovative smart technologies which include the development and the demonstration of a small, robust and advanced uninhabited air vehicle exhibiting high speed cruise and vertical take-off and landing capabilities. The program also includes developing smart technologies such as fully autonomous flight, collision awareness and avoidance, health monitoring and self-restoration, intelligent mission control, and real-time robust data link. These smart technologies will be applied to the Smart UAV. Potential missions for the Smart UAV include surveillance and intelligence, using infrared/optical sensor or radar. The SUAV program began in July 2002 and is scheduled to finish in 2012. Major features of the Smart UAV can be shown in FIG 1, and FIG 2 shows the time schedule of the program. A major objective of the first stage as shown in Fig.2 is to design a small and robust unmanned air vehicle capable of high speed and vertical take-off and landing.

The philosophy is to design an unmanned aerial vehicle that has remarkable performances while maintaining effectiveness as well as reliable system features to fit into the market needs for high speed VTOL in near future. One of the primary applications for the Smart UAV is to be the patrol and maritime security in National Maritime Police. Fig.3 shows example of mission radiuses with center positions at several Maritime Police Stations in Korea.

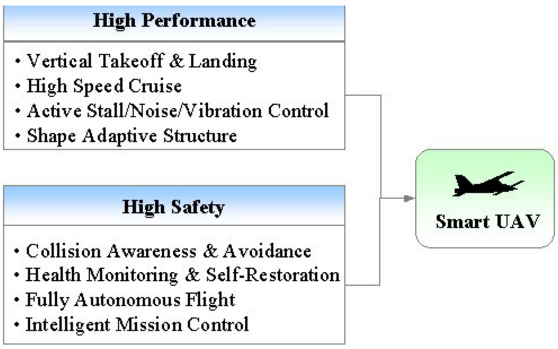

FIG 1. Technical Features of Smart UAV Program

FIG 2. 3 Development Stages of Smart UAV Program

FIG 3. Mission Radius of Smart UAV

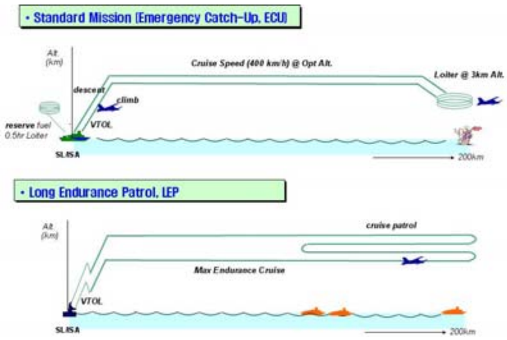

FIG 4. Baseline Mission Profile of Smart UAV

Major features of the Smart UAV can be shown in Fig.1, and Fig.2 shows the time schedule of the program. A major objective of the first stage as shown in Fig.2 is to design a small and robust unmanned air vehicle capable of high speed and vertical take-off and landing. The philosophy is to design an unmanned aerial vehicle that has remarkable performances while maintaining effectiveness as well as reliable system features to fit into the market needs for high speed VTOL in near future. One of the primary applications for the Smart UAV is to be the patrol and maritime security in National Maritime Police. Fig.3 shows example of mission radiuses with centering several Maritime Police Stations in Korea. Baseline mission profile as shown in Fig.4 shows the mission radius of 200km without data-link relay and the time on station of 3 hours. The requirement of maximum cruise speed is 500km/hr.

2. WHY TILTROTOR CONCEPT

2.1. Initial Stage Concept Screening

Rotorcrafts which utilize rotating blade to produce thrust and control power have inherent limitation in high speed capability due to compressible drag in advancing blade tip and retreating blade stall. Due to this problem, maximum velocity of helicopter even in case of experimental aircraft could not exceed 160 ~ 170 kts. Practically 120kts is the maximum velocity for conventional helicopters up to now. Economic velocity gets even down to 80 ~ 100kts. With equivalent Turbo-prop engine, the economic operating speed of helicopter falls in between Mach 0.12 ~ 0.15 while fixed wing aircrafts fly in between Mach 0.45 ~ 0.6.

Although rotorcraft has advantage in VTOL/hovering capability, max speed limitation put the bar in its application especially when mission range or response time becomes an issue. A number of experimental air-vehicles have been explored for many decades to find a practical VTOL solution to overcome the operational limitation of conventional helicopters in terms of speed, endurance, and other features such as altitude and noise. Out of these investigations into a new concept of VTOL aircraft, only a few ideas have become successful in drawing continuing attentions of aircraft industry. Figure 5 shows the concepts explored for the past decades to develop new viable VTOL aircraft concept and most of them headed to achieve high speed.

To simplify the concepts explored and presented in the name of “VTOL wheel” (refer to center of Fig.5) SUDC re-categorized those concept into 12 categories. Out of these categories, SUDC focused on the concepts which succeeded in getting continued attention from aerospace research institute or industries. Fig.6 shows the result of first concept screening and opportunity survey.

FIG 5. VTOL Wheel

FIG 6. Advanced VTOL Concepts (First Stage Concept Screening)

2.2. Concept Selection

2.2.1. Second Stage Concept Screening

Out of 8 candidates, 3 concepts (concept number 5,6,7 in Fig.6) had been discarded due to speed limitation. SUDC performed technical feasibility study and performance comparison on remaining 5 concepts which led to the conclusion of deleting two concepts - tilt wing and tail sitter – from the list of candidates due to technical risk of conversion flight and operational problem.

While doing these technical feasibility study and concept evaluations, SUDC also performed requirement refinement and rearranged the design goals : VTOL, High Speed(500Km/h), Endurance(5hr), GW(1000Kg), Size(5m), Max Cruise Altitude (> 5km) which was accepted as most challenging yet promising targets in the advanced VTOL development competition. (Refer to Fig.7 and Fig.8)

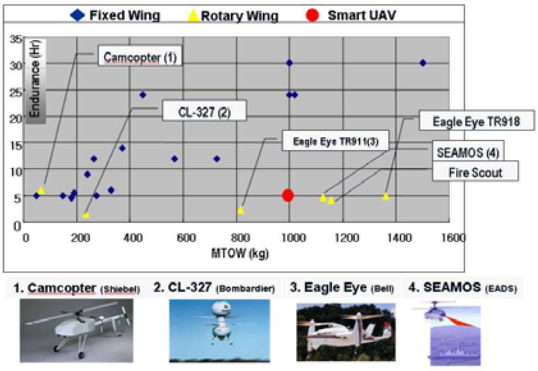

FIG 7. Endurance VS MTOW trend

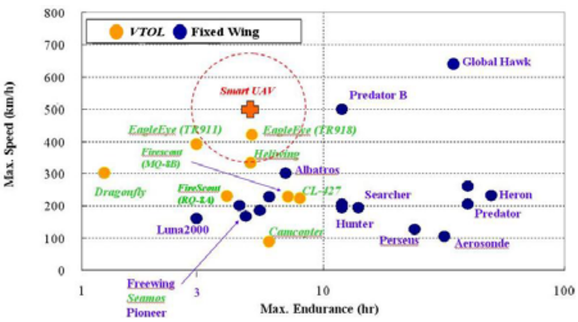

FIG 8. Max Speed VS Max Endurance trend

2.2.2. Conceptual Design Evaluation

Only three concepts - Stopped rotorcraft, Tilt rotorcraft, Advanced Gyroplane - remained for continued evaluation and study through second level concept screening process. Extensive and international cooperation have been done to come up with successful and viable concept definition for the program from second stage concept screening process. Intelligence and experiences from Bell Helicopters(US), Georgia Institute Technology(US), Elbit(Israel), and some experts of KARI have been introduced to make right comparison and risk identification associated with each concept. Initially, as shown in Fig.9, stopped rotor concept which is also called as Canard Rotor Wing drew more attention, but the tilt-rotor concept was selected through this concept screening process.

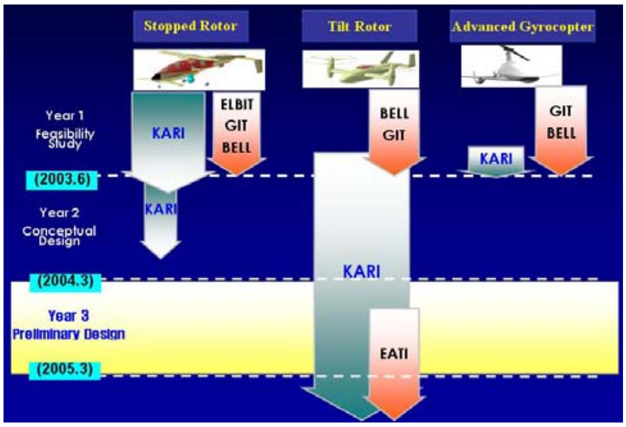

FIG 9. Internationl Efforts for the Evaluation of Candidates

3. TILTROTOR PLATFORM DEVELOPMENT

SUDC completed detail design of tiltrotor platform and preparing for flight test. SUDC also initiated, as part of risk reduction program, 40% scaled version to validate flight control OFP (operational flight program). Current manufacturing and subsystem level test status of Smart UAV will be described in chapter 4 and 40% scaled version development status will be described in chapter 5.

3.1. From Conceptual Design to Detail Design

Fig.10 shows the brief summary of the process that how Smart UAV final configuration design definition has been reached. To realized innovative aircraft concept with practical performance capability, not only high level technical achievement but also systematically coupled engineering process have been incorporated and pursued.

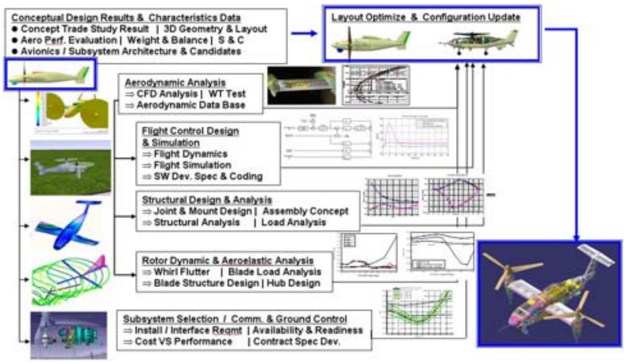

FIG 10. Platform Configuration Definition Process

3.2. Key Technologies Required and Developed

To realize tiltrotor platform based UAV, lots of high level design technology required. The items listed below are the key technologies that have been developed and implemented in Smart UAV program.

- Tiltrotor Sizing and CATIA based 3D Digital Mock-up Integration technology to realize compact size and layout for light weight.

- Rotor aero-elastic analysis & Load analysis considering dual RPM operation mode to achieve stable rotor system in high speed and conversion mode. (See FIG. 11)
- Aerodynamic analysis & Design for optimum blade and wing design for both rotor mode and propeller mode. (See FIG. 12)
- Dual RPM engine control by DFCC to enhance aerodynamic performance in terms of high speed and endurance.
- Stable rotor hub & Rotor control system design which is key to realize tilt rotor vehicle.
- Nacelle conversion system & Automatic conversion flight
- High performance & Low weight drive system development
- Automatic flight control and mode conversion logic / system development for full automatic operation from lift-off to landing
- Differential left & right rotor pitch control with optimum control mixing for rotor mode and propeller mode.
- Dual-system architecture implementation & H/W development for reliable flight control system design
- Reliable and long range data link system development

All of these technologies have been successfully developed during past few years and will be tested and validated through current on-going component/system level ground tests to be ready for first flight.

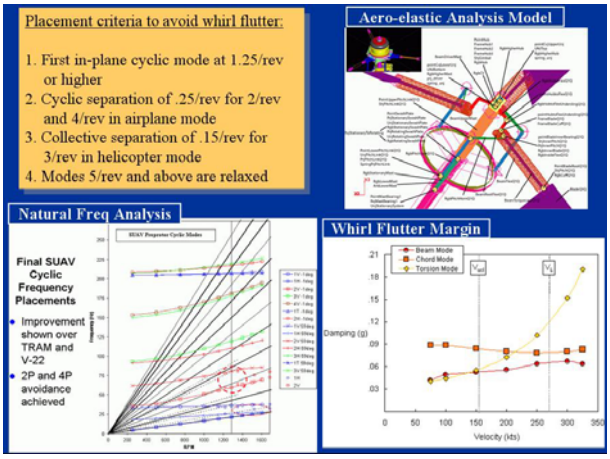

FIG 11. Rotor Dynamics Design Analysis to avoid Whirl Flutter at High Speed

Fig.11 shows the technical achievement example in the case of rotor aero-elastic analysis technology which had been implemented to optimize the stiffness of rotor design, hub design, and wing design for whirl flutter elimination in mission range. Smart UAV rotor system, control system, and supporting structure have been evaluated to have sufficient whirl flutter margin even at the speed of 300 kts as is shown in Fig.11

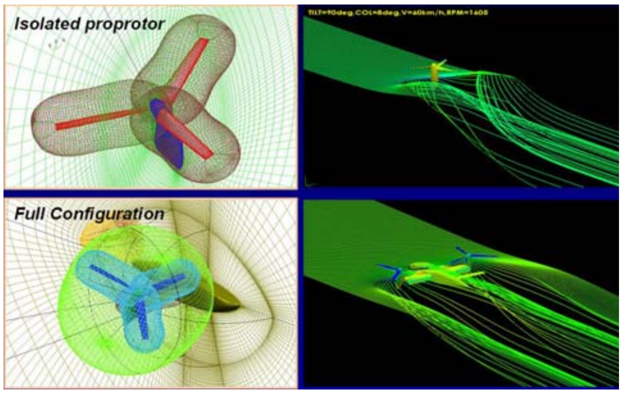

FIG 12. CFD Application with Power Effect

(Following subjects will be included in the complete paper, it is prepared already and will be submitted right after this acceptance of this abstract)

4. SYSTEM LEVEL DEVELOPMENT STATUS & ACHIEVEMENTS

5. 40% SMART UAV DEVELOPMENT AND TEST STATUS