Vertical take-off and landing (V/STOL) aircraft important against A2/AD environment and future Urban Warfare

Uber recently unveiled plans to launch flying taxis by 2020. To remove the need for runways, these cars will rely on vertical take-off and landing technology, known as VTOL. Meanwhile, Munich-based aviation startup Lilium aims to offer an on-demand flying taxi service that it claims will be five times faster than travelling in a car. And, at the 2017 Geneva Motor Show, Airbus showcased a prototype flying hybrid car. The modular vehicle can disconnect from it wheels, after which it is picked up by a flying set of rotors. What's more, NASA has developed the battery-powered GL-10, which take off and land vertically but flies efficiently like a conventional plane. The current prototype is a two-seater aircraft shaped like a conventional plane that uses a VTOL system. VTOL technology is increasingly making its way into more aircraft, from small recreational drones up to the traditional systems in helicopters and military jets.

VTOL technology means aircraft can theoretically take off and land almost anywhere, making them far more flexible. They're also able to perform various manoeuvres not possible with a conventional plane; a significant advantage for aircraft in combat situations. What's more, VTOL aircraft, such as drones, that use electric motors are more energy efficient than those using jet engines.

The F-35B Standard Take-off and Vertical Landing (STOVL) is a

single-engine, fifth generation fighter aircraft designed and developed by Lockheed Martin. It is the first aircraft to combine stealth technology with STOVL capabilities and supersonic speeds. The tricycle type retractable undercarriage design allows the aircraft to take-off from and land on the deck of small naval ships, unimproved airstrips, rough airfields and roads. “With the fielding of the F-35B, the Navy almost doubles its theoretical “first day of war,” fixed wing capable, carrier force. This means that more ships capable of operating high-performance, low-observable, multi-role fighters, can be in more places at a single time,” writes Tyler Rogoway.

Customer orders of the F-35B include USMC (340) and Italian Navy (22). The UK ordered two F-35Bs in 2009. The third F-35B was ordered by the UK Government in January 2010. The UK Ministry of Defence plans to procure up to 138 F-35Bs for the Royal Air Force and the Royal Navy.

VTOL Aircraft are also more suited to future Urban Warfare. Future battlefield is also increasingly urban. 80% of the world’s population will live in urban environments by the year 2030. Urban Warfare poses unique challenges because of Physical constraints like size, weight, and maneuverability, Wind tunneling effects, Line-of-sight obstructions and Public intolerance for collateral damage. While conventional Airplanes can only fly in straight lines, forward only, VTOLs have much more control to move forward, backward, and up and down, spin around, etc which may be able to better counteract turbulence and wind.

Broadly there are two different types of VTOL technology: rotorcraft and powered-lift. Rotorcrafts, or rotary wing aircraft, are those that use lift generated by rotor blades spinning around a central mast, so helicopters, quadcopters and gyrocopters. While helicopters provide most efficient hover/loiter, good low speed maneuverability and low empty

weight low max speed. They have lowest cruise efficiency (range), limited high speed maneuverability, rotating component RCS and highest vibration environment. Powered-lift vehicles are those that take off and land vertically but perform differently from rotorcraft when in flight.

Airbus tests VTOL vehicle propulsion system

Airbus Helicopters has concluded the first full-scale test of the propulsion system for its CityAirbus vertical take-off and landing (VTOL) vehicle demonstrator.The test was conducted using a full-scale CityAirbus demonstrator, which is a self-piloted, multi-passenger electric VTOL vehicle designed for use in urban air mobility applications in crowded megacities.

CityAirbus will be able to carry up to four passengers on pre-planned routes with a cruising speed of 120km/h once fully operational. The vehicle’s four-ducted propeller configuration is designed to offer safer operations and a low acoustic footprint.

Airbus examined the individual performance of the ducted propellers throughout the trial procedure. Tests were also carried out to check the integration of the full-scale propulsion unit with two propellers, as well as the 100kW, Siemens-built electric motors and all of the demonstrator’s electrical systems.

Airbus Helicopters CityAirbus chief engineer Marius Bebesel said: “We now have a better understanding of the performance of CityAirbus’ innovative electric propulsion system, which we will continue to mature through rigorous testing, while

beginning the assembly of the full-scale CityAirbus flight demonstrator.”

CityAirbus’ demonstrator will initially be piloted remotely, though a test pilot is also planned to be deployed on-board to ease the certification process and encourage public acceptance at a later date. The proposed tests are expected to enable the CityAirbus VTOL vehicle to conduct fully autonomous operations in future.

Military advantages

VTOL aircrafts shall also be necessary against adversary like China which is developing large number of fighter aircraft, surface-to-surface ballistic missiles, land-attack cruise missiles and bomber aircrafts that could pulverize Taiwan’s air bases within hours of a war, according to RAND report. None of Taiwan’s fighter aircraft would survive or be deployable on runways turned into a lunar landscape. The Ministry of National Defense said on 16th March 2017 in “Taiwan’s Quadrennial Defense Review” (QDR) that the country plans to acquire stealth fighters and vertical/short takeoff and landing (V/STOL) aircraft to strengthen its defense forces, particularly as China has announced it will increase its military budget 7 percent to a reported US$147 billion this year.

China itself has successfully tested its vertical takeoff and landing fighter during field test as reported by Japan in 2016.

This technology has advantage that you can always operational, can be in place a small landing can be in building or any other ground easily camouflage. On the battlefield survival

rate is the highest. Followed by the aircraft carrier can be equipped with a large number of landing and landing aircraft, for sea warfare is a great advantage. The last point is eliminating the preparation time on the runway, operational response time greatly improved.

They also have disadvantage some deficiencies: first is the fuel consumption is too large, take-off requires a third of the amount of oil consumed, so on the voyage is greatly reduced. Second is the bomb load small. Take for instance the British harriers, the warplanes of the bomb load only 2271 kg is one-third of the conventional aircraft, but also unable to truly vertical take-off and landing, it is better to develop conventional aircraft. The last point is that the operation is too difficult, the requirements of the pilot is very high, bad training, the accident rate is very high, very much time and money

The F-35B STOVL is powered by a single Pratt & Whitney F135 afterburner turbofan engine rated at 125kN of dry thrust. The engine can produce 191.3kN of thrust afterburner. The aircraft is fitted with a refuelling probe on the right side of the front fuselage to carry out mid-air refuelling during combat missions. The weapon loads and cockpit layout of the F-35B are similar to those of the F-35 Joint Strike Fighter (JSF).

F-35B Lightning II Joint Strike Fighter STOVL Variant, United States of America

The F-35B Standard Take-off and Vertical Landing (STOVL) is a single-engine, fifth generation fighter aircraft designed and developed by Lockheed Martin. It is the first aircraft to combine stealth technology with STOVL capabilities and

supersonic speeds.

The F-35B will supersede the F/A-18 Hornet and AV-8B Harrier II fighter aircraft currently in service with the United States Marine Corps (USMC). It will also replace GR7, GR9 and Sea Harrier aircraft deployed in the fleet of the Royal Navy and Royal Air Force.

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The F-35B STOVL is powered by a single Pratt & Whitney F135 afterburner turbofan engine rated at 125kN of dry thrust. The engine can produce 191.3kN of thrust afterburner. It is the successor of F119-PW-100 turbofan engine. It is equipped with full authority digital engine control, a gearbox, and health and usage monitoring system.

A shaft-driven LiftFan propulsion system built by Rolls-Royce is incorporated at the aft of F-35B’s cockpit to accomplish the STOVL capabilities. Doors fitted above and below the vertical fan open as the fin spins up for vertical lift of the aircraft. The counter-rotating LiftFan produces more than 20,000lb of thrust with the help of the gas turbine.

Three-bearing swivelling exhaust nozzle is appended by two roll control ducts on the inboard section of the wing. The engine combined with the vertical LiftFan renders the requisite STOVL capability.

The length and diameter of the engine are 5.5m and 1.3m respectively. The inlet diameter is 1.1m.

Performance

The F-35B can fly at a maximum speed of 1,960km/h. The combat radius and maximum range of the aircraft are 833km and 1,667km respectively.

Armaments

The F-35B is fitted with a 25mm GAU-22A Gatling cannon which has 220 rounds per gun of firing capacity. It has two internal weapon pods and four external underwing hardpoints to expand its mission lethality.

The aircraft can carry 6,803kg of weaponry payload. It is equipped with AIM-120C AMRAAM medium range air to air missiles, air to surface missiles, two GBU-32 JDAM guided bombs, six GBU-38 bombs and munitions dispensers.

Countermeasures and Radars

The F-35B is equipped with AN/APG-81 Active Electronically Scanned Array (AESA) multi-functional radar built by Northrop Grumman. It also houses AN/AAQ-37 Distributed Aperture System (DAS), Barracuda AN/ASQ-239 electronic warfare system, Multifunction Advanced Data Link (MADL) communication system and missile warning system.

Vertical and/or short take-off and landing (V/STOL) aircraft technology

A vertical and/or short take-off and landing (V/STOL) aircraft is an airplane able to take-off or land vertically or on short runways. Vertical takeoff and landing (VTOL) aircraft are a subset of V/STOL craft that do not require runways at all. Generally, a V/STOL aircraft needs to be able to hover.

A rolling takeoff, sometimes with a ramp (ski-jump), reduces the amount of thrust required to lift an aircraft from the ground (compared with vertical takeoff), and hence increases the payload and range that can be achieved for a given thrust. This is especially useful for a military plane loaded up with heavy weapons.

For instance, the Harrier is incapable of taking off vertically with full weapons and fuel load. Hence V/STOL aircraft generally use a runway if it is available. I.e. short takeoff and vertical landing (STOVL) or conventional takeoff and landing (CTOL) operation is preferred to VTOL operation.

Most powered-lift planes in use today, including the Harrier, V-22 Osprey and the new F-35B, are considered to be V/STOL (vertical and/or short take-off and landing) vehicles. They tend to make a rolling takeoff from a runway when possible as this requires less thrust.

It requires powered lift, means a heavier-than-air aircraft capable of vertical takeoff, vertical landing, and low speed flight that depends principally on

1. **Engine-driven lift devices or engine thrust for lift during these flight regimes.**

Engine driven/ engine thrust for lift is most successful in VTOL era. Harrier Jump jet aircraft is successfully flying till now. It uses Rolls-Royce Pegasus engine, the engine is not only able to power a jet aircraft forward, but also to direct thrust downwards via swiveling nozzles.

2. **On non rotating airfoil(s) for lift during horizontal flight:**

Convertible plane is used to takes off under rotor lift like a helicopter, then transitions to fixed-wing lift in forward flight.

Tilt rotor: A tilt rotor or prop rotor tilts its propellers or rotors vertically for VTOL and then tilts them forwards for horizontal wing-borne flight, while the main wing remains fixed in place.

Tilt wing: A tilt wing has its propellers or rotors fixed to a conventional wing and tilts the whole assembly to transition between vertical and horizontal flight.

Tail-sitter: A tail-sitter sits vertically on its tail for takeoff and landing, then tilts the whole aircraft forward for horizontal flight. it was not most successful aircraft.

Fan-in-wing: In the fan-in-wing configuration, a ducted fan is enclosed within the main wing shape. The craft takes off and land using fan lift, then transitions to wing-borne lift in forward flight. The fans may or may not have covers which close over them in forward flight.

Some of the Challenges in VTOL are that It takes enormous power to lift/hover, High Maintenance and fuel consumption, Payload will be less and Complex functioning – Mechanization required to change direction of thrust with respect to aircraft.

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