Centre for Air Power Studies

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GROUND EFFECT VEHICLE – LARGE AMPHIBIAN AIRCRAFT

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The Pentagon's premier research agency, the Defence Advanced Research Projects Agency (DARPA), has announced that it will demonstrate a C-17 size liberty lifter amphibian aeroplane (Figure 1).[1] They have released a concept design and are seeking bidders. Earlier, DARPA's Tactical Technology Office (TTO) had begun inquiring if it was possible to design an ocean-crossing cargo vessel that could operate at around 100 knots cruise speed while carrying an 80-ton load. They hope to demonstrate such an airlifter by 2028. Interestingly, the proposal is to have an aircraft that would be a combination of a Wing in Ground Effect (WIGE) and a flying boat. It would thus take off and land on water. The aircraft would fly low over the water surface using ground effect and yet have the ability to climb to altitudes of around 10,000 feet.[2]

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Nature's Inspiration

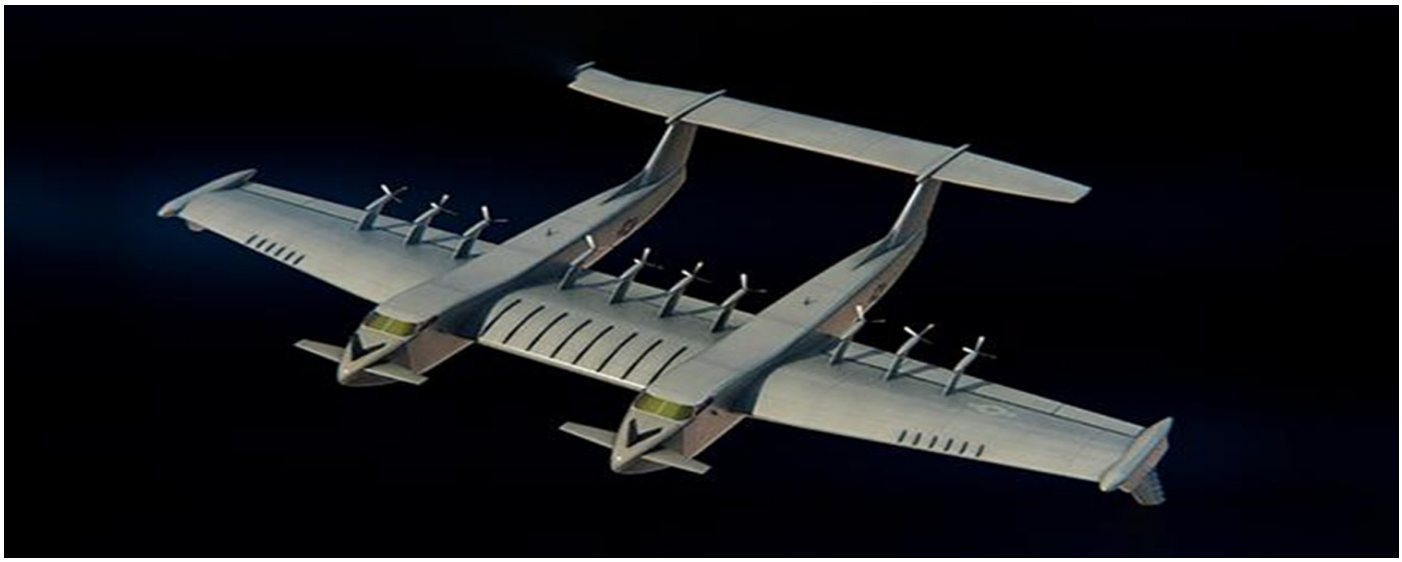
Pelicans, albatrosses, and some other seabirds fly low over the sea and ocean surface and cover thousands of kilometres with minimal flapping of their wings.[3] They thus conserve energy and use the low flight to take benefit of the air cushion that is referred to as the ground effect. This cushion helps generate greater lift. Flying close to the water, with wing downwash angles and tip vortices suppressed, results in nearly 70 per cent less drag than normal and outstanding cruise efficiency.

What is WIGE?

The International Maritime Organization recognizes Ground Effect Vehicles (GEV) in three categories: those that remain in ground-effect; those that go beyond the influence of ground effect but not higher than 150m above the surface; and those that can go to even higher heights.

Wing-in-ground-effect (WIGE) is a vehicle that can move over the surface by taking support of the air cushion that gets created between the aircraft and the surface of the earth or water, which is also called the 'ground effect'. The aerodynamics of ground-effect were well known by the 1920s. The air cushion caused when the aircraft flew near the ground increased the lift and reduced the power required for level flights. It is an aerodynamic interaction that can best be harnessed over large water bodies like marshes, lakes, and seas because the surface is flat and free of obstructions. The wingspan of these aircraft is significantly shorter, and they require a high aft-placed horizontal tail to maintain stability. Only the main wing is in ground effect, but even the tail generates some lift in addition to stabilising. There have been differences of opinion on whether to classify them as aircraft or boats. The International Maritime Organization recognizes Ground Effect Vehicles (GEV) in three categories: those that remain in ground-effect; those that go beyond the influence of ground effect but not higher than 150m above the surface; and those that can go to even higher heights.

Figure 1. Conceptual Design: Liberty Lifter Demonstrator



Source: Steve Trimble, "DARPA To Demonstrate Flying, C-17-Size Liberty Lifter Amphibian", *Aviation Week*, June 01, 2022, https://aviationweek.com/defense-space/multi-mission-airaircraft/darpa-demonstrate-flying-c-17-size-liberty-lifter-amphibian. Accessed on July 08, 2022.

WIGE Aircraft

The concept of WIGE aircraft had matured by the 1960s. The Soviet Union, a leader in the domain, made a 550-tonne, 92m long military "ekranoplan" that was named "Caspian Sea Monster" by the U.S. intelligence. It flew at 20m above the surface and

reportedly achieved a top speed of around 400 knots in developmental flights. The Soviets also produced the more successful, 125-ton, A-90 Orlyonok ekranoplan (Figure 2).[4] From 1979 to 1992, the Soviet Navy operated around 30 of these in the Black Sea and Baltic Sea regions. The very huge 400-ton Lun-class ekranoplan was built in 1987 and was meant to be used as an aircraft for carrying a large complement of anti-shipping missiles. However, it was never operationally used. A smaller, eight-seater Volga-2 has been built since 1985. There was also a proposal for a larger aircraft, the Beriev Be-2500, for cargo, but it did not materialise.

The aircraft would be a combination of a cargo transport aircraft and an amphibious assault ship. DARPA envisages that it will be able to operate at Sea State 5 with waves as high as 18 feet. In the case of heavy shipping density or when the sea is about to become very choppy, the aircraft is meant to fly away to a safer high altitude.

Germany developed the X-112, a reversed delta wing with a T-tail. These could be flown out of the ground effect as well. The prototype aircraft was later bought by Singapore-based Wigetworks. More designs evolved later. The USA, Australia, China, Japan, Korea, and Taiwan have also been working on WIGE aircraft. Iran also developed the two-seat Bavar Ground-Effect Vehicle (GEV). More recently, there have been plans to use GEVs for English Channel crossing services, or operations along Florida's east coast. The DARPA "Liberty Lifter" project would be able to carry 100 tonnes of load over 7,500 km, flying well above the sea waves.

Figure 2. A-90 Orlyonok Ekranoplan

Source: Alex Carchidi, "The A-90 Orlyonok Ekranoplan: A Soviet Sea-Skimming Plane, Disciples of Flight", *Disciples of Flight*, https://disciplesofflight.com/a-90-orlyonok-ekranoplan/. Accessed on July 09, 2022.

A good WIG aircraft concept design, 'Pelican,' was evolved by Boeing Phantom Work in 2002 (Figure 3).[5] It was to be larger than the Boeing 747 and was supposed to transport U.S. Marines and their armoured Amphibious Combat Vehicles (ACV). Having a floodable cargo well deck was being considered.

Figure 3. Boeing Phantom Works' Pelican WIG Super Transport plane

Source: "Boeing Pelican Air Force Extra Large Cargo Airplane Concept", *Sia Magazin*, April 25, 2022, https://siamagazin.com/boeing-pelican-air-force-extra-large-cargo-airplane-concept/ Accessed on July 09 2022.

DARPA's Proposal

DARPA's Wing-in-Ground (WIG) cargo aircraft's Request for Information (RFI), was released on August 18, 2021.[6] DARPA has proposed a twin-fuselage combination with canard controls ahead of a long-wing and powered by 10 turbo-shaft engines on the trailing edge. However, vendors could propose alternative designs. DARPA wants the price tag to be pegged at around half that of the C-17, which costs roughly $340 million each. The DARPA specification was that the aircraft should be able to carry two 35-ton weighing Marine Corps Amphibious Combat Vehicles. Alternatively, it should carry six 20-foot standard containers. The aircraft should be able to manoeuvre into a harbour and be able to operate within 100m distance from the beach.[7] The aircraft will need an active computer-managed flight-control system that will use fly-by-wire signalling. It will also need advanced wave-monitoring sensors. The aircraft will be able to automatically choose its flight profile based on wave heights. DARPA, in theory, seeks a WIG plane fuselage longer than that of the C-17. Such a huge aircraft, if and when inducted, will require large parking hangars and other related infrastructure.

Operational Employment

Operationally, it would be a combination of a cargo transport aircraft and an amphibious assault ship. DARPA envisages that the aircraft will be able to operate at Sea State 5 with waves as high as 18 feet. In the case of heavy shipping density or when the sea is about to become very choppy, the aircraft is meant to fly away to a safer high altitude.[8] When the aircraft flies literally at the sea-skimming anti-ship cruise missile's altitude, its low height

helps avoid adversary radar detection and also keeps it safer from air-defence missile threats. It would cross the Pacific Ocean in about a day, compared to nearly two weeks for a sea-freighter. With the geo-strategic action shifting to the Indo-Pacific, such a plane would have great operational significance. The aircraft will also be able to fly over land at an altidue of 10,000 feet.

With large island territories, greater action unfolding in the Indian Ocean region, and the Indian armed forces having a significant amphibious force capability, such a lifter could fit the force structure requirement in the long term.

The aircraft will not require large runways and other infrastructure that goes to support them. It will score over the Vertical Take-off and Landing (VTOL) in terms of both range and payload capacities. It will also have the advantage of increased range, endurance, and survivability. Salt-corrosion-resistant and lighter materials would allow greater design options. The aircraft also does not need cabin pressurisation. The next logical step would be to have an unmanned aircraft. All of this reduces manufacturing costs. They do have manoeuvring limits in a congested environment, and sometimes they may have issues with obstacle clearance. They could also be affected by severe weather conditions.

The aircraft could be armed[9] with rockets and precision ground munitions, as is the case with the U.S. KC-130J 'Harvest Hawk'. It could be modified into a gunship like the AC-130 with a high-calibre automatic cannon and a laser-firing turret. The potential missions[10] could be amphibious operations, Expeditionary Advanced Base Operations (EABO), logistics missions in a threat environment, and Combat Search and Rescue (CSAR), including mass casualty rescue and long-duration patrols over large lakes, major seas, or even the Arctic region.

Employability in India

The USA has yet to decide on the end-user service, and the same could be between the U.S. Air Force, U.S. Navy, U.S.M.C., U.S. Special Forces, and U.S. Coast Guard. Finally, the operator could be the Air Force's aircraft-focused Air Mobility Command, the Navy's ship-oriented Military Sealift Command, or both. For some years, India has been considering the purchase of 12 Japanese ShinMaywa US-2i Amphibious and Rescue (SAR) aircraft. The subject resurfaced during Defence Expo 2020.[11] But it has remained on the back-burner due to lower priority for funding. With large island territories, greater action unfolding in the Indian Ocean region, and the Indian armed forces having a significant amphibious force capability, such a lifter could fit the force structure requirement in the long term. The new amphibian force lifters will take nearly a decade to evolve. This would give India an opportunity to assess operational employability without facing the developmental cost risks.

Notes:

[1] Steve Trimble, "DARPA To Demonstrate Flying, C-17-Size Liberty Lifter Amphibian", *Aviation Week*, June 01, 2022, https://aviationweek.com/defense-space/multi-mission-airaircraft/darpa-demonstrate-flying-c-17-size-liberty-lifter-amphibian. Accessed on July 08, 2022.

[2] Ibid.

[3] Austin Weber, "Nature Inspires Wing-in-Ground-Effect aircraft", *Assembly*, November 12, 2021, https://www.assemblymag.com/articles/96716-nature-inspires-wing-in-ground-effect-airaircraft. Accessed on July 08, 2022.

[4] Alex Carchidi, "The A-90 Orlyonok Ekranoplan: A Soviet Sea-Skimming Plane, Disciples of Flight", *Disciples of Flight*, https://disciplesofflight.com/a-90-orlyonok-ekranoplan/. Accessed on July 09, 2022.

[5] "Boeing Pelican Air Force Extra Large Cargo Airplane Concept", *Sia Magazin*, April 25, 2022, https://siamagazin.com/boeing-pelican-air-force-extra-large-cargo-airplane-concept/. Accessed on July 09, 2022.

[6] Peter Ong, "DARPA Requests Information For Wing-In-Ground Effect Aircraft For The U.S. Military", *Naval News,* August 24, 2021, https://www.navalnews.com/naval-news/2021/08/darpa-requests-information-for-wing-in-ground-effect-airaircraft-for-the-u-s-military/. Accessed on July 09, 2022.

[7] Justin Katz, "DARPA's revolutionary seaplane wants to change how the Pentagon hauls cargo", *Breaking Defense,* May 27, 2022, https://breakingdefense.com/2022/05/darpas-revolutionary-seaplane-wants-to-change-how-the-pentagon-hauls-cargo/. Accessed on July 09, 2022.

[8] Ibid.

[9] n. 6.

[10] Ibid.

[11] Huma Siddiqui, "DefExpo 2020: Japanese amphibious plane back on track for the Indian Navy?", *Financial Express*, February 5, 2020, https://www.financialexpress.com/defence/defexpo-2020-japanese-amphibious-plane-back-on-track-for-the-indian-navy/1857302/. Accessed on July 09, 2020.

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