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ConcordLift, Very Heavy Lift

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This is a "Thought Experiment" of a span loader for transportation of standard shipping containers. The design goal is the lowest cost per ton / mile. It has been long known the most efficient design is to carry the load along the wingspan. The standard mode of cargo transportation is the use of intermodal shipping containers. An obvious idea would be to carry them from wingtip to wingtip. Low wing loading allows for low flight speed, low power, low fuel per pound per mile, low altitude, non pressurized, low construction cost. This requires research and development before actual aircraft can be designed. This is a novel configuration of multiple wings and two stage landing gear. It is a tandem wing joined to an airfoil cargo carrier.

I. Controlling dimensions and assumptions

Ocean ship container are measured in Twenty-foot Equivalent Units (TEU) 20 ft. × 8 ft. usually 8.5 ft. high. The dimension for a one TEU wing is a 20 ft. wingspan. Thickness at 10% of chord, results in a chord of 100 ft. for 2,000 sq. ft. The average load, 30,000 lb., results in a wing load 15 lb. / sq. ft. Scaled up to the maximum airport width, 80 meters, a 260 ft. wingspan, 13 TEU, results in 390,000 lb. load at 15 lb. / sq. ft. This value suggests there is potential for a very heavy lift aircraft with low wing load. In 2010 there were a reported 26,365,489 TEU.[2] There are over 5 million shipping containers in motion. Those containers are transported by ship to ocean ports at the lowest costs. Barges, trains and trucks carry cargo at higher costs away from the ports. An alternative is higher cost air freight. The initial target is to be a better alternative to long distance truck and train, especially into areas like Central Asia, Central Africa. It may be desirable to move some cargo now carried by ocean ship faster and direct. There is a considerable but unknown number of shippers that would pay a premium for that delivery. Moving a small percentage of the current containers would require a large number of heavy lift aircraft.

The following numbers also suggest this is worth examination. It is difficult to estimate performance numbers for something that is not designed but "ballpark" estimates can be derived. Truck, train and barge costs have a broad range and are higher than ocean ship. Container ship costs are proprietary and difficult to accurately determine. The following give an indication of the current situation. The end of 2010 index cost to transport one 40 ft Container (2TEU) across the Atlantic including port charges, fuel and all surcharges: New York – Rotterdam: East bound was $1810, and West bound $2520.[3] The sailing, loading and unloading takes over a week. The ConcordLift™ 78 TEU version, at that rate, can earn $70,590 to $98,280 per trip and be able to make 5+ trips a week. As a projection 5 ConcordLift™ can deliver 3900 TEU in the same time as one container ship. From published data, computation derives 346 lb. fuel per container in transatlantic service for a 4400 TEU ship at 23 Kt.[4] For the same route, ConcordLift™ at 100 Kt is estimated to use about 420 lb. per container. That is a rough estimate but should not be off by a factor of 10. ConcordLift™ can load and unload quickly, 78 TEU through 6 doors on each side simultaneously. One runway, one ConcordLift™ every 5 minutes, has a capacity of 936 TEU per hour, 22,264 TEU per day. The entire port of New York in 2010 handled 14,694 a day.[5]

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[1] Principal, Private venture, PO Box 28205, AIAA Associate Member.
[2] World Shipping Council http://www.worldshipping.org/about-the-industry/containers/global-container-fleet [cited 12 June 2012].
[3] Rodrigue, Jean-Paul, TheMaritime Transportation Rates for a 40 Foot Container between Selected Ports, 2010, http://people.hofstra.edu/geotrans/eng/ch7en/conc7en/map_container_shipping_rates.html [cited 12 June 2012].
[4] Container Handbook, 1.3.1.1 Container-carrying vessels, part 1, Fourth generation container ship, http://www.containerhandbuch.de/chb_e/index.html [cited 12 June 2012].
[5] http://en.wikipedia.org/wiki/List_of_world%27s_busiest_container_ports [cited 12 June 2012].

Low wing load permits low speed, low powered flight, and maximizes the load that can be moved by a quantity of fuel. The aircraft could be constructed with the technology of 1940. Nothing is necessarily complex or "high tech". It is large but cost is not commiserate with size. ConcordLift ™ is much faster than ships and can deliver cargo direct to interior locations. There are hundreds of millions of people in central Asia, Africa, Indonesia, the Philippines and elsewhere that have no access to low cost or speedy transportation. ConcordLift ™ is less costly per ton / mile than highway truck. Containers have to be moved to ports and collected until shipped. Fewer containers needed for a load increases shipper convenience and savings in transit time. ConcordLift ™ can fly in ground effect for improved efficiency and still fly into continental interiors.

A quick mental overview reveals the standard configuration is unworkable because of the great length from nose to tail surfaces when the cord is 100 ft. A way must be found to shorten that distance. In addition a cord of 100 ft. potentially creates a strong low pressure beneath the wing near the ground. A way must be found to minimize that so the aircraft can take off and land safely. A cord of 100 ft. and a span of 260 ft. has a terrible aspect ratio, very high drag. The obvious problems suggest the great potential is unreachable.

The following are not engineering designs. They are illustrations to assist understanding the concept. The central concept of ConcordLift™ is the configuration. In order to explain and illustrate, airfoils and other design features are shown. They were selected for convenience not because they are best. The illustrations and animation are by an artist, not an aeronautical engineer. The design issues are complex and quickly move into unknown areas. Considerable effort, including wind tunnel work, is needed to determine the actual potential of this configuration. The first generation aircraft should be greatly improved in later generations.

This novel configuration creates a new type of aircraft capable of very heavy payload for new uses. It is not expected to be a competitor for existing airfreight. Building one ConcordLift™ a week will hardly impact the market. A sustained build rate of 500 a year is reasonable!

II. Configuration and Benefits

ConcordLift ™ is a cargo carrier airfoil pod and auxiliary wings connected by the vertical fins. The auxiliary wings, essentially a tandem wing aircraft without fuselage, provide the lift needed for take off and enhance stability.

Before this, very large, deep chord wings could not be stable landing and taking off. The deep chord wing, moving slowly, creates a venturi between wing and ground. Local instabilities have time to develop great force. When the trailing edge is closer to the ground than the leading edge, air pressure pulls it even closer to the ground. This makes flaps and ailerons problematical. The same effect occurs when one wingtip is closer to the ground.

The cargo airfoil must have the shortest distance between wing and ground at the center of lift. The goal is to obtain maximum lift and at the same time the least negative pressure between wing and ground.

A. The Cargo Carrier, Slots and Spoilers

The very large, thick, spanloader cargo carrier airfoil cannot have flaps but can have leading edge slots and spoilers. Span is up to 260 feet. This is the same as the 80 meter box for large aircraft. At 150 ft. chord, a 260 ft. span would be able to carry 20 53' trailer bodies or 52 20' shipping containers in four rows of cargo channels from wing tip to wing tip. The airfoil may be straight or be swept back. If an inverted airfoil is used, it may have a maximum angle of attack, with a thickness 10% of the chord, of about 5.7° on the ground. There have been many specialty airfoils proposed but never used. Some may be useful in this application.

The center of the load, mid point of the channels, has to be at the center of the lift, which is usually at 1 / 4th of the cord. Container channels cannot fill the wing. Each end of the container channel has a door, so there is fast loading time. Between the container channels are trusses from wingtip to wingtip. These serve as the wing spars, for great strength with light weight. Those trusses combined with trusses joining them above and below the container channels comprise a very strong wing box. The shape of the wing is formed by a space frame also for great strength and light weight. The wing has great size and minimal weight.

The great cargo wing surface creates high drag from boundary layer air and needs to be addressed. There are various ways to minimize that. One historic concept, illustrated below, is to draw boundary layer inside the wing and exhaust it.[6] This wing is a great void with a little internal structure from the space frame. If the wing surface was perforated, the interior would become a plenum. It could be exhausted by fanjets that would add to the thrust for flight. Pulling the intake air through the perforations and plenum would reduce the intake air pressure for the fanjets. Fanjets are designed for high altitudes, low pressures. This aircraft is intended for low altitudes. The reduced intake air pressure should not be a great problem. There are a number of other suggested ways for drag reduction that have

[6] Chambers, J.R., Innovation in Flight Research of the NASA Langley Research Center on Revolutionary Advance Concepts for Aeronautics, NASA SP-2005-4539, p.133f.

not been utilized in the past. They also may be useful in this application.

B. Auxiliary Wings, Tandem Wings, adjustable incidence, high lift devices

The auxiliary wings are major structures. They are mounted on pivots so the angle of attack can be changed. Since the auxiliary wings are fixed to the fins at both ends, they must have a suspension to absorb the turbulence that cantilevered wings absorb by flexing. They provide the extra lift needed at take off and landing. Flaps and slots may extend their full width, since this concept may not need a portion of the wing dedicated for ailerons. The adjustable incidence is necessary to provide flare for landing and rotation for take off. At optimum angle of attack and with full high lift devices, a wing can produce 2 ½ times as much lift as considered normal.[7] If the auxiliary wings are 20% of the total wing area, at optimum deployment, they equal 5/13 in lift.

C. Wing Extensions, adjustable incidence high lift devices

The main cargo wing might only extend 5 TEU wide, 100 ft or less. If the deep cord cargo wing is 100 ft wide there would be room within the 80 meter wide airport limitation for 80 foot wings extending out the sides for a total 260 ft wingspan. If the center cargo section was 260 feet wide, extensions could be made to fold like those for use on an aircraft carrier. The total flying width could be 700 feet with 220 foot extensions.

The total lift of the ConcordLift™ is not determined by the deep cord cargo wing portion alone.
Wings work together in harmony - "Concord" - to accomplish what otherwise cannot be done.

D. Yaw, directional change, roll and pitch

At the front and rear of the cargo wing are vertical fins with rudders. One function is to carry tension, lift, from the auxiliary tandem wings to the cargo wing. They need no more area than needed for directional stability. Tension is the lightest, least space demanding load to transmit. At altitude, the ConcordLift ™ will turn and bank in the normal manner. Close to the ground, yaw is controlled by variation of engine power, spoilers automatically compensate for the increased lift of the outside wing, so turns can be with the wings level. The rear fins could extend to the rear edge of the main wing. An additional horizontal surface could be placed between them to serve as a tail plane to enhance passive yaw stability.

Pitch control for the cargo wing is provided by auxiliary wings. They can be used independently or together to control the angle of attack of the main wing. The auxiliary wings, higher than the main wing, are affected less by ground effect instabilities and provide good flight pitch stability.

E. Engines

Engine weight is not an issue with ConcordLift™. Since prop wash over the top of the wing increases lift, many small engines might be an advantage. Heavy engines in front of the center of lift help balance the structure behind.

On takeoff and landing, with the auxiliary wings set for maximum lift, the vector for drag will move higher. It may be necessary to mount some engines high on the fins so the thrust vector matches the drag vector. It may be effective to use cables to connect the front fins to the rear fins. At the slow airspeeds the drag from cables is minimal.

Flights may last several days, over 9000 miles. Heavy, fuel efficient engines, could make for less total weight. Many constant speed diesels with constant speed, contra-rotating, propellers might achieve the maximum efficiency.

F. Landing gear and operation for landing and take off

The force of the venturi beneath the cargo wing could be minimized with very long gear legs. The following may be a better solution. In addition to the normal main gear, have a set of "stabilizing gear". The closer the cargo wing is to the ground the greater is the danger of instability. The following is a "guess" at what might be sufficient. The "guess" is 10 ft. is too short for safe landing.

First contact with the ground is made with the cargo wing high above the runway by very large diameter wheels. The illustrations show a 30 ft. height with 10 ft. wheels. The auxiliary tandem wings rotate for flare. The stabilizing wheels carry a portion of the total load, the rest is carried by the lift, while the legs are controlled to descend to the main gear.

At take off, the auxiliary tandem wings rotate for maximum lift. The ConcordLift ™ lifts off from the main gear while the stabilizing gear, still in contact with the runway, carry a portion of the load. The extension of the stabilizing gear legs may be powered, lifting the aircraft without using lift generated by the engines, enhancing take

[7] Denker, John, 5.5.1 Effect on Stalling Speed, "See How It Flies"
http://www.av8n.com/how/htm/vdamp.html © 1996-2005 [cited 12 June 2012].

off speed increase. The aircraft finally leaves ground with the cargo wing already high above the runway.

ConcordLift™ has two separate take off speeds. The slower speed is when it has enough lift to unload the weight on the main gear. The aircraft begins to lift off while the rest of the weight is still carried on the stabilizing gear. As the distance between the ground and main wing increases, the force of the venturi in between is reduced. The second take off speed is when the aircraft has developed enough lift to carry the total weight.

The main gear is of standard design. Standard runways are 150 feet wide. For example, the 260 foot wingspan, 52 TEU, design has 4 sets of 4 stabilizing wheels and 10 sets of 4 main gear for a total of 56 wheels. The heavy load is distributed over the total runway surface. The multitude of landing gear creates drag, increases the air pressure under the wing and reduces the force of the venturi between the wing and ground.

This complex two stage landing gear and process may appear unnecessary. Container Ships occasionally sink, without much media comment. The crash of one ConcordLift™ will make a very big, media event. This aircraft changes altitude very slowly. It will spend a long time, near the ground. Local instabilities will have time to develop great force between wing and surface. An automated landing system is designed to make the proper counter actions. The stabilizing gear makes smooth transition to the main gear possible. At the extreme, ConcordLift™ may take two minutes and 5000 ft to accelerate to final take off and another minute to reach the runway threshhold at 50 ft altitude. At times local conditions will be less than ideal. The aircraft must always land and take off safely.

The main gear retracts into the wing in front and in back of the cargo channels. The stabilizing gear is too large to retract inside the wing. It retracts into fairings under the wing. All landing gear are attached to the wing box. The fairings could have enough internal volume to serve as floats for ocean ditching. Illustrations, documentation and animation of the take off procedure can be seen at www.concordlift.com.

G. Crew, Flight deck, automatic flight management control

Long distance flights will take several days. Space is needed for relief crew. Several ConcordLift™ flying together provide relief for each other. The flight deck needs video screens showing what is visually obstructed in many directions. The interior also needs to be monitored, since it would be possible to “stowaway” in the vast space.

In addition to the standard instrumentation this craft needs air pressure sensors located around and beneath the aircraft to measure the forces on the craft, radar to detect surface ships and aircraft, and detailed ground scan of the landing area since irregularities in the land strongly affect the aircraft.

Ground effect instabilities are self propagating and self reinforcing. They require immediate management. The base design should be able to fly and land without computerized flight control in smooth air over flat surface. In ground effect, the sensors detect variations in air pressure above and below the wing, and counteract instabilities before they affect the flight path. Development is needed for those controls to manage the multiple flight control surfaces. Automated landing and take off is also intended and is current state of the art for aircraft.

Storms move faster than ships and overtake ocean shipping. ConcordLift™ is faster than storms. Weather forecasting should prevent ConcordLift™ to ever be flown into dangerous weather. The craft should still carry weather radar so it could fly around local conditions.

H. Join for a better Aspect Ratio and for lower cost per ton / mile

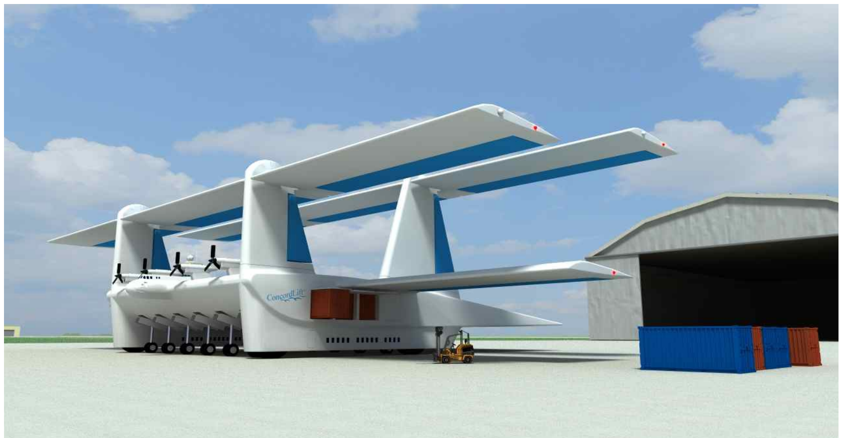
The actual aspect ratio may be difficult to compute because of the complex interaction of cargo airfoil, deep and short cord sections, auxiliary wings and wing extensions. Even so the AR of a single ConcordLift ™ has poor performance. The very large wingtips of the cargo wing enable them to join together. A spanloader has no maximum wingspan. Six ConcordLift ™ could have a combined AR of 10. Aircraft could take off separately, join up, cross the ocean, and go to separate destinations. The wingtip, 15 ft. high, 150 ft. long, is robust enough to enable connection at the slow flying speed. There are conceptual designs for this. Many professionals could design a number of different mechanisms. The smaller wing extensions of perhaps 30 ft. cord and 3 ft. thickness might be tricky to join because of their small dimensions but the wind loads would also be less.

I. Manufacture

The main wing could be a space frame for great strength and flexibility with light weight at low cost. Twenty 13 foot frames could be assembled into a 260 foot craft in 40 hours. Wide and narrow cargo main wings could be made on the same assembly tool. The only “new” items are the stabilizing gear and controls. They are well within current abilities. Construction could be done with 1940’s technology.

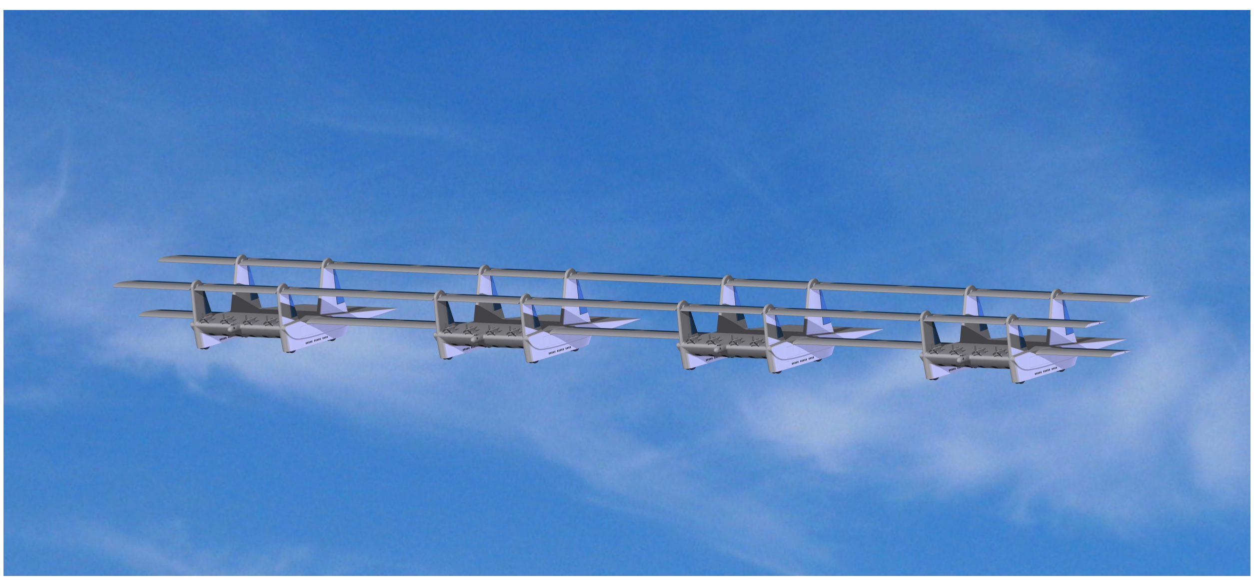
J. Illustrations of selected versions

The ConcordLift ™ is a configuration that can be actualized in many ways. The following illustrate a few of them and some selected features. In order to explain and illustrate an inverted airfoil and other design features are shown. The illustrations are by an artist. Little has been attempted in aeronautical engineering. The design issues are complex and quickly move into unknown areas.

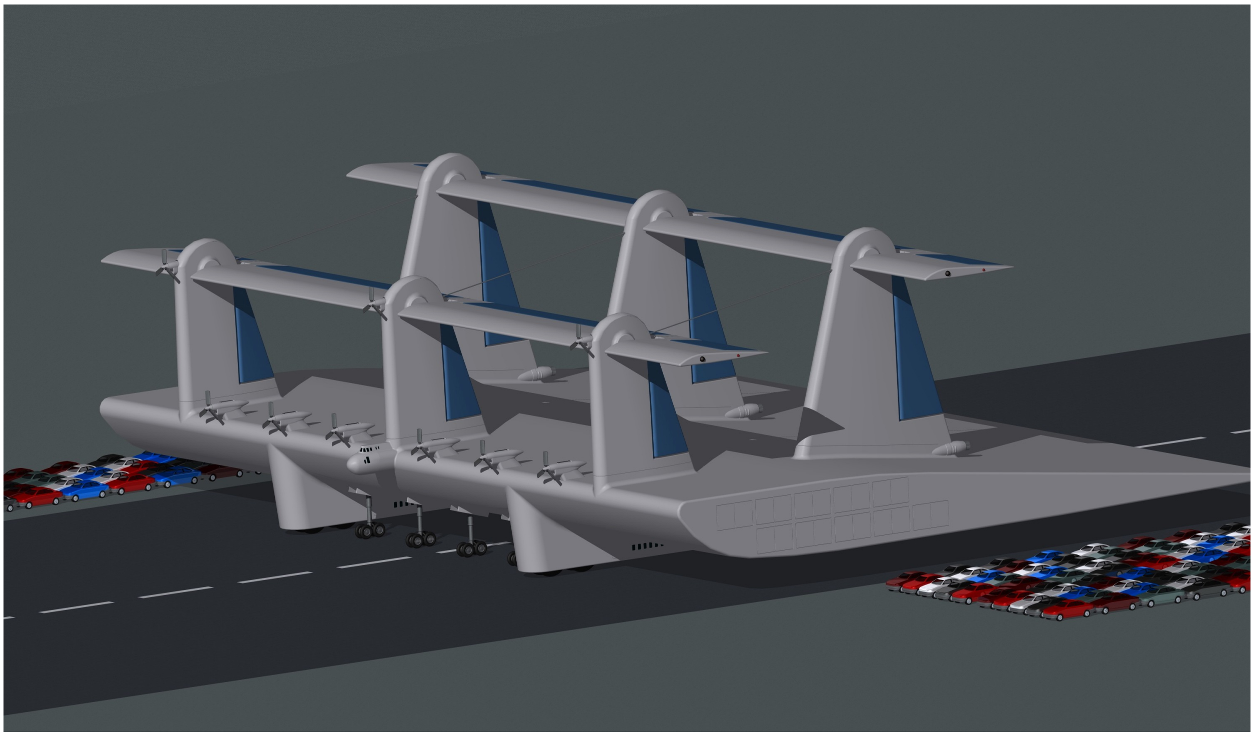


This version carries 20 TEU in 4 channels of 5 each. The cargo airfoil pod is 100 ft. wide with 80 foot extensions on both the cargo wing and the auxiliary wings above. It has 35,000 sq. ft. of wing. Using 20 lb. per sq. ft., it has a GWT of 708,000 lb. Windows and doors are shown for scale, however cargo ships used to carry a few passengers.

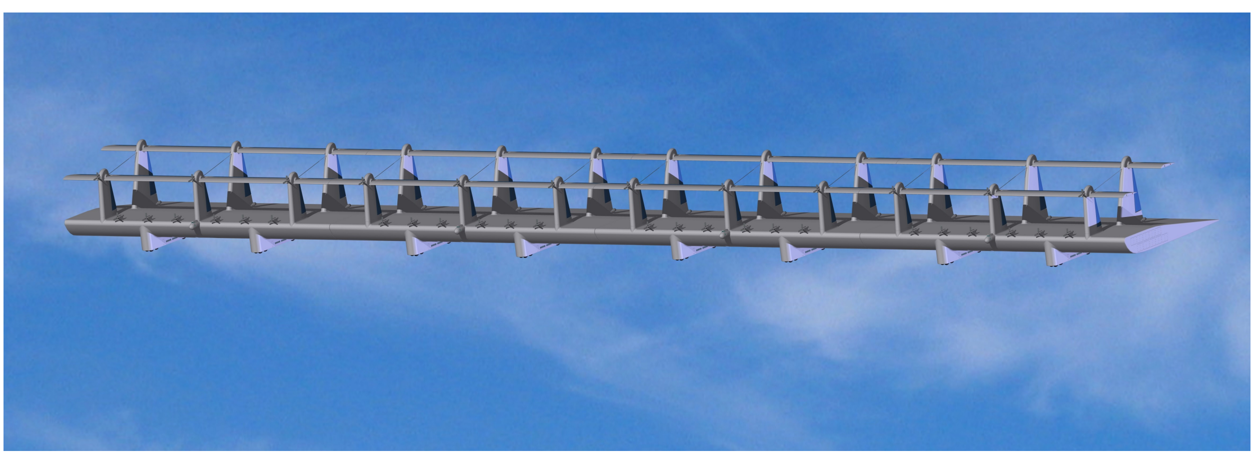
The Illustration below shows it in flight joined with others.



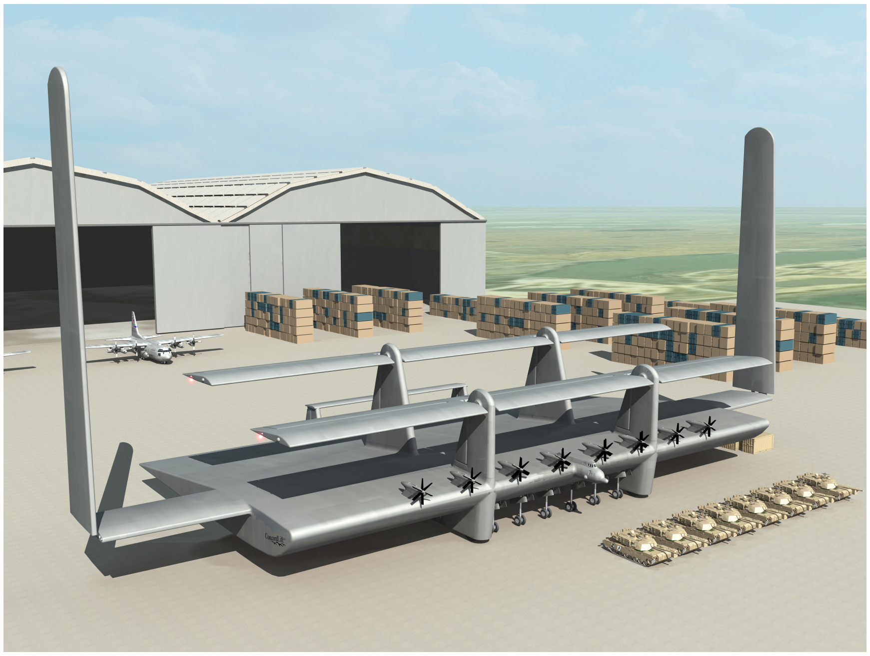
The next version, shown as a Ro – Ro, carries 320 automobiles in 20 channels. It could carry 78 TEU in 6 channels of 13 each. The cargo airfoil pod has a 200 ft. cord and fanjet exhausts for the boundary air system. The cargo wing and the auxiliary wings above have 260 ft. spans. It has 62,100 sq. ft. of wing. Using 20 lb. per sq. ft., it has a GWT of 1,242,000 lb. This could carry passengers and their automobiles across the Atlantic in 24 hours at low cost.



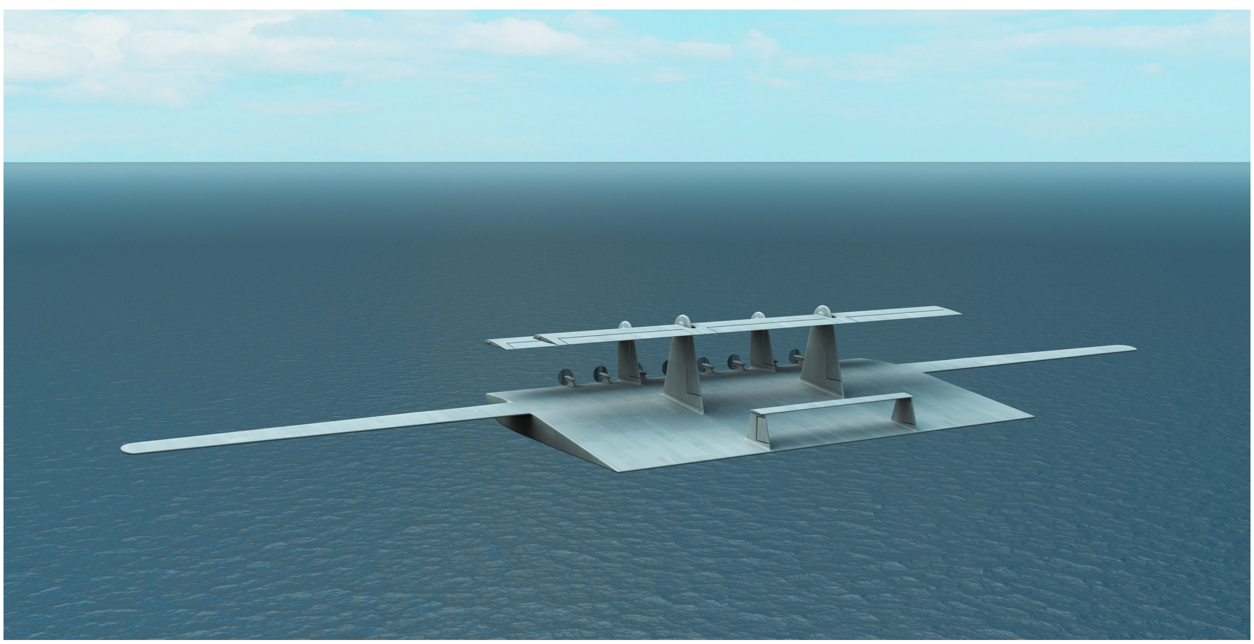
The Illustration below shows it in flight joined with others. At http://www.concordlift.com/ there is an animation of the take off procedure and shows it joined in flight with others.



This has folding wing extension, and an additional tailplane. It could carry 52 TEU in 4 channels. The illustration below shows it with the wings folded. It could carry the eight Abrams tanks in front.



Cargo and auxiliary wings 260 ft. spans, total span of 700 ft. 69,300 sq. ft. of wing and a GWT of 1,396,000 lb.



III. OPERATIONAL USE Air Traffic and Air Ports

ConcordLift™ will fly slower and below commercial jet traffic. It could remain in ground effect across the oceans, and climb above coastal ranges to interior airports. It is incompatible with existing air traffic. The initial concept is designed to fit on current large airport runways when there is no other traffic. It is expected specialized Container Air Ports will be built, similar to the specialized sea-borne Container and Ro-Ro ports. They would not need to be near population centers, just near rail and road. The size of the container handling yards will be greater than the extent of the runways. The specialized Container Air Ports could be designed to handle aircraft with much wider spans and better AR.

The major limiting factor for usage will be the regulatory bodies. This does not fit current aircraft categories. ConcordLift™ is not intended to compete with current air cargo. ConcordLift™ is low altitude, slow speed, trans-oceanic. The nominal flight would be at low altitude, 100 knots in moderate weather conditions. High value, time sensitive cargo will continue to use existing cargo aircraft.

IV. Future Developments

Central Asia, Africa, South America have large populations with very poor connections for heavy cargo. Just supplying the cargo needs of these and similar areas will require a large number of these very heavy lift container aircraft. The auto, truck, passenger ferry versions will transform Indonesia, the Philippines and many other areas. This will greatly reduce transportation cost while providing good profits. Because of the great profit potential to the owner, the aircraft should sell at a good profit.

In the coming years major improvements will make it more useful. The weight of structure will be lighter, stronger, making possible larger versions. It may be possible to fly without using any fuel, if the great wing surfaces were covered by improved photovoltaics. Bulk products would not need transportation to ocean ports. Inaccessible places would come within easy reach. Airline industry focus is on faster, higher, sexy! That can only be done at higher cost to build and operate! All the interest is on sports cars but which is most useful, makes the most profit, has the highest production rate: Lamborghini or the makers of dump trucks? Which will make the most impact: offering one hour service New York – London for high price or Jakarta – Dubai for bus fare?

As part of this there are design concepts for ground handling tug, automated takeoff and landing controls, a version the size of a light twin with a 10,000 lb. load. The three wings working together can be swept back and thin. Mated with a fuselage, they could provide high speed, high altitude very high capacity cargo and passenger service. For use as an ocean patrol craft there is a kind of “ship's boat” that provides the ability to place and retrieve personnel from the surface. The passenger concept for 1400 passengers is designed to make a complete turn around, passengers, baggage and consumables in a half hour. The fast turn around would permit slower cruise speed and lower fuel usage.

V. Conclusion

This is a “thought experiment”. Research will correct, modify or disprove the concept. The examination must include multiple units joined for better AR and the other enhancements. Since it is unique, existing engineering principles and wind tunnel data may not be adequate. Even if placed in operation, second and third generation aircraft should show further improvement.

VI. Origin of idea and reason for name

Except for work on distributed load, span load, there are no parallels in published work. The ConcordLift™ configuration and operation have nothing in common with lifting body, wing-in-ground, three wing, or flying wing. There are no papers, or prior art, to reference that would increase understanding. This needs new original research and development. The essential features are: very deep cord wing, with auxiliary wings for control and the lift needed for take off and landing. The main and auxiliary wings could be cantilevers to support a central load or fuselage. The two stage landing gear may not be essential.

The name for this configuration is “ConcordLift”™, because the wings work in concord – harmony. The name is specified in Patent Application #12/653,489.