

# Lowest Possible Cost - Highest Efficiency Flight

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## **What is the Lowest Possible Cost - Highest Efficiency Flight?**

**No aircraft has implemented all the well known factors for maximum efficiency: Spanloader for standard shipping containers, laminar-flow control, the highest possible Aspect Ratio. It has been long known the most efficient design is to carry the load along the wingspan. The standard mode of cargo transportation is intermodal shipping containers. An obvious idea would be to carry them from wingtip to wingtip. The ConcordLift™ configuration may be the lowest possible cost per ton per mile. This is a thought experiment and call for research.**

## **I. Abstract**

This is a theoretical examination of the problems and solutions for the design and operation of a span loader for transportation of standard shipping containers. At slow air speed, the cost per ton / mile is potentially competitive to the cost for ship. Existing configurations are unable to develop a design with the necessary very thick wing and great expanse of wing surface for slow speed operation. The proposal is a novel configuration of multiple wings and two stage landing gear. This configuration and operation have no antecedents.

## **I. Rationale**

Heavy Lift air cargo has far greater potential for growth than the mature passenger model. There is a search throughout the aeronautical industry for new, better ways. The wing and tube concept has reached the end of its development possibilities. A long time ago air cargo was abandoned to a small specialty niche.

In 2016 there were a reported 34 Million Standard Shipping Containers, TEU.<sup>i</sup> In 2015 the world's container ports transshipped 560 million TEU.<sup>ii</sup> Barges, trains and trucks carry TEU away from those ports. Current air freight, requires TEU containers to be repacked in order to fit into the aircraft. Slow flight can have lower cost than truck and rail.<sup>iii</sup> Instead of ground transportation from the interior to ocean port, containers would travel directly from interior to distant interior destinations. Moving a small percentage of current TEU containers would require a large number of ConcordLift™ aircraft. There are over a billion people with no access to low cost, speedy transportation. The smaller number of containers needed for an aircraft load increase shipper convenience and savings in time.

Basic theory for high efficiency includes: the spanloader, that distributes load from wingtip to wingtip, Laminar-Flow Control: (30% increase in efficiency) termed "The Holy Grail of Aerodynamics"<sup>iv</sup>, the highest possible Aspect Ratio (AR) and perhaps flight in ground effect ( 10% near the ground ). No aircraft has implemented all these well known factors.

Metric units are not used in this paper. Standard shipping containers are in English units. Standard shipping containers are counted in Twenty-foot Equivalent Units (TEU). The base unit measures 20 ft. long × 8 ft. wide and usually 8.5 ft. high. Most are double units - 40 ft. long, some extra long 45 and 53 ft. and some extra high 9.5 ft. The average container load is 30,000 lb. The maximum load is 80,000 lb.

## **II.**

### **Blended Wing Body efficiency**

A BWB spanloader described by: R. H. Liebeck of The Boeing Company, Huntington Beach, California 92647 in a paper in The JOURNAL OF AIRCRAFT Vol. 41, No. 1, January–February 2004 Design of the Blended Wing Body Subsonic Transport.<sup>v</sup> That suggested design is for 800 passengers and 7000 mile range. Very large passenger loads have been found undesirable. On the basis of that paper's computation, ten TEU can be transported at high speed 3000 miles for a fuel burn of 100,000 lb. or 10,000 lb. each. Laminar Flow Control could reduce that by 30% for a fuel burn per TEU about 7000 lb. This is less fuel than a Highway Truck would use and would make the trip ten times faster! Trucks would also require the labor of about 25 man days. ConcordLift™ at one fourth the speed has on sixteenth the drag and required energy, fuel.

## **III.**

### **ConcordLift™**

The ConcordLift™ configuration is designed as a spanloader that carries TEU inside the wing to achieve the lower possible cost per ton mile. This paper sets forth both general and specific illustrations of that configuration. ConcordLift™ could be constructed with the technology of 1940. Nothing is necessarily complex or “high tech”. This needs to be considered as a totally new category to serve in a totally new transportation market with new appropriate regulations.

Spanloader research has been in high altitude solar aircraft.<sup>vi</sup> They are low speed, low power, tailless with distributed propulsion. They demonstrate it is possible to control an aircraft with ConcordLift™ parameters. Included is an illustration of a successful NASA aircraft.

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. The name for this configuration is “ConcordLift™”, because the wings work in concord – harmony. The name is specified in Patent US20110168832.

## **IV.**

### **Controlling dimensions and assumptions**

Wingspan for a spanloader of one standard shipping container, TEU is 20 ft. and a minimum wing thickness of 10 ft. Normal slow aircraft have a wing thickness about 10% of chord, that results in a chord of 100 ft. which is 2,000 sq. ft per TEU. The average container load, 30,000 lb. gives a wing load 15 lb. / sq. ft. Scaled up to the maximum airport width, 80 meters, a 260 ft. wingspan, 13 TEU, results in a potential 390,000 lb. load. Those values suggests there is potential for a very heavy lift aircraft.

The flight parameters in this paper are those of a plane with a similar wing load. There is no reason why heavier wing load, faster speed and high altitude could not be achieved. Different intended usages could lead to different flight parameters. ConcordLift™ could use the same runway length as a light plane, less than 1200 ft.

A quick overview shows the standard configuration with a tail control surface is unworkable. To control angle of attack a great distance, hundreds of feet, is needed between wing and horizontal control surface. In addition a cord of 100 ft. creates a strong low pressure venturi beneath the wing near the ground. Angle of attack, rotation for take off and flare for landing are challenging to achieve. A cord of 100 ft. and span of 260 ft. has a terrible aspect ratio. The obvious problems suggest the great potential is unreachable.

The common slow airfoil has the center of lift at 1/4 cord. In the ConcordLift™ usage that airfoil must be inverted in order to obtain the angle of attack, for takeoff. Even then the value is inadequate, additional lift is required. The center of load has to match the center of lift and the throat of the venturi beneath. ConcordLift™ obtains angle of attack, rotation for take off and flare for landing by a pair of auxiliary wings. In order to explain and illustrate, airfoils and other design features are shown. They were selected for convenience, not because they are known to be best. The engineering issues are complex, and have not been researched. The illustrations and animation are by an artist, not an aeronautical engineer.

## V.

### Configuration and Benefits

ConcordLift™ is a cargo carrier airfoil pod and auxiliary wings connected by vertical fins. Essentially it is a tandem wing aircraft without fuselage but with a cargo airfoil pod suspended beneath. The auxiliary wings provide the lift needed for take off and assure pitch stability. At this point it has not been determined if slow and low in ground effect, or the thin air of high altitude, is most efficient. There may be versions for both applications. The slowest speed at the highest altitude may be the most efficient. Only the crew space would require pressurization.

Wing In Ground effect aircraft have a reputation for pitch instability. All aircraft fly in ground effect take off and landing. The ConcordLift™ deep chord wing, creates a venturi between wing and ground. When the trailing edge is closer to the ground than the leading edge, low air pressure pulls it even closer to the ground. This makes flaps and ailerons problematical. The inverted airfoil pins the throat of the venturi under the center of lift and creates a useful angle of attack for landing and take off. The auxiliary wings, high above, assure pitch stability. The great wingspan possible with ConcordLift™ permits it to fly safely in ground effect hundreds of feet above the surface.

#### A. Basic Design Form

There is no inherent limit to the span of a spanloader. The 80 meter box is the limit for passenger aircraft loading gates. That would seem to limit ConcordLift™ to a 260 ft. span. The passenger limit does not apply for cargo aircraft. The slow, low wing load, ConcordLift™ is able to use a runway less than 1200 feet long.

Aspect Ratio (AR) the ratio between the wingspan and the cord has powerful affect because the higher the ratio the greater efficiency. Sailplane soar without power because of their great AR. Airfields could have a 1200 ft. wide runway for ConcordLift™. Ground handling could appear difficult. The entire aircraft could be made up of sections for ground handling. Latches would join the ends of structural wing spars. A 300 ft. section would be able to fly with a poor Aspect Ratio of 3. ConcordLift™ would use the same runway length as a light plane. The smallest version, one container wide, could operate from a grass strip 100 ft. by 1000 ft. ConcordLift™ can serve almost anywhere.

#### B. The Auxiliary Wings - Tandem Wings, adjustable incidence, high lift devices

The two auxiliary wings 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 need a suspension to absorb the turbulence cantilevered wings absorb by flexing. They provide the extra lift needed at take off and landing. Flaps and slots may extend their full width. 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.<sup>vii</sup> In this paper the auxiliary wings are considered to be 20% of the cargo carrier cord. At optimum deployment, they provide 5/13 of the total lift. Pitch control for the cargo wing is provided by auxiliary wings. The auxiliary wings are affected less by ground effect instabilities and provide good flight pitch stability.

The vertical fins between the auxiliary wings and cargo carrier introduce issues to study and solve. What is illustrated could be far from their final form. One major function is to carry tension, lift, from the auxiliary tandem wings down to the cargo pod airfoil. They need no more area than needed for directional stability. Tension is the lightest, least space demanding load to transmit. The front fins could be much smaller than the rear fins. Flight conditions, interference from turbulence, may require them to be much higher above the cargo carrier with greater vertical separation. They could be made to extend for flight and retract on the ground.

**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.**

#### C. The Cargo Carrier can be designed from small to very large capacities

A common version may be a one container channel 100 ft. cord with three 300 ft. sections. This would carry 45 TEU for 1,350,000 lb. at a net load of 12.5 lb per sq. ft. and AR of 7.5. Four 300 ft. sections, 1200 ft. wingspan, 60 TEU, capacity of 1,800,000 lbs. would have an AR of 10. Six 150 ft. cord four channel would have an AR of 10 for 360 TEU, load of 10,800,000 lb. All need a runway less than a wingspan. High capacity of TEU is not necessarily desirable since a major benefit is frequent service. Large ConcordLift™ are not more efficient. It is possible to

construct ConcordLift™ for one TEU container.

The very large, thick, spanloader cargo carrier airfoil cannot have flaps and ailerons but can have leading edge slots and spoilers. An inverted airfoil can have a maximum angle of attack, with a thickness 10% of the chord, about 5.7°. Container channels cannot fill the wing. The center of lift is at the center of lift about 1/4 cord. The ten to one thickness to cord ratio has to be kept in order to maintain the angle of attack. Loading doors are at the wingtips of the sections. Between the TEU channels are trusses wingtip to wingtip. Those are the wing spars, for great strength with light weight. Those trusses combined with trusses above and below the container channels comprise a very strong wing box. There is room with that airfoil for one channel at 100 ft. cord, four channels with a 150 ft. cord or with 200 ft cord six channels.

The very large size of ConcordLift™ makes visualizing the features difficult. This paper has illustrations of smaller versions that take off separately and then join. On the Web Page<sup>viii</sup> there is an animation of a smaller version showing the deployment of the auxiliary wings and landing gear on take off. ConcordLift™ would use the same runway length as a light plane.

**People do not think big enough.**

#### **D. Laminar-Flow Control**

The great cargo wing surface creates high drag from boundary layer air. Laminar-Flow Control: has been termed “The Holy Grail of Aerodynamics”<sup>ix</sup>. It has been unusable in practice because aircraft wings have not had the necessary internal volume for the required duct work. The boundary layer is pulled inside the wing through slots, reducing the drag, power, fuel by 30%.<sup>x</sup> The cargo carrier is a great void with little internal structure to restrict airflow. Ducts could be exhausted by fanjets that would add to the thrust for flight. Pulling the intake air through the perforations would reduce the intake air pressure for the fanjets. Fanjets are designed for high altitudes, low pressures. The reduced intake air pressure should not be a great problem.

#### **E. Wing Extensions**

The main cargo wing might only extend 5 TEU wide or less. If the deep cord cargo carrier is 100 ft wide there would be room within the 80 meter wide airport limitation for 80 ft. wings extending out the sides for a total 260 ft wingspan. A 20 ft. wide, 100 cord could carry 1 TEU. One illustration shows a version with a total flying width of 700 ft. with a main wing of 260 ft. and two 220 ft. extensions. The smallest version, 1 TEU is 20 ft. wide. Wing extensions could give it a total width of 100 ft. The following should be more popular, 2 TEU or 53 ft. trailer body. Instead of the complex landing gear, tricycle stabilizing wheels should be adequate. The wing extensions would securely mount to the top latches that join sections together. If needed a brace could extend to the bottom latch. This could deliver up to 80,000 lbs. to a 100 ft. by 1000 ft. grass strip. People also need to think small.

#### **F. Yaw, directional change**

At the front and rear of the cargo wing are vertical fins with rudders. At altitude, the ConcordLift™ will turn and bank in the normal manner. Close to the ground, yaw is controlled by variation of engine power. Power is increased on the outside end of the aircraft while spoilers automatically compensate for the increased lift, so turns could 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.

#### **G. Engines**

Engine weight is not an issue with ConcordLift™. Since prop wash over the top of the wing increases lift, many small propellers might be an advantage. On takeoff and landing, with the auxiliary wings set for maximum lift, the vector for drag will move higher. It is necessary to mount some engines high on the fins so the thrust vector matches the drag vector. Cables connect the front fins to the rear fins to connect the thrust from the front engines to the drag from the back wing. The drag from cables is minimal.



Flights may last several days, over 9000 miles. Heavy, fuel efficient engines, could make for less total weight. New power sources are in constant development. The highest efficiency may be railroad diesel electric sets to power electric motors. The wing surfaces could also be covered with photocells to supplement the power.

## **H. 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. It is less a problem with the shorter cord. The following may be a better solution. In addition to the normal main gear, have a set of “stabilizing gear”. The closer the cargo carrier 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. between cargo wing and ground is too short for safe landing. The actual dimension will be determined in engineering. The animation shows the various parts in action on take off. The illustrator was instructed to show a 5000 ft. runway because it was feared the viewer would be unable to accept the actual less than 1200 ft. take off distance. ConcordLift™ has the flight perimeters of a Cessna 172.

First contact with the ground is made with the cargo wing high above the runway by very large diameter “stabilizing gear”. The animation uses 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, carry a portion of the load. The extension of the stabilizing gear legs may be powered. 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 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. For example, the 300 ft. wingspan, 15 TEU, section has 4 sets of 4 stabilizing wheels and 8 sets of 4 main gear for a total of 48 wheels. All wheel sets caster in order to handle cross winds on take off and landing. Wheel sets for sections to be joined on the ground caster in order to travel end first until transition to mate. The heavy load distributed over the total runway surface make this capable for unpaved fields. The multitude of landing gear creates drag under the wing and reduces the force of the venturi between the wing and ground, enhances lift.

This complex two stage landing gear and process may be unnecessary. Even though the runway distance needed is short, the slow speed will permit the time needed for the take off procedure given above. The stabilizing gear makes smooth transition to the main gear possible.

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 is attached to the wing box. The fairings could serve as floats for ocean ditching. The fairings could also be used for passengers.

## **I. Crew, Flight deck, automatic flight management control**

If designed for high altitudes only the crew area would need to be pressurized. ConcordLift™ is intended to fly in good flying conditions. It is expected to avoid all predicted harsh conditions. Storms move faster than ships and overtake ocean shipping. ConcordLift™ is faster than storms. Weather forecasting should prevent ConcordLift™ from ever being flown into dangerous weather. 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. Ground effect instabilities require immediate management. Automated landing and take off is also intended and is current state of the art for aircraft.

## **J. Manufacture**

The cargo carrier could be a space frame for great strength and flexibility with light weight at low cost. Fifteen 20 ft. frames could be assembled into a 300 ft. section in 40 hours. The only “new” items are the stabilizing gear and controls. They are well within current abilities. Construction could be done with 1940’s technology.

## **K. Illustrations of selected versions**

The ConcordLift™ is a configuration that can be actualized in many ways. The following illustrate some selected features. The engineering issues are complex and unknown. The illustrations are by an artist. The web site has a number of other illustrations.

ILLUSTRATION #1  
Helios - NASA aircraft



ILLUSTRATION #2

This version carries 20 TEU in 4 channels of 5 each. The cargo airfoil pod is 100 ft. wide, 150 ft. cord, with 80 ft. extensions on both the cargo wing and the auxiliary wings above. Windows and doors are shown for scale.

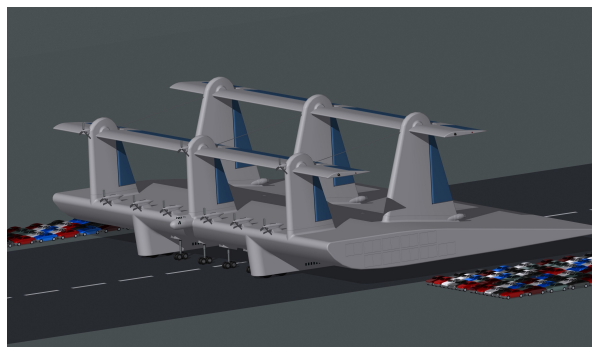


ILLUSTRATION #3

The cargo pod and the auxiliary wings have 260 ft. spans, 62,400 sq. ft. This could carry passengers and their automobiles across the Atlantic at low cost. It is illustrated as a Ro – Ro, for 320 automobiles in 20 channels.

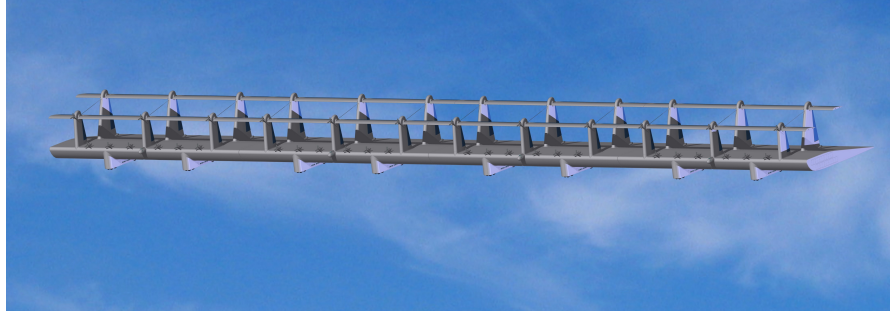
This could carry 78 TEU in six channels of 13 each or 26 TEU in two channels.

The cargo airfoil pod has a 200 ft. cord and fanjet exhausts for the laminar-flow control.



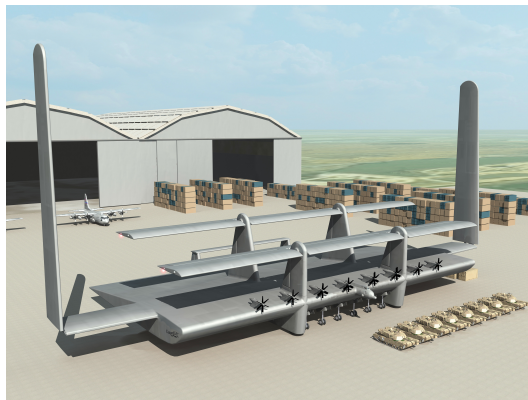
#### ILLUSTRATION #4

Four joined in flight, runway needed is less than the total wing span.



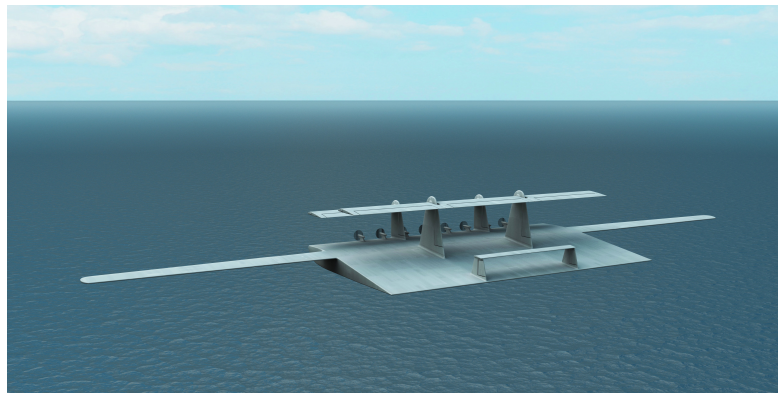
#### ILLUSTRATION #5

This has 150 ft. cord, 260 ft. span plus folding wing extensions 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. A C-130 is shown for scale.



#### ILLUSTRATION #6

Cargo and auxiliary wings 260 ft. spans, total span of 700 ft. 69,300 sq. ft. of wing.



## **V. OPERATIONAL USE Air Traffic and Air Ports, Earnings, Future**

ConcordLift™ is designed to fit on current large airports when there is no other traffic. It is expected specialized Container Air Ports will be built, similar to the specialized ocean Container and Ro-Ro ports. They do 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. Since this is a short field aircraft, a runway pad less than 2000 feet square at sea level would allow runways in four directions. The runway needed is less than the wingspan. High speed, high altitude versions would require longer runways.

The following compare ConcordLift™ to freight rates currently charged. The target users are high value, time sensitive items: perishable foods, electronics, clothing for new trends. Those shippers who do not need priority air freight and are hampered by slow container ships. Most container shippers are expected to remain with the slow providers they now have. ConcordLift™ will be able to charge a premium because it provides fast direct service. The initial users will be willing to pay the highest premium rates. The initial buyers of ConcordLift™ will have high profits and be willing to pay the builder a premium. The initial builder will make high profits. As the market becomes saturated, rates will come down, experience will reduce costs, until the economic equilibrium is reached. It may take many thousands of ConcordLift™ to be built before that point is reached. There will remain an ongoing build to maintain and expand the fleet. No competitor is possible in the distant future. ConcordLift™ provides the lowest possible cost for heavy lift. Future developments will just reduce the cost to build and operate ConcordLift™.

First world truck rates are near \$.40 ton / mile. The ConcordLift™ 60 TEU version, at that rate, earns \$288,000 in 8 hours, providing faster delivery. First world train rates are around \$.10 ton / mile for unit trains. Railroad carry individual containers at a higher rate. The ConcordLift™ 240 TEU version, longer than a long train, at the lowest rate, earns \$288,000 in 8 hours, in many areas providing lower cost per TEU than rail.

ConcordLift™ will transform new car delivery. A Ro-Ro for new car transport holds about one month production at one car a minute. The cost is not just the cost of transport. There is the capitol cost of a month's unsold production and the inability to offer custom orders. ConcordLift™ will also be a strong competitor long distance new car rail delivery. This is expected to be the market sector quickest to convert to ConcordLift™.

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. Passenger, car ferries will cross the oceans and continents, providing overnight accommodations for the 24 hour trip. It will be possible to bring the personal car, for less than the price of passenger tickets, hotel and car rental.

ConcordLift™ could serve as a Sea Control, Ocean Patrol craft. It would have long endurance and cover large areas. A kind of "ship's boat" based on existing technology could land and return from the surface.

Bulk products, ore and petroleum, will not need transportation to ocean ports. Massive industrial equipment will be moved by specialized very heavy lift versions. Inaccessible places will come within reach. ConcordLift™ are far better than the hybrid airships and will open up areas that are now inaccessible.

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.<sup>xi</sup> The sailing, loading and unloading takes over a week. ConcordLift™ 540 TEU version, at the westbound rate, can earn \$689,000 per trip and makes 5+ trips a week. ConcordLift™ is five times faster and direct to the interior without unloading at the ocean terminal.. One runway, one 540 TEU ConcordLift™ an hour, is 14,400 TEU per day. The entire port of New York in 2010 handled 14,694 TEU a day.<sup>xii</sup>

In the coming years improvements will make it more useful. The weight of structure will be lighter, stronger. The airline industry focus is on faster, higher, sexy! That can only be done at higher cost to build and operate! All interest is on sports cars but which is most useful, makes the most profit, has the highest production rate: Lamborghini or dump trucks? Which will make the most impact: offering one hour service New York – London at high price or Jakarta – Dubai for bus fare? A passenger concept for 1400 passengers is designed to make a complete turn around, passengers, baggage and consumables in a half hour. As part of this are design concepts for aircraft and container ground handling equipment. 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 or for space launch.

Because of the great profit potential to the owner, the aircraft should sell at a good profit to the builder. There is no foreseeable alternative, competition. 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 ConcordLift™. A combined sustained build rate of 1000 a year would be reasonable.

## **VI. Evolution of Concept**

ConcordLift began as a spanload Wing in Ground (WIG) or Ground Effect Vehicle (GEV) for standard shipping containers. Wing in Ground has a 10% increase in efficiency for flight. The benefit is restricted to an altitude equal to the wingspan. Narrow span WIG means flight close to the surface and limited ability to fly higher. Spanloaders are known for high efficiency, the higher the Aspect Ratio (AR) the better. Many WIG designs are seaplanes. The large sponsons on ConcordLift™ began as floats. The massive damage from the wake of a heavy, high speed craft limit them to open ocean. Ships have a 6 knot speed limit in harbors. ConcordLift was changed to a land plane. The load of an aircraft on the ground is determined by the size and number of wheels. ConcordLift can have enough wheels for acceptable ground pressure. It could even be made to use unpaved fields.

Wing in Ground aircraft have a reputation for being unstable in pitch. The two auxiliary wings above the main cargo pad, instead of a tailplane, corrected pitch stability. Between the wing and the ground is the throat of a venturi, low pressure. Rotation and flare, for take off and landing, locates the rear edge of the wing closest to the surface. Flaps cause the lowest pressure to be at the rear edge of the wing. Instability beneath the wing on the ground is self propagating. Low pressure pulls the wing closer which increases the low pressure. That seemed to end the concept. The airfoil was inverted to fix the throat of the venturi under the center of lift, center of load. The angle of attack for lift is still inadequate, but the auxiliary wings can be designed to provide the lift needed.

The problem that remained was major. The Aspect Ratio was very low, inefficient. The heavy load, slow speed and narrow AR create dangerous wingtip vortices. Several solutions were considered. The center cargo pod could be just a few TEU wide with wing extensions so the combined AR would be better. Another solution would be for a number of ConcordLift aircraft take off separately and join together in flight to form a single craft with good AR. Those concepts was presented to the AIAA and posted on the Internet. They are shown in the illustrations. The animation was made with a 10,000 ft. runway, because the short field ability was considered too hard for the viewer to accept.

The mechanism for joining the separate aircraft was left for the future. It is a challenging problem. The major issue was developing a way for the aircraft to separate safely. Power is needed to overcome the turbulent low pressure between the wingtips. A process and mechanism were developed in principle. It is unpublished and proprietary. The low pressure between the smaller wingtips of the wing extensions is less powerful, easier to separate and join.

The final solution for the problem of Aspect Ratio was the realization, it is unnecessary for ConcordLift™ to be restricted to the width of a standard airport runway. Instead of joining in flight, ConcordLift™ could take off as a unit. The high AR minimizes the wingtip vortices. The runway would be wide but would not necessarily long. This is the concept presented in this paper. The thick wing does not mean high altitude is out of reach.

## **VII. Conclusion**

This is a “thought experiment”. Research will correct, modify or disprove the concept. Since it is unique, existing engineering principles and wind tunnel data are not adequate. Even when placed in operation, the second and third generation aircraft should show further improvement.

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