= Liquid fly @-@ back booster =

Liquid Fly @-@ back Booster (LFBB) is a cancelled German Aerospace Center 's (DLR 's) project to develop a reusable liquid rocket booster for Ariane 5 in order to significantly reduce a high cost of space transportation and increase environmental friendliness . LFBB would replace existing solid rocket boosters , providing main thrust during the liftoff . Once separated , two winged boosters would perform an atmospheric entry , fly back autonomously to the French Guiana , and land horizontally on the airport like an airplane .

Additionally a family of derivative launch vehicles was proposed in order to take an advantage of economies of scale , further reducing launch costs . These derivatives include a Reusable First Stage in a class of small and medium size launch vehicles like Vega and Arianespace Soyuz , the Super @-@ Heavy Lift Launcher capable of lifting nearly 70 tonnes to the orbit , and a Two @-@ Stage @-@ To @-@ Orbit system operating a dedicated reusable orbiter .

German Aerospace Center studied Liquid Fly @-@ back Boosters as a part of future launcher research program from 1999 to 2004 . After the cancellation of the project , publications at DLR continued until 2009 .

= = Development = =

The German Aerospace Center (DLR) studied potential future launch vehicles of the European Union under the Ausgewählte Systeme und Technologien für Raumtransport (ASTRA ; English : Systems and Technologies for Space Transportation Applications) programme from 1999 to 2005 , with additional studies continuing until 2009 . The LFBB design was one of two projects within the ASTRA program , the other being Phoenix RLV . During development , scale models were constructed for testing various configurations in DLR 's supersonic Trisonische Messstrecke Köln (TMK ; English : Trisonic measuring section at Cologne) and in their Hyperschallwindkanal 2 Köln (H2K ; English : Hypersonic wind canal at Cologne) wind tunnels . The preliminary mechanical design of other major elements was done by the companies EADS Space Transportation and MAN .

The advantages of reusable boosters include simplicity from using only one type of fuel , environmental friendliness , and lower reoccurring costs . Studies concluded that reusable fly @-@ back boosters would be the most affordable and the least risky way for European space launch systems to start becoming reusable . These fly @-@ back boosters had the potential to reduce launch costs . However , when other projects , such as Space Shuttle or VentureStar , undertook this objective , they failed to meet their goals . Supporting technologies needed for LFBB construction can be developed within 10 years , and additional launchers can be developed based on fly @-@ back boosters to minimise costs and provide maintenance synergy across multiple classes of launch vehicles . Eventually , the hardware grew too large and the LFBB project was scrapped , with one member of the French space agency (CNES) remarking :

The thing that shocked me was that at the beginning , this reusable flyback booster was just a cylinder with engines and little wings , just a turbo fan in the back . And three years later these were complete Airbuses in terms of size with four engines in each of them .

= = Description = =

The overall concept of the liquid boosters in the LFBB programme was to retain the Ariane 5 's core and upper stages , along with the payload fairings , and replace its solid rocket boosters (EAP P241 , from French Étages d ? Accélération à Poudre) with reusable liquid rocket boosters . These boosters would provide the main thrust during take @-@ off . After separation , they would return to a spaceport in French Guiana for landing . This vertical take @-@ off , horizontal landing (VTHL) mode of operation would allow liquid fly @-@ back boosters to continue operating from the Guiana Space Centre , thus avoiding any major changes to the ascend profile of Ariane 5 . Launch vehicle payload performance of the Cryogenic Evolution type @-@ A (ECA) variant would increase from

10 @,@ 500 kg (23 @,@ 100 lb) to 12 @,@ 300 kg (27 @,@ 100 lb) .

In the reference design , each LFBB consists of three engines installed in a circular arrangement at the aft of the vehicle . Each engine is a Vulcain engine with reduced expansion ratio . An additional three turbofan air @-@ breathing engines , installed in the nose section , provide power for fly @-@ back . The fuselage is 41 m (135 ft) long , with an outer tank diameter of 5 @.@ 45 m (17 @.@ 9 ft) , specifically designed to match the existing Ariane 5 core stage and to reduce manufacturing costs . A low @-@ wing V @-@ tail canard configuration was selected , with a wingspan of approximately 21 m (69 ft) and an area of 115 m2 (1 @,@ 240 sq ft) . The aerofoil was based on a transonic profile from the Royal Aircraft Establishment (RAE 2822) . The gross lift @-@ off mass (GLOW) of each booster is 222 @.@ 5 tonnes (245 @.@ 3 short tons) , with 54 tonnes (60 short tons) upon separation and 46 @.@ 2 tonnes (50 @.@ 9 short tons) dry mass . In comparison , the GLOW for EAP P241 is 273 tonnes (301 short tons) .

The booster was designed to have four independent propulsion systems , the first of which ? main rocket propulsion ? would be based on three gimbaled Vulcain engines fueled by 168 @,@ 500 kg (371 @,@ 500 lb) of propellant . Second , Eurojet EJ200 fly @-@ back turbofan engines would be propelled with hydrogen to reduce fuel mass . Further , ten 2 kN (450 lbf) thrusters placed on each side of the vehicle would be used by the reaction control system . Finally , the fourth propulsion system would be based on solid rocket motors that separate the boosters from the core stage . An up @-@ scaled version of the motors used in existing EAP boosters would be mounted in the attachment ring and inside the wing 's main structure .

A typical mission profile would begin with the ignition of a main stage and both boosters , followed by an acceleration to 2 km / s (1 @.@ 2 mi / s) and then a separation at the altitude of 50 km (31 mi) . As the main stage continues its flight into orbit , the boosters follow a ballistic trajectory , reaching an altitude of 90 ? 100 km (56 ? 62 mi) . After low @-@ energy atmospheric entry , the boosters reach denser layers of the atmosphere where they perform a banking turn toward the target airfield . Gliding continues until they achieve an altitude that is optimal for engaging turbofan engines and entering cruise flight . At this point , about 550 km (340 mi) from the launch point , the boosters would be flying over the Atlantic Ocean . The cruise back to the airport requires about 3 @,@ 650 kg (8 @,@ 050 lb) of hydrogen fuel and takes over two hours to complete . An undercarriage is deployed and each booster lands autonomously . After separation , the boosters are not under threat of collision until they land due to small differences in their initial flight trajectories .

= = Derivatives = =

The development of liquid fly @-@ back boosters has the potential to enable three additional space transportation systems with an objective of increasing production and creating economies of scale . The aim of the LFBB project at DLR was to reduce Ariane 5 operational costs and to develop future derivatives , including a reusable first stage of a small @-@ to @-@ medium launch vehicle , a super @-@ heavy launch vehicle capable of lifting 67 tonnes (74 short tons) to Low Earth orbit , and a reusable two @-@ stage @-@ to @-@ orbit launch vehicle . Initially , LFBBs would be used only on Ariane 5 . Over time , alternative configurations could phase out Arianespace Soyuz and Vega .

= = = Reusable first stage = = =

The LFBB was studied with the three upper stage composites , to attain a Reusable First Stage (RFS) configuration . The first was a Vega derivative , with a Zefiro 23 second stage , a Zefiro 9 third stage and an AVUM upper stage . With the LFBB replacing the P80 stage , the payload to sun @-@ synchronous orbit (SSO) would increase to 1 @,@ 882 kg (4 @,@ 149 lb) , compared to the 1 @,@ 450 kg (3 @,@ 200 lb) of the Vega . The second was an Ariane 4 derivative called H @-@ 25 . It was based on an H10 upper stage with a Vinci rocket engine and 25 tonnes (28 short tons) of cryogenic fuel . Depending on the method of deceleration , the payload to SSO is between 1

@,@ 481 and 2 @,@ 788 kg (3 @,@ 265 and 6 @,@ 146 lb) . The third was a large cryogenic upper stage , called H @-@ 185 , based on an alternative , yet @-@ to @-@ be @-@ developed Ariane 5 main stage with 185 tonnes (204 short tons) of cryogenic fuel . Its payload to SSO is 5 @,@ 000 kg (11 @,@ 000 lb) .

Two of the lighter configurations (the Zefiro 23 and the H @-@ 25) use upper stages mounted on top of the booster . Due to the lower weight , it might have been necessary to lower the amount of fuel in a booster to ensure that the separation velocity , the flight path , and the reentry do not exceed design bounds . In the case of H @-@ 25 , it might be necessary to accelerate the fly @-@ back boosters to above 2 km / s (1 @.@ 2 mi / s) to help the upper stage achieve its desired orbit . Consequently , two solutions were proposed to decelerate the boosters after separation . The first option was to actively decelerate them using 10 tonnes (11 short tons) of fuel and reduce the velocity by 300 m / s (980 ft / s) . However , launch performance would drop below that of the Vega derivative . Another option is to use aerodynamic forces to decelerate . However , a hypersonic parachute was deemed too expensive and too complex . As a result , an alternative ballute was proposed . Flight dynamics simulation revealed that a ballute with a cross @-@ section of 45 m2 (480 sq ft) offered the best compromise between loads on the booster and deceleration by aerodynamic forces . In this configuration , a launch performance of up to 2 @,@ 788 kg (6 @,@ 146 lb) could be achieved , partly thanks to a higher separation velocity .

The heaviest configuration uses a single booster with an asymmetrically mounted , large , expendable cryogenic stage designated H @-@ 185 . It was proposed as a future variant of the Ariane 5 core stage (H158) , eventually meant to phase out the main stage in a standard launch configuration with LFBB . H @-@ 185 would use a new Vulcain 3 main engine , with increased vacuum thrust . When launched with a single booster , both stages would be operated in parallel , and be delivered to a 180 by 800 km (110 by 500 mi) orbit before separation . The remaining upper stage composite would weigh 7 @,@ 360 kg (16 @,@ 230 lb) , with a 5 @,@ 000 kg (11 @,@ 000 lb) payload performance to SSO . When launching to Low Earth orbit , payload mass can be increased to over 10 @,@ 000 kg (22 @,@ 000 lb) .

= = = Super @-@ heavy lift launcher = = =

The Super @-@ Heavy Lift Launcher (SHLL) would consist of a new cryogenic main stage , five liquid fly @-@ back boosters , and a re @-@ ignitable injection stage . This configuration was designed to provide increased capabilities for complex missions , including manned explorations to the Moon and to Mars , as well as the launch of large solar @-@ powered satellites .

The new core stage would stand 28 @.@ 65 m (94 @.@ 0 ft) tall and have a diameter of 10 m (33 ft) , feeding 600 tonnes (660 short tons) of LOX / LH2 to three Vulcain 3 engines . The increased circumference of the main stage allows five LFBBs to be integrated with either retractable or variable @-@ geometry wings . The upper stage would be a derivative of the Ariane 5 ESC @-@ B , with the size upped to 5 @.@ 6 m × 8 @.@ 98 m (18 @.@ 4 ft × 29 @.@ 5 ft) , and strengthened to bear higher loads . The Vinci engine was proofed to be sufficiently powerful for orbital insertion . Payload would be enclosed in an 8 m × 29 @.@ 5 m (26 ft × 97 ft) fairing . The launch vehicle would have a total height of 69 m (226 ft) and a mass of 1 @,@ 900 tonnes (2 @,@ 100 short tons) . The payload to LEO would be 67 @,@ 280 kg (148 @,@ 330 lb) .

When launched to a 200 km × 600 km (120 mi × 370 mi) Low Earth transfer orbit , the LFBBs would separate at an altitude of 51 km (32 mi) , at a speed of 1 @.@ 55 km / s (0 @.@ 96 mi / s) . To avoid simultaneous separation of all boosters , either a cross @-@ feed to the main stage , or throttling could be used . The return flight of the boosters would require an estimated 3 @,@ 250 kg (7 @,@ 170 lb) of fuel , including a 30 % reserve .

= = = Two @-@ stage @-@ to @-@ orbit = = =

A reusable Two @-@ Stage @-@ To @-@ Orbit (TSTO) launch vehicle was planned to be implemented about 15 years after the addition of LFBBs to Ariane 5 . However , only a preliminary analysis of TSTO was completed . The proposed configuration consisted of two boosters with retractable wings attached to the external fuel tank , and a reusable orbiter with fixed wings carrying payload on top of it . During geostationary transfer orbit (GTO) missions , an additional , expandable upper stage would be used .

The external tank , being a core of the system , would have a diameter of 5 @.@ 4 metres (18 ft) and a height of 30 @.@ 5 metres (100 ft) , carrying 167 @.@ 5 tonnes (184 @.@ 6 short tons) of propellant . The attached orbiter would be 28 @.@ 8 metres (94 ft) tall and 3 @.@ 6 metres (12 ft) in diameter , carrying 50 tonnes (55 short tons) of propellant . The payload fairing mount atop the orbiter would be 5 @.@ 4 by 20 @.@ 5 metres (18 ft × 67 ft) . For LEO missions , the launch vehicle would be 57 @.@ 3 metres (188 ft) tall , with a gross lift @-@ off mass of 739 @.@ 4 tonnes (815 @.@ 0 short tons) . The payload to LEO would be 12 @,@ 800 kilograms (28 @,@ 200 lb) , with an increase to 8 @,@ 500 kilograms (18 @,@ 700 lb) to GTO when using an expandable upper stage .