European Space Policy Institute

ESPI PERSPECTIVES 5

More affordable satellite launchings

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Europe must take the lead in making access to space more affordable and more practical. Now is the time to be smart and combine two European strengths in exploiting the world largest freighter aircraft, the Airbus 380, with the largest and most efficient Solid Rocket, the VEGA.

Launching VEGA from the Airbus 380 gives maximum flexibility, selecting always the energy optimal starting point for any orbit and any inclination, and with minimum weather dependency.

ESPI proposes an elegant design for connecting the VEGA to any AIRBUS 380 freighter with safe release at a height of 10km with a speed of 800km/hour and gaining up to 22% in performance.

With dramatically reduced costs for the launch campaign, no launch range fees, space will become both more practical and affordable for many new satellite owners.

Launching rockets from aircraft is a well proven method. The U S company Orbital Sciences has since 1994 used a Lockheed 1011 aircraft to orbit satellites weighing up to 400 kg with a 23 ton solid engine rocket called Pegasus.

Now air launching also have been proved for manned rocket planes and is the basis for the Space Tourism business championed by the European owned Virgin Galactic Company which will take tourists to 110 km with the rocketplane Space Ship 2.

With this report ESPI proposes a way of connecting much larger rockets to much larger aircraft with their safe release at the very optimum coordinates. Europe with the Airbus 380 freighter and the 137 tons Solid Engine Rocket, the VEGA, is now in a unique position to be the first to really reduce the cost of access to space.

The author of these ESPI Perspectives had the privilege to be the representative from Norway in the Long term Space Policy Committee (LSPC) appointed by ESA Council.

In its second report to ESA Council from May 1999, LSPC proposed 20 Action Items which were welcomed by the ESA Ministerial Council held in Brussels in 1999. One of these recommendations was to establish a European Think Tank on Space Policy, the result of this recommendation is the European Space Policy Institute (ESPI).

Another recommendation is on launchers, the author still remembers how difficult it was to convince the other members of LSPC of the final text displayed below:

ACTION 2
Cheaper Access to Space

Purpose:
Put Europe among the winners in the competition to achieve substantial launch-cost reduction.

This action is complementary to ESA's proposed Future Launcher Technology Programme (FLTP), aiming at strengthening European competitiveness and massive cost reductions for large payloads. This action is focussed on low- to medium-mass payloads, particularly for the constellation market, and is based upon using proven technologies in new and innovative ways. The emphasis is on minimising both cost and time to first launch.

Strategy:
1. Detailed study of current American, Russian and Ukrainian plans for achieving drastic cost reductions for launching 1 tonne-class payloads to Low Earth Orbit (LEO).
2. Identification of the most promising fully and partly reusable launcher technologies.
3. Detailed study of an air-launch system, in which the first stage is aircraft-based, the third stage is expendable, and the second stage is reusable, demonstrating technologies and operations applicable to future reusable launch systems for large payloads.

First Step:
Take an initiative towards a joint venture with international partners for an air-launch space-transportation system.
Funding needed: 2 ME.

Only with the support from the UK representative on LSPC, Mr John Shrimplin, the author was able to get consensus on this text which he drafted. Now 10 years later he has the privilege of being at ESPI where he was the study leader and responsible for the report: Commercialization of space and its evolution; will new ways to share risks and benefits open up a much larger space market?

This report devotes its largest chapter to the development of commercial launchers and ends this chapter with the following recommendation as its conclusion:

Conclusion
Thanks to European institutional investments in launchers with the Ariane family, and now also the forthcoming Vega and Soyuz from Kourou, Europe has secured its guaranteed access to space with a choice of launchers depending on the requirements (typical the orbit and weight). More than securing access to space, initially Ariane 4 and now Ariane 5 became globally competitive over several decades in the most important business, the launching of communication satellites to their Geostationary Transfer Orbit (GTO) where they became the global market leaders.

The author believes it would be risky for Europe to rest on its laurels in the belief that the current strong market situation will last and that the new entrepreneurial efforts in the US will all fail.

What neither Europe nor the US so far has achieved is to really reduce the cost of access to space*. The author believes that it would be good government policy to create more space activities and also be an insurance against the new launchers designed to be globally competitive if the future European launcher policy also would focus on the following:*

- *To really reduce the cost of access to space due to smart design, efficient manufacturing and low cost launch campaigns.*
- *To ensure that new launchers be globally competitive for their class and without need for subsidies nor for future support.*

A pragmatic attitude should be selected if low cost is achieved through reusability, partly reusability or partly refurnishable or simply by developing a launcher with low manufacturing cost using state of the art manufacturing and cost effective subsystems. What is more important is to find the lowest cost both to governments for their initial funding and afterwards for each launch.

If Europe could combine the strength of the capabilities in Russian launcher companies with those in the ESA member states, there should be no doubt that Europe can combine a good business case and reduce cost of access to space. It is therefore recommended to establish a road map for bringing up a Euro-Russian family of globally competitive low cost launchers. What, at the end may be more important for Europe, is the fact that cheaper access to space will bring more space activities and an increased space market both for smaller and highly capable satellites and the applications derived from such satellites."

The author believes that, even more than 10 years later, Europe needs now to address the issue of really reducing the cost of access to space. He got a renewed interest and inspiration in the concept of using an airplane as the first stage, or an air launch rocket, by seeing the just released design for the White Night 2 plane and the Space Ship 2 rocket plane now under fabrication for Virgin Galactic for its new Space Tourism business financed by the UK entrepreneur Sir Richard Branson.

Air launch of manned rocket planes has already been proven with Space Ship 1 , and also air launch of satellites have being going on since 1994 with the United States Pegasus small launcher using the Lockheed 1011 freighter as launch platform. It used to be conventional wisdom that air launchings could only be used for small launchers and therefore only for low mass satellites. Pegasus, weighing only 23 tons can take a satellite of 400 kg to a 200 km Low Earth Orbit (LEO).

However, this is no longer the case. The US military have under development a concept for air launch using a DC-10 freighter with the rocket inside the cargo hold to be glided out into the air at a height of around 10 km and ignited at a safe distance from the aircraft. This method is of some risk, and has until now not been tested for a real launch, only the concept of dropping the launcher from the DC-10 have been tested.

In this report, the author will for the first time propose an alternative method of using aircraft as the first reusable stage for medium sized rockets up to a launcher weight of 200 tons.

We will first comment upon the three alternative ways to carry the rocket on an airplane and use this aircraft as a flying launch platform:

- The rocket to be carried inside a freighter aircraft, like the DC-10 demonstrator. This method significantly limits the size of the rocket, its length and its diameter and also its weight and therefore its performance. In addition it is risky with a rather delicate method of releasing the rocket from the cargo bay.

- The rocket to be carried on top of the aircraft, like the way the Space Shuttle is transported on top of the Boeing 747 when being freighted from its alternative landing sites back to Cape Kennedy. This method can not be used for actual launch, mainly due to the fact that the aircraft needed to be put upside known before the release of the rocket, and no freighter aircraft is actually designed to be flown upside down.
- The rocket to be carried below the belly of the aircraft like Pegasus or Space Ship 2. This normally would limit the diameter of the launcher to the safe distance between the belly and the ground.

There are now three alternative large freighter aircraft with a capacity to carry much larger rockets than the Pegasus on the Lockheed 1011 and/or the DC-10.

Table 1 shows the main specifications (all figures in metric tons) for the three largest freighters available (or soon to be available).

	Airbus 380	Antonov An-124	Boeing 747-8
Empty weight	280	175	200
Max take-off weight	590	392	310
Normal maximum Cargo weight	150	150	76
Difference between Empty plane and Maximum take-off	310	217	110

Table1. Main specifications for the three largest freighter aircraft.

This table really shows how much larger the Airbus 380 is compared to the Boeing 747-8

With modest fuel requirements because of the distance from airport of start to actual launch coordinates, both the Airbus and the Antonov can carry around 200 tons under their belly, the Airbus with 310 tons in difference of maximum take-off weight and empty weight might carry a 250 ton rocket plus some 50 tons of fuel plus the needed computers and other electronics needed for the launch. This means it could carry a Delta II class launcher. The smallest Delta II weighs 164 tons and can launch a 1600kg satellite to an 800 km Sun Synchronous Orbit (SSO). The largest Delta II weighs 233 tons and can take 3200 kg to 800 km SSO.

However, the ideal launcher for this air launch initial configuration is VEGA, it weighs around 137 tons, it can when launched from Kourou, lift around 1400 kg to 800 km SSO. More important, it is like Pegasus, a Solid Engine Rocket, and much more safe and easier to launch from an aircraft.

Being only 30 meters long and with a maximum diameter of 3 meters it may be arranged to fit under the belly of either the Airbus 380 or the Antonov 124.

How to carry a 130 tons, 30 meters long rocket with 3 meters diameter beneath the belly of a large freighter, where the distance from the aircraft belly to the ground is less than these 3 meters?

Here is the authors' original idea for these ESPI Perspectives:
Use a dedicated aircraft transporter (AT) only for take-off and whose sole purpose is to safely increase the distance from the bottom belly of the aircraft to the ground such that there is sufficient distance for the rocket to be mounted below the belly of the aircraft.

First the author needs to stress that the detailed construction and the method of connecting the rocket to the Airbus 380 freighter and its release need to be both simulated in complete detail and discussed with both design engineers and Airbus 380 pilots. The authors' personal background is in computer science and cybernetics, and I have just had a brief discussion with an Airbus 340 pilot on checking out the main concept.

The mechanical design of the proposed AT is based upon the concept that each of the complete set of wheels (the set of wheels called a bogey) of the aircraft is placed on another set of bogies which lifts the aircraft enough to provide clearance between the aircraft and its connected rocket, to the ground. With a 3 diameters VEGA and normal distance from the aircraft to ground of more than 2 meters, these additional bogies need to lift the aircraft approximately 2 meters with around 1 meter clearing available for the top and the bottom of the rocket. Since all its wheels is positioned directly beneath the wheels of the Aircraft, the AT bogey needs just to have strong and stiff enough vertical beams to carry the load between these two sets of wheels on their respectively bogies. The AT needs to carry up to 560 tons for the Airbus 380.

Each wheel of the aircraft is positioned in a well to transfer the horizontal forces during acceleration and braking between the aircraft and the bogies of the AT. The front AT bogey wheels is designed such that any steering movements of the front wheels of the aircraft above are copied by this front AT bogey.
The computer system controlling the brakes of the aircraft is also controlling the similar computer controlled AT braking system for its corresponding bogey. This system will allow both normal turning and aborted take-offs, however by discussing with a pilot a longer than normal airport landing field is desirable to permit less forceful wheel braking for an aborted take-off.

Note that the AT bogies are physically separated with no connections between them, each is foreseen to be without a driver, and designed such that when the wheels of the aircraft clears completely the well where they have been placed during aircraft acceleration for takeoff, automatic braking and steering will take place.

The Airbus 380 has an extra center bogey. It needs to be investigated if it is necessary to also have an AT bogey beneath this extra center bogey.

When the aircraft is rotated for take-off, special considerations need to be taken into account to make certain the AT bogey beneath the nose wheel of the aircraft will have enough clearance to the rocket. A possible solution is to use a telescopic mast with retracting springs such that the AT front bogey, being temporarily connected to the nose wheels, will follow the nose wheel until reaching sufficient clearance (3 meter above ground). With enough clearance this telescopic mast will be folded due to its springs and the AT front bogey will be free from the aircraft. During aircraft take-off rotation (probably with slow rotation) the aircraft will have its rear wheels upon the AT until the aircraft wheels clear the well of the AT. After complete aircraft separation the AT bogies simply stays on the ground and their breaking system is automatically applied when the load of the transported aircraft disappears. They will be braked and steered by GPS/Galileo, using computer controlled braking of independent sets of wheels.

The runway needs to be long enough to provide both for aircraft take-off and aborted take-offs, and also for all the separated AT bogies to come to a complete stop before the end of the runway. (The Antonov could carry a VEGA and take off using only 1200 meters of runway).

One feature of this design is that the AT will consist of 3 sets of bogies not connected and they can be transported on the actual Airbus 380 launcher aircraft. This makes the system totally independent of any infrastructure on the airport. The aircraft will inside its cargo bay carry these 3 bogies plus the 3 hydraulic jacks needed to lift the aircraft and place the bogies directly beneath the three original sets of bogies of the Airbus 380.

To lift the aircraft with the rocket launcher, three sufficient hydraulic jacks, a large enough gantry crane or a not to steep ramp may be used with the aircraft being lifted or towed to a position directly above the wheels of the AT.

How to best connect and disconnect the rocket to the aircraft needs to be thoroughly simulated, using both computing models and also wind tunnel testing. One rather conventional method is during actual launch to fly the aircraft horizontally in the direction of the desired orbit at the optimal combination of height and speed, assumed to vary between 10-12 km of height and 700-1000 km/hour of speed.

With a vertical slip of the rocket, the rocket will first travel horizontally and soon the gravity will cause the rocket to arrange itself in an angle to the vertical with nozzle down (wings or fins may be used to achieve such position). Just after some seconds the aircraft will be in front of rocket, and when safe distance is assured, the launch control system and its staff located in the aircraft will push the ignite button and the rocket ignites.

The computer controlled guidance system in the rocket will at all times have its own position and position of the aircraft using Galileo/GPS. Using redundant computer systems the rocket will only be ignited when there is absolutely no danger of the rocket hitting the aircraft.

The rocket may be connected to the aircraft using the same system as normally used by launching sounding rockets. The plane is equipped with a long rail (or for better stability, three parallel long rails) which inside the aircraft is connected to the main structure of the circular beams on the aircraft and further strengthened by connecting to beams on the cargo floor for distributing the load of the rocket evenly to the structure of the aircraft.

For controlled drop off, this rail system may be longer than the rocket and may extend further back of the aircraft, making certain that there is no danger for the rocket to hit the airplane during drop off.

In preparing for the launch the aircraft will either fly horizontally or at maximum permitted angle of attack and pointing directly to the desired orbit, with maximum climb speed. Simulation will determine the best method.

When the aircraft reaches the desired coordinates for the actual launch, the rocket will be mechanically released by command from the aircraft. The Rocket will glide down the rail the same way as sounding rocket launching, except that now gravity will cause the rocket to glide down, and into the thin air around 10-11 km height, and disconnecting its umbilical cord at drop-off.

After drop-off the on board navigation computers will take over and when safe distance from the aircraft is achieved the rocket engine will be ignited, and with steerable nozzles the guidance system will put the rocket on the right track to its desired orbit. An umbilical cord has connected the launcher computers to the launch support system onboard the aircraft the same way as for a ground launch. Compared to a normal ground launch, the complete infrastructure found in the so-called “block-house” is in the aircraft. GPS/Galileo will provide for low cost tracking also assisted by ground radars and telemetry going both directly to the aircraft and to the ground. All such systems are routinely used with the air launch of Pegasus.

It must be mentioned like a launch from the ground, when the first stage of a multi stage rocket have been started, there is no way going back. With air launch when the aircraft rotates and leaves the AT, it means the first stage has been ignited and the launcher is either successful, or if any failure before drop off, it would have to be dropped in the ocean and a launch failure have occurred. Remember though that air launch will be used for manned rocket flights with Space Ship 2; with solid rockets the probability of engine failure is very low.

There are many advantages with using an aircraft as a reusable first stage:

- Actual launch will always be over an ocean, minimizing safety concerns and restrictions for launch.
  Launchings will always take place from the most energy efficient location, if final orbit is Geostationary, the aircraft will fly to 10 km above an ocean point at the Equator with many airports to choose from, an obvious one is Cayenne in French Guiana. If other inclinations the starting point has a latitude equal to the inclination of the final orbit. (Launchings to ISS will be from 56 degrees North or South).
- No need for expensive launch towers and other ground infrastructure, only need is an airport.
- Dramatically reduced costs for launch campaigns due to more computerized systems and far fewer people involved.
- Satellite payload integration may be done either where the satellite is integrated or where the rocket launcher is integrated. Both the Airbus 380 and the Antonov have a range up to more than 10 000 km, to allow for any combination of integration location and coordinates for drop off and launch.
- The aircraft may be used for normal commercial business between launch campaigns, no changes to the aircraft which reduces its commercial potential as a freighter.
- Much less dependence on weather conditions, if the aircraft can take off, then the actual launch can take place, at 10-12 km height above ground well above possible clouds, thunderstorms and winds.
- More flexibility in timing of a launch, the aircraft can fly to a location where there is a possible launch window, allowing flexibility in aircraft take off timing.
- Higher performance mainly due to the start height of 10-12 km where the air is less dense with much less friction, the delta-v is less important (720 km/hour is only 0,2 km/s) and around 3% of the needed speed to reach orbit (Mach 27 or 7.2 km/s)
- Less stress on the launcher, much lower acoustic stress and no need for water tower to reduce acoustic noise.

The increased performance of the current VEGA for an 800km SSO is from 1470kg to between 1700kg and 1800kg according to initial preliminary calculations or up to 22%.

The current VEGA and the current Airbus 380 Freighter is a natural initial combination to make competitive satellite launchings with all the benefits described above.

However, even more important will be the next step by combining the full potential of the largest Airbus 380 freighter with an optimal combination of rocket stages. These stages to come from a combination of the current VEGA and/or from the Ariane 5 Solid Rocket Booster (each of Ariane 5 boosters weigh 237 tons in current configuration) with a new specially designed 4^{th} stage with reignitable capabilities. I am convinced this is the way to compete with the Falcon 9 from SpaceX.

An air launched rocket has much less structural load and will therefore, if specially designed for air launch be lighter and have better performance. It need to be investigated what can be achieved of performance with an optimal use of the Airbus 380. This combination could launch multiple Galileo satellites directly to their final orbits.

The authors' intuition tells him it will be possible to launch a typical communication satellite directly to its final Geostationary Orbit without a transfer orbit. This is a huge potential for Europe's space industry if they could deliver directly to the final orbit such a state-of-the art solution with a new generation of communication satellites optimized for this much lower cost launching.

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