Skylon (spacecraft)

Skylon is a design for a single @-@ stage @-@ to @-@ orbit spaceplane by the British company Reaction Engines Limited (REL) , using SABRE , a combined @-@ cycle , air @-@ breathing rocket propulsion system , potentially reusable for 200 flights . In paper studies , the cost per kilogram of payload carried to low Earth orbit in this way is hoped to be reduced from the current £ 1 @,@ 108 / kg (as of December 2015) , including research and development , to around £ 650 / kg , with costs expected to fall much more over time after initial expenditures have amortised . In 2004 , the developer estimated the total lifetime cost of the programme to be about $ 12 billion .

The vehicle design is for a hydrogen @-@ fuelled aircraft that would take off from a purpose @-@ built runway , and accelerate to Mach 5 @.@ 4 at 26 kilometres (16 mi) altitude using the atmosphere 's oxygen before switching the engines to use the internal liquid oxygen (LOX) supply to take it into orbit . Once in orbit it would release its payload (of up to 15 tonnes) . The vehicle will be unpiloted , but also be certified to carry passengers . All payloads could be carried in a standardised container compartment . The relatively light vehicle would then re @-@ enter the atmosphere and land on a runway , being protected from the conditions of re @-@ entry by a ceramic composite skin . When on the ground , it would undergo inspection and necessary maintenance . If the design goal is achieved , it should be ready to fly again within two days .

As of 2012 , only a small portion of the funding required to develop and build Skylon had been secured . The research and development work on the SABRE engine design is proceeding under a small European Space Agency (ESA) grant . In January 2011 , REL submitted a proposal to the British government to request additional funding for the project and in April REL announced that they had secured $ 350 million of further funding contingent on a test of the engine 's precooler technology being successful . Testing of the key technologies was successfully completed in November 2012 , allowing Skylon 's design to advance to its final phase . On 16 July 2013 the British government pledged £ 60M to the project : this investment will provide support at a " crucial stage " to allow a full @-@ scale prototype of the SABRE engine to be built .

If all goes to plan , the first ground @-@ based engine tests could happen in 2019 , and Skylon could be performing unmanned test flights by 2025 . It could carry 15 tonnes of cargo to a 300 km equatorial orbit on each trip , and up to 11 tonnes to the International Space Station , almost 45 % more than the capacity of the European Space Agency 's ATV vehicle .

Research and development programme

Background and early work

Skylon is based on a previous project of Alan Bond , known as HOTOL . The development of HOTOL began in 1982 , at a time when space technology was moving towards reusable launch systems such as the Space Shuttle . In conjunction with British Aerospace and Rolls @-@ Royce , a promising design emerged to which the British government contributed £ 2 million . However , in 1988 , the government withdrew further funding , and development was terminated . Following this setback , Bond decided to set up his own company , Reaction Engines Limited , with the hope of continuing development with private funding .

After securing more funding in the 1990s , the initial design underwent radical revision and , since 2000 , Reaction Engines has been working with the University of Bristol to develop an engine design vital to the success of Skylon . The STRICT / STERN designs resulting from this programme were deemed a great success . The next stage of development will be to construct a full @-@ sized working prototype of the SABRE Engine .

There are several differences compared with HOTOL . Whereas HOTOL would have launched from a rocket sled , to save weight , Skylon uses a conventional retractable undercarriage . Skylon 's revised engine design , the SABRE engine , is expected to offer higher performance . HOTOL 's rear mounted engine gave the vehicle intrinsically poor in @-@ flight stability . Early attempts to fix this problem had ended up sacrificing much of HOTOL 's payload potential , and contributed to the failure of the project . Skylon solves this by placing engines at the end of its wings , but further forward and much closer to the vehicle 's centre of mass longitudinally .

= = = Project brief = = =

REL intends ultimately to operate as a for @-@ profit commercial enterprise , manufacturing Skylon vehicles for multiple international customers ; these customers will operate their fleets directly , with support from REL . While REL intends to manufacture some components directly , such as the engine precooler , other components have been designed by partner companies and a consortium of various aerospace firms is expected to handle full production of Skylon . According to Management Today , Skylon has been discussed as a possible replacement for NASA 's Space Shuttle .

In service , Skylon could potentially lower satellite launch costs from the current £ 15 @,@ 000 / kg to £ 650 / kg , according to evidence submitted to the UK parliament by Reaction Engines Ltd . Funding for the project from the British government has often been difficult to obtain . Speaking on the topic of Skylon in 2011 , David Willetts , the UK Minister of State for Universities and Science , stated :

The European Space Agency is funding proof of concept work for Skylon from UK contributions . This work is focusing on demonstrating the viability of the advanced British engine technology that would underpin the project . Initial work will be completed in mid 2011 and if the trial is successful , we will work with industry to consider next steps .

= = = Funding and engine development = = =

An unsuccessful request for funding from the British government was issued in 2000 . This involved a proposal offering a potentially large return on investment . Subsequent discussions with the British National Space Centre (which later became the UK Space Agency) led to a major funding agreement in February 2009 between the British National Space Centre , European Space Agency (ESA) and REL for ? 1 million ($ 1 @.@ 28 million) to produce a demonstration engine for Skylon by 2011 .

The Technology Demonstration Programme will last approximately 2 @.@ 5 years and will benefit from another ? 1 million from ESA . This programme will take Reaction Engines Ltd from a Technology Readiness Level (TRL) of 2 / 3 up to 4 / 5 . The former UK Minister for Science and Innovation in 2009 , Lord Drayson , commented on Skylon in a speech : " This is an example of a British company developing world @-@ beating technology with exciting consequences for the future of space . "

As of 2012 , the funding required to develop and build the entire craft has not yet been secured , and so current research and development work is focused on the engines , under an ESA grant of ? 1 million . In January 2011 , REL submitted a proposal to the British Government requesting additional funding for the Skylon project . On 13 April 2011 , REL announced that the Skylon design had passed several rigorous independent reviews . On 24 May 2011 , ESA publicly declared the design to be feasible , having found " no impediments or critical items " in the proposal .

The major milestone of the commencement of static testing of the engine precooler and the SABRE engine was achieved in June 2011 , marking the start of Phase 3 in the Skylon development programme . An REL spokesperson announced that they had secured $ 350 million of further funding , contingent on successful completion of the full @-@ sized precooled jet engine test in June 2011 . Engine testing was initiated in June 2011 , and was expected to continue to the end of that year . However , testing was delayed until April 2012 .

On 9 May 2011 , REL stated that a preproduction prototype of the Skylon could be flying by 2016 , and the proposed route would be a suborbital flight between the Guiana Space Centre near Kourou in French Guiana and the North European Aerospace Test Range , located in northern Sweden . Pre @-@ orders are expected in the 2011 ? 2013 time frame coinciding with the formation of the manufacturing consortium . On 8 December 2011 , Alan Bond , speaking at the 7th Appleton Space Conference , stated that Skylon would enter into service by 2021 @-@ 2022 instead of 2020 as previously envisaged .

In April 2012 , REL announced that the first phase of the precooler test programme had been successfully completed . On 10 July 2012 , REL announced that the second of three series of tests has been completed successfully . The test facilities underwent upgrades to allow the third and final phase of testing to proceed . On 13 July 2012 , ESA Director @-@ General Jean @-@ Jacques Dordain told Space News that ESA would hold talks with REL to develop a further " technical understanding " .

Following a successful propulsion system test that was audited by ESA 's propulsion division in mid @-@ 2012 , the company announced that it would begin a three @-@ and @-@ a @-@ half @-@ year project to develop and build a test rig of the Sabre engine to prove the engine 's performance across its air @-@ breathing and rocket modes . In November 2012 , it was announced that a key test of the engine precooler had been successfully completed , and that ESA had verified the precooler 's design . The project 's development is now allowed to advance to its next phase , which involves the construction and testing of a full @-@ scale prototype engine . In June 2013 , George Osborne , The Chancellor of the Exchequer stated on his Twitter account that the British government would be giving £ 60 million towards the further development of the SABRE engine . Osborne 's tweet stated : " Just seen SABRE -a rocket engine that cools air from 1000 degrees to -150 in fraction of a second . We 're backing the future with £ 60m funding " . The first grant of £ 50 million was approved by the European Commission in August 2015 . The second grant of £ 10 million was approved by the European Space Agency in July 2016 .

In October 2015 , BAE Systems entered into an agreement with Reaction Engines where it would invest £ 20 @.@ 6 million in Reaction Engines to acquire 20 % of its share capital and help develop the SABRE engine .

= = Technology and design = =

= = = Overview = = =

Skylon is a fully reusable single stage to orbit (SSTO) vehicle , able to achieve orbit without staging . Proponents of SSTO claim that staging causes a number of problems due to its complexity that includes being difficult or impossible to recover and reuse many parts , leading to great expense , and therefore believe that SSTO designs hold the promise of reducing the cost of space @-@ flight . It is intended for Skylon to take off from a specially strengthened runway , fly to low earth orbit , re @-@ enter the atmosphere , and land upon a runway like a conventional aeroplane .

The design of the Skylon C2 features a large cylindrical payload bay , 13 m (42 ft 8 in) long and 4 @.@ 8 m (15 ft 9 in) in diameter . It is designed to be comparable with current payload dimensions , and able to support the containerisation of payloads that Reaction Engines hopes for in the future . To an equatorial orbit , Skylon could deliver 15 t (33 @,@ 000 lb) to a 300 km (190 mi) altitude or 11 t (24 @,@ 000 lb) to an 800 km (500 mi) altitude . Using interchangeable payload containers , Skylon could be fitted to carry satellites or fluid cargo into orbit , or , in a specialised habitation module , up to 30 astronauts in one launch .

Because the engine uses the atmosphere as reaction mass at low altitude , it will have a high specific impulse (around 2 @,@ 800 seconds) , and burn about one fifth of the propellant that would have been required by a conventional rocket . Therefore , it would be able to take off with much less total propellant than conventional systems . This , in turn , means that it does not need as much lift or thrust , which permits smaller engines , and allows conventional wings to be used . While in the atmosphere , using wings to counteract gravity drag is more fuel @-@ efficient than simply expelling propellant (as in a rocket) , again reducing the total amount of propellant needed .

The payload fraction would be significantly greater than normal rockets and the vehicle should be fully reusable (200 times or more) .

= = = SABRE engines = = =

One of the most significant features of the Skylon design is the engine , called SABRE . The engines are designed to operate much like a conventional jet engine to around Mach 5 @.@ 5 (1 @,@ 700 m / s) , 26 kilometres (16 mi) altitude , beyond which the air inlet closes and the engine operates as a highly efficient rocket to orbital speed . The proposed SABRE engine is not a scramjet , but a jet engine running combined cycles of a precooled jet engine , rocket engine and ramjet . Originally the key technology for this type of precooled jet engine did not exist , as it required a heat exchanger that was ten times lighter than the state of the art . Research conducted since then has achieved the necessary performance .

Operating an air @-@ breathing jet engine at velocities of up to Mach 5 @.@ 5 poses numerous engineering problems . Several previous engines proposed by other designers worked well as jet engines but performed poorly as rockets . This engine design aims to be a good jet engine within the atmosphere , as well as being an excellent rocket engine outside . The problem with operating at Mach 5 @.@ 5 has been that the air coming into the engine rapidly heats up as it is compressed into the engine ; due to certain thermodynamic effects , this greatly reduces the thrust that can be produced by burning fuel . Attempts to avoid these issues typically make the engine much heavier (scramjets / ramjets) or greatly reduce the thrust (conventional turbojets / ramjets) . In either case the end result is an engine that has a poor thrust to weight ratio at high speeds , resulting in an engine that is too heavy to assist much in reaching orbit .

The SABRE engine design aims to avoid this by using some of the liquid hydrogen fuel to cool helium in a closed @-@ cycle precooler , which quickly reduces the temperature of the air at the inlet . The air is then used for combustion much like in a conventional jet , and once the helium has left the pre @-@ cooler it is further heated by the products of the pre @-@ burner , giving it enough energy to drive the turbine and the liquid hydrogen pump . Because the air is cooled at all speeds , the jet can be built of light alloys and the weight is roughly halved . Additionally , more fuel can be burnt at high speed . Beyond Mach 5 @.@ 5 , the air would become unusably hot despite the cooling , so the air inlet closes and the engine relies solely on on @-@ board liquid oxygen and hydrogen fuel as in a normal rocket .

= = = Fuselage and structure = = =

The fuselage of Skylon is expected to be a carbon @-@ fiber @-@ reinforced polymer space frame ; a light and strong structure that supports the weight of the aluminium fuel tanks and to which the ceramic skin is attached . Multiple layers of reflective foil thermal insulation fill the spaces of the frame .

The currently proposed Skylon model C2 will be a large vehicle , with a length of 82 metres (269 ft) and a diameter of 6 @.@ 3 metres (21 ft) . Because it will use a low @-@ density fuel , liquid hydrogen , a great volume is needed to contain enough energy to reach orbit . The propellant is intended to be kept at low pressure to minimise stress ; a vehicle that is both large and light has an advantage during atmospheric reentry compared to other vehicles due to a low ballistic coefficient . Because of the low ballistic coefficient , Skylon would be slowed at higher altitudes where the air is thinner . As a result , the skin of the vehicle would reach only 1 @,@ 100 K (830 ° C) . In contrast , the smaller Space Shuttle was heated to 2 @,@ 000 K on its leading edge , and so employed an extremely heat @-@ resistant but fragile silica thermal protection system . The Skylon design does not require such a system , instead opting for using a far thinner yet durable reinforced ceramic skin . However , due to turbulent flow around the wings during re @-@ entry , some parts of Skylon would need to be actively cooled .

= = = = Wheels and runway = = = =

At a gross takeoff weight of 275 tonnes , of which 220 tonnes is propellant , the vehicle is capable of placing 12 tonnes into an equatorial low Earth orbit . A reinforced runway will be needed to tolerate the high equivalent single wheel load . It will possess a retractable undercarriage with high pressure tyres and water @-@ cooled brakes . If problems were to occur just before a take @-@ off the brakes would be applied to stop the vehicle , the water boiling away to dissipate the heat . Upon a successful take @-@ off , the water would be jettisoned , thus reducing the weight of the undercarriage , in the C1 design 1200 kg of water allows the weight of the brakes alone to be reduced from over 3000 kg to around 415 kg . During landing , the empty vehicle would be far lighter , and hence the water would not be needed .

Specifications (Skylon D1)

Data from the Skylon User Manual
General characteristics
Crew : None , remote controlled from ground
The proposed Skylon Personnel / Logistics Module (SPLM) has provision for a Captain .
Capacity : 0
up to 24 passengers in the SPLM
Potential for up to 30 passengers (in a special passenger module)
Payload : 15 @,@ 000 kg nominal (33 @,@ 000 lb nominal) 17 @,@ 000 kg (37 @,@ 000 lb) to equatorial 160 km (99 mi) orbit from equatorial launch site
approx 2 @,@ 800 kg (6 @,@ 200 lb) to 98 ° (sun @-@ synchronous) 600 km (373 mi) orbit from equatorial launch site
Length : 83 @.@ 133 m (272 @.@ 75 ft)
Wingspan : 26 @.@ 818 m (87 @.@ 99 ft)
Height : approx 13 @.@ 5 m (44 ft)
Empty weight : 53 @,@ 400 kg (117 @,@ 000 lb)
Loaded weight : 325 @,@ 000 kg (717 @,@ 000 lb)
Powerplant : 2 × SABRE 4 synergistic combined cycle rocket engine , 2 @,@ 000 kN (450 @,@ 000 lbf) each
Fuselage diameter : 6 @.@ 3 m (20 @.@ 67 ft)
Performance
Maximum speed : Orbital (air @-@ breathing Mach 5 @.@ 14 , rocket Mach 27 @.@ 8)
Service ceiling : 28 @,@ 500 m air @-@ breathing , 90 km SABRE ascent , 600 km exoatmospheric (93 @,@ 500 ft air breathing , 56 mi rocket ascent , 373 mi exoatmospheric)
Specific impulse : 4 @,@ 100 seconds (40 @,@ 000 N @-@ s / kg) -9,200 seconds (90 @,@ 000 N @-@ s / kg) air @-@ breathing , 460 seconds (4 @,@ 500 N @-@ s / kg) rocket , 465 @.@ 2 seconds (4 @,@ 562 N @-@ s / kg) orbital
SABRE engine thrust / weight ratio : up to 14 atmospheric