

= Black Arrow =

Black Arrow , officially capitalised BLACK ARROW , was a British satellite carrier rocket . Developed during the 1960s , it was used for four launches between 1969 and 1971 . Its final flight was the first and only successful orbital launch to be conducted by the United Kingdom , and placed the Prospero satellite into low Earth orbit .

Black Arrow originated from studies by the Royal Aircraft Establishment for carrier rockets based on the Black Knight rocket , with the project being authorised in 1964 . It was initially developed by Saunders @-@ Roe , and later Westland Aircraft as the result of a merger .

Black Arrow was a three @-@ stage rocket , fuelled by RP @-@ 1 paraffin (kerosene) and high test peroxide , a concentrated form of hydrogen peroxide . It was retired after only four launches in favour of using American Scout rockets , which the Ministry of Defence calculated to be cheaper than maintaining the Black Arrow programme .

= = Development = =

Black Arrow originated from a Royal Aircraft Establishment proposal for a rocket capable of placing a 317 @-@ pound (144 kg) payload into low Earth orbit , in order to test systems designed for larger spacecraft . In the autumn of 1964 , the programme was authorised by Conservative Aviation Minister Julian Amery . Then , following a general election in October , the incoming Labour government put the project on hold to reduce expenditure . Following another election , the government approved the continuation of the programme with several modifications , including the reduction of the test programme from five to three launches . The first launch was set for 1968 .

Most of the technology and systems used on Black Arrow had already been developed or flight @-@ proven on the Black Knight rocket , or the Blue Steel missile . Black Arrow was designed to reuse as much technology from the earlier programmes as possible in order to reduce costs , and simplify the development process . Many senior staff of the Black Knight programme transferred directly to Black Arrow , including the Chief Missile Scientist , Roy Dommett , the Chief Design Engineer , Ray Wheeler and the Deputy Chief Engineer , John Underwood .

Initial development was conducted by Saunders @-@ Roe , which merged into Westland Aircraft in 1964 . Westland was subsequently the prime contractor for the Black Arrow , and assembled the first and second stages at East Cowes on the Isle of Wight . Bristol Siddeley produced the first and second stage engines at a factory in Ansty , Warwickshire . The engines were test fired at the factory before being shipped to the Isle of Wight , where they were integrated into the rocket and the first stage engines were fired again at High Down . Bristol Aerojet produced the third stage in Somerset , while the Explosives Research and Development Establishment produced its solid propellant in Waltham Abbey , Essex . The Rocket Propulsion Establishment , based in Westcott , Buckinghamshire , was responsible for the design and integration of the stage .

The name Black Arrow came from the Ministry of Supply policy of assigning designations consisting of a colour and a noun , unofficially known as Rainbow Codes , to research programmes conducted by the Armed Forces .

= = Vehicle = =

The first and second stages of the Black Arrow were fuelled by RP @-@ 1 paraffin (kerosene) , burnt using high test peroxide as an oxidiser . Due to the optimum mixture ratio being about 7 , a larger oxidiser tank was required compared to many contemporary launch systems . The oxidiser tanks were located below the fuel tanks , following the practice of putting the more dense propellant at bottom in order to lower the centre of gravity and make the rocket easier to control . This arrangement had been pioneered by Germany and the United States , whereas the Soviet Union had placed oxidiser tanks above fuel tanks , making it easier for the lower tank to be filled first .

Thrust vectoring was used to provide attitude control on the first two stages . The eight first stage combustion chambers were arranged in pairs which could gimbal either way along one axis . Two of

the pairs were arranged perpendicular to the other two , and when all four pairs were used together , they provided roll , pitch and yaw control . The second stage had two combustion chambers , which could gimbal along two axes , providing the same level of control . During a coast phase after second stage cut @-@ off , the rocket was controlled by a reaction control system . The third stage did not have an attitude control system , and was instead spin @-@ stabilised .

The first stage was powered by a single Gamma 8 engine , which burned for 127 seconds . The Gamma 8 was an eight @-@ chamber engine , derived from the Gamma 301 engine used on the Black Knight . It was 6 @.@ 9 metres (23 ft) long , and had a diameter of 2 metres (6 ft 7 in) , the same diameter as the French Coralie . Coralie was used as the second stage of the Europa rocket , and the decision to give Black Arrow the same diameter as Coralie was taken in order to make it compatible with Blue Streak , which was used as the first stage of Europa . This would have allowed Black Arrow 's payload capacity to have been increased , and would also have allowed Britain to use the first stage of Black Arrow as a backup to the Coralie . For this reason , all dimensions in the original specification were given in imperial units except the first stage diameter , which was given in metres .

The first and second stages were connected by an interstage structure containing four Siskin IB separation and ullage motors , which separated and ignited seven seconds after the first stage had cut off . The interstage separated from the second stage six seconds later . The second stage , which was 2 @.@ 9 metres (9 ft 6 in) long and measured 1 @.@ 37 metres (4 ft 6 in) in diameter , was powered by a two @-@ chamber Gamma 2 engine which ignited shortly after the separation motors , and continued to burn for 123 seconds . Three minutes after launch , during the second stage burn , the payload fairing separated .

About 257 seconds into the flight , the second stage cut off , and the rocket entered a coast phase to apogee . Immediately after cut @-@ off , the second stage attitude control system was pressurised . During the coast the correct orientation for third stage separation was maintained by means of the attitude control system . Towards the end of the coast period , the third stage was spun up to a rate of 3 hertz (180 rpm) by means of six Imp rockets . Five seconds later , the third stage separated , and following ten more seconds of coasting , it ignited . The third stage was a Waxwing solid rocket motor , which burned for 55 seconds .

Just over a minute after the third stage had burned out , the payload was released , and gas generators were used to push the spacecraft and spent upper stage apart . The delay between burnout and separation was intended to reduce the risk of recontact between the upper stage and payload due to residual thrust . Despite this , following spacecraft separation on the R3 launch , the upper stage collided with the Prospero satellite , damaging one of the spacecraft 's communications antennae ; however the spacecraft was still able to successfully complete its mission . On the R3 launch , the ascent took 710 seconds (11 @.@ 8 min) from liftoff to spacecraft separation .

Although none were ever built , several derivatives of Black Arrow were also proposed , as ways of increasing its payload capacity . One proposal added eight Raven solid rocket motors from the Skylark programme to the first stage as booster rockets . Another suggestion was to mount the entire rocket atop a Blue Streak missile , while a third proposal involved replacing the Gamma engines with the more powerful Larch .

= = Launches = =

Four Black Arrows were launched between 1969 and 1971 . The first two launches were demonstration flights , with battleship third stages and a boilerplate payload . On the first flight an electrical fault caused a pair of first stage combustion chambers to pivot back and forth . Before it cleared the launch pad , the rocket was rolling erratically , and about a minute later it began to disintegrate . After the first stage engine failed , and the rocket began to fall back to earth , it was destroyed by range safety . The second launch was successful . The first all @-@ up launch on 2 September 1970 was the third launch of the Black Arrow , and Britain 's first attempt to launch a satellite . The launch failed due to a leak in the second stage oxidiser pressurisation system , which caused it to cut out early . The third stage fired , but the rocket did not reach orbit , and re @-@

entered over the Gulf of Carpentaria . The fourth launch successfully orbited the Prospero satellite , making the United Kingdom the sixth nation to place a satellite into orbit by means of an indigenously developed carrier rocket . The satellite , also known as X @-@ 3 , was named Prospero after the character Prospero in Shakespeare 's The Tempest . The name was chosen as a reference to events in the play , in which Prospero , a sorcerer , gives up his powers . Prior to the cancellation of the Black Arrow programme , the satellite was to be named after Puck from A Midsummer Night 's Dream .

All four launches were conducted from Launch Area 5B at the Woomera Prohibited Area in Australia , which had previously been used as a test site for the Black Knight rocket . During the development programme , launch sites in Barbados , Uist and Norfolk were also considered . The launch sites at Uist and Norfolk were rejected because the former was too remote , while there was a risk that a rocket launched from the latter might drop spent stages on an oil rig in the North Sea .

= = Cancellation = =

The Minister of State for Trade and Industry , Frederick Corfield , announced the cancellation of the Black Arrow project in the House of Commons on 29 July 1971 . As the R3 rocket had already been shipped to the launch site , the second stage having arrived three days earlier , permission was given for it to be launched .

The programme was cancelled on economic grounds , as the Ministry of Defence decided that it would be cheaper to use the American Scout rocket , which had a similar payload capacity , for future launches . Prior to the cancellation of Black Arrow , NASA had offered to launch British payloads for free ; however , this offer was withdrawn following the decision to cancel Black Arrow .

The final Black Arrow to be completed was R4 , which did not fly , and is preserved in the Science Museum , London , along with the flight spare for the Prospero satellite . A replica of the Black Arrow rocket stands in the Rocket Park at Woomera . In addition , the remains of the first stage of Black Arrow R3 were recovered from the Anna Creek cattle station and are displayed in the William Creek Memorial Park .

The launch facilities at Woomera were demolished within a year of the final flight , and half of the engineers who had worked on the programme were laid off . The X @-@ 4 satellite , which had been manifested for launch by Black Arrow R4 , was eventually launched on 9 March 1974 , by an American Scout D @-@ 1 rocket flying from Space Launch Complex 5 at the Vandenberg Air Force Base in California .

As of 2014 , the United Kingdom is the only country to have successfully developed and then abandoned a satellite launch capability . All other countries that have developed such a capability have retained it either through their own space programme or , in the case of France , through its involvement in the Ariane programme .