This paper traces the line of descent from Black Knight to Black Arrow, and at the same time looks at various proposed projects, both civil and military, which were to be Black Knight derivatives, but which for one reason or another never saw the light of day. Research in this area is rather akin to anthropological work, tracing fossils from Homo erectus (Black Knight) to Homo sapiens (Black Arrow), knowing that a lot of the fossils found will not be on the direct line of descent, but represent branches that became extinct. This article attempts to cover designs, which, although they never made it to hardware, are none the less interesting technically, or shine light on the evolution of design philosophy.

1. The “Shining” Black Knight

Black Arrow is the only descendent of Black Knight that survived to operational hardware. As a launch vehicle for re-entry studies, Black Knight was an outstanding success (fig. 1). Black Arrow’s active life was too short to make an effective judgement of its reliability or effectiveness, but it also had the potential to become as successful. It can be argued that many of the other proposals to be outlined in this paper were technically driven rather than driven by policy, and that is one of the reasons that they never made the light of day. All of these, except of course Black Knight and Black Arrow, remained as paper studies. Some paper studies were more significant than others, and only failed to make it through to hardware as a result of budgetary cuts rather than as a result of any technical shortcomings. However, it is interesting from various standpoints to look at those studies. They can be considered as ‘might have beens’. They can be looked at in terms of the technology they were to have used. They can also be used to point up the lack of a UK coherent space programme.

The rationale behind Black Knight is not difficult to find. In 1955 the UK was about to embark on an extremely expensive and ambitious project in the form of the large ballistic missile, Blue Streak, without any previous significant British background experience in rocketry other than the launch of three V2s in Operation Backfire immediately after the war. Black Knight would give experience in a host of fields: guidance, instrumentation, steering by the use of gimballed engines, and general hands-on experience [1]. In addition, it had a more specific task to carry out: the testing of the design concept for the re-entry head which would carry the nuclear warhead of Blue Streak.

Given that Black Knight was the UK’s first sub-
stantial liquid fuelled ballistic rocket, it was extremely successful. The first four launches effect-
vively covered the whole programme of vehicle prov-
ing and re-entry head validation [2]. All the follow-
on launches but one were carried out, often in con-
junction with the US, to study re-entry phenomena.

One of the principal reasons for this was to dis-
cover the observables during re-entry, with the
thought of ballistic missile defences in mind. The
UK would eventually decide that an antiballistic de-

fence was beyond its own capabilities, but it also
wanted to ensure that its own re-entry vehicles would
be as difficult to observe as possible. Hence the
Gaslight and Dazzle programmes were set up, us-
ing Black Knight in successively improved forms,
as the launch vehicle.

Indeed, Black Knight was so successful (and
cheap! Vehicles were costed at £41,000 each [3])
that the design was considered for a variety of
areas where it was less than suitable. The original
design was crucially that much too small to be a
first stage for a satellite launcher (indeed, too small
for a second stage for Blue Streak [4]).

The original Black Knight engine was the Gamma
201, which derived from a relatively early design
produced at RPD Westcott in the early 1950s. BK16,
which was launched in August 1962, was the first
Black Knight to use the new Gamma 301 engine.
This had a slightly greater thrust - initially 16,800 lb
- in order to cope with the extra payload and upper
stage, yet the lift-off acceleration was kept at 1.3g.
But it had also been substantially redesigned: the
combustion chambers in this engine were derived
from the small combustion chamber of Stentor, the
engine powering the stand-off bomb, Blue Steel.
According to its specification in Blue Steel, it “is to
be capable of producing a smoothly variable thrust
from a minimum of 1000 lb to a maximum of 6,200 lb
at 45,000 f/s”. Hence 4,200 lb was eminently feasi-
ble. Various other improvements were also incorpo-
rated relating to fuel/oxidant mixture ratio control
and other features. It should be noted, however,
that the Gamma 301 could easily be uprated to 4 x
6,200 lb - i.e., 25,000 lb thrust, and it was this ver-
sion that was almost always considered in any Black
Knight derivative. Indeed in the last six Black Knight
flights (BK19 to BK25), the engine was used at a lift-
off thrust of around 21,500 lbs.

Why were there so many designs descending
from Black Knight? It was a highly successful vehi-
cle - the launcher almost always worked even when
the experiments did not. The job Black Knight was
given to do made it more tolerant of faults. Failures
which would have jeopardised orbital attempts had
less impact on re-entry studies. The very first flight
of all, BK01, ended prematurely when the destruct
system operated inadvertently. There were also
problems with engine overheating leading to kero-
sene starvation and resultant long “cold thrusting”,
particularly in the second (BK03) and fourth flights
(BK05), but again, these were solved relatively early
in the programme. Cold thrust occurs when the en-
gine consumes HTP in the absence of kerosene:
decomposition still takes place, but the thrust and
the SI is very sharply reduced. In addition, on many
flights the kerosene was exhausted before the HTP,
resulting in a few seconds of cold thrust after “all
burnt”. The discrepancy between the calibration
during test firing and the actual launch was never
pinned down.

The following Black Knight launches can be de-
scribed as completely successful from the first stage
viewpoint - 15 of the 22 launched:

BK 04, 06, 08, 09, 13, 17, 15, 16, 18, 11, 19, 20, 21,
24, 25.

(NB: the ordering is the order in which the vehicles
were fired.)

Others:

BK 01’s self destruct mechanism was accidentally
triggered near the end of the flight.

BK 03 and 05: overheating in the engine bay led to
a fuel lock in the kerosene pipes, and a long period
of cold thrusting was the result. This was due to
reverse flow into the engine bay at supersonic
speeds from interactions of the plumes from the
four motors.

BK 07: One chamber reverted to cold thrust after
100 seconds. Over 80% nominal velocity achieved.

BK 14: Pipe failure caused loss of kerosene: cold
thrust after 130 seconds. 85% nominal velocity
achieved.

BK 12: 6.8% difference in mixture ratio between
flight and calibration.

BK 23: Premature shut down of engine due to
gearbox failure 3 seconds before expected flame
out [5].

Of the 22 flights listed above, seven would not
have made it to orbit if they had been satellite launch
vehicles. To be fair, however, as a very first attempt
at a modern liquid fuel ballistic vehicle, this is a
fairly good record! It is also a tribute to the engi-
ners at Saunders Roe and at Armstrong Siddeley
Motors. However, it would be also be fair to say that
Black Knight was not designed as a satellite launch
vehicle, but instead to project a re-entry vehicle to
the greatest possible velocity, and so the criteria were different. For the job it was intended for, it was very successful, but it does not then follow that it would be equally successful in a different and more demanding role.

But as a potential satellite launcher even the Gamma 301 Black Knight was far too small. Indeed, as mentioned, it was even too small for the second stage of Black Prince - the proposed three stage satellite launcher based on Blue Streak and Black Knight, and another ‘might have been’. In addition, even the Gamma 301 version did not carry a payload of more than a few hundred pounds, including the second stage Cuckoo II motor, implying that it could not then carry the upper stages needed to put even a small technology satellite into orbit. However, reading back to the specification for the Stentor engine, it should be noted that the chamber was capable of producing a maximum of 6,200 lb thrust [6] - or 25,000 lb for a four chambered engine. This thrust would allow a lift-off mass of around 19,000 lb, and since Black Knight itself weighed 13,000 lb all up, this left up to 6,000 lb for upper stages and payload, although the first stage would need some structural strengthening. Such a weight distribution could have meant reasonably efficient stage matching.

At this point it is worth doing some comparisons between Black Knight and the first stages of two other “first time” satellite launchers: Vanguard and Diamante:

This does tend to indicate that by the early 1960s a satellite launcher based around a basic Black Knight core was not really a viable proposition.

<table>
<thead>
<tr>
<th>First Stage</th>
<th>Weight</th>
<th>Thrust</th>
<th>Burn time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black Knight</td>
<td>13,000 lb</td>
<td>25,000 lb*</td>
<td>100 seconds (approx)*</td>
</tr>
<tr>
<td>Vanguard</td>
<td>16,850 lb</td>
<td>27,000 lb</td>
<td>144 seconds</td>
</tr>
<tr>
<td>Diamante</td>
<td>32,400 lb</td>
<td>62,000 lb</td>
<td>93 seconds</td>
</tr>
</tbody>
</table>

*uprated to maximum thrust level.

2. "Mix and Match" Space Launchers

The Blue Streak/Black Knight combination, often referred inelegantly to as the BSSLV (Blue Streak Satellite Launch Vehicle) in official files [7,8], or as Black Prince after the Saunders Roe brochure, was criticised on the grounds that the stages were mismatched. This is to some extent true, and was true for Europa as well. The fault lay as much with Blue Streak as with Black Knight: with a first stage mass of close to 200,000 lb and an engine thrust of 270,000 lb, there was not much to spare for an upper stage. But the second stage of BSSLV/Black Prince used the Gamma 301 uprated to its maximum of 25,000 lb, which again implied a maximum upper stage weight of 19000 to 20,000 lb - only 10% of the weight of the first stage. This design, originally postulated as early as 1959, came very much to the fore after the cancellation of Blue Streak as a weapon, although the cynical might say that the announcement of the conversion of Blue Streak to a satellite launcher in April 1960 was a political device intended to reduce political embarrassment. The Cabinet committee set up to consider it shows little enthusiasm for the project [9], and there was no great urgency to the project in the months that followed. Black Prince was eventually displaced by Europa as the Government sought to involve European partners in the project.

There were several constraints to the BSSLV design, the greatest of which were financial. To keep costs as low as possible, the design was further constrained by the necessity to use High Down and Woomera facilities with as little change as possible. This immediately imposed a 54 inch maximum diameter limitation on the upper stage diameter. In the RAE/Saunders Roe proposal, the second stage was then intended to have an all burnt weight of 1,520 lb, a propellant capacity of 16,000 lb, and use a Gamma 301 uprated to 25,000 lb thrust (in vacuo, where the SI was estimated at 248). There would have been a small third stage (2,500 - 4,300 lb propellant) also using HTP/kerosene.

It seems perplexing in retrospect - although hindsight always makes things appear much easier than they were - that the large Stentor chamber was not used more extensively. It was rated at 25,500 lb thrust at 40,000 feet, and would have been a perfect substitute for the four Gamma chambers, and could, of course, have been used clustered in a two or four chamber configuration. But this idea brings us to the next fossil in the saga.

Bristol Siddeley produced a brochure for an IRBM [10], dated October 1958, based as much on the Blue Steel stand off bomb as on Black Knight technology. It was designed to have an exterior diameter of 72 inches, double that of Black Knight, and with almost no increase in tank length, this would give an increase in mass of approximately four times. Given this increase in mass, it would not have been possible to uprate the Gamma engine any further to cope. Instead, it was proposed to use the same
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basic design as Black Knight but to replace the Gamma chambers with the large Stentor chamber - PR27 - from Blue Steel. The original Gamma chamber 201 chamber had a thrust of just over 4,000 lb, whereas the Stentor large chamber sea level thrust was around 23,000 lb, which fits in well with a mass increase of a factor of 4, or effectively greater than 4, with the extra payload that an IRBM has to carry. The vehicle would then have a lift-off thrust of around 92,000 lb and a weight of approximately 70,000 lb. The design for the engines was given in great detail, but the rest of the vehicle was only sketched in. This is a design from a rocket motor engineer, rather than a missile designer, and is illustrated in figures 2 and 3.

The vehicle was a single-stage design, and some calculations were given as to the range of the missile, but given the uncertainty of the weight of the payload - re-entry vehicle, warhead, and so on - these would be fairly simplistic. However, this was the time at which light-weight warheads were becoming available. Blue Streak was designed with a payload of up to 4,000 lb; the Skybolt light-weight warhead and re-entry vehicle amounted to around 720 lb. For a payload weight of 1,000 lb, the range given is 3,000 miles: a distinctly optimistic estimate, looking at the design! It is unlikely, however, that the designer, David Andrews, of Bristol Siddeley, was aware of the light-weight warhead at the time. This was the first of the missile proposals to be made using HTP technology, apart from some studies made for a short-range (600 mile) missile in 1956 and 1957.

Blue Streak was cancelled early in 1960, although the decision was not announced until April 14th. The document was again submitted to the Ministry of Defence in March 1960, which is, of course, the month before the official announcement of the Blue Streak cancellation in the House of Commons, and before the announcement of the intention to pursue Skybolt as an alternative. The brochure did not rise from any Operational Requirement or other formal inquiry from the Ministry of Defence, but almost as a challenge to the powers that be, to show that a respectable missile could be produced entirely from British technology, with no need for any American derived alternatives. Given the timing, and advance knowledge of the cancellation of Blue Streak, it must have been put up as a Blue Streak substitute, since considerable play is made of the ability to fill the fuel tanks and leave them sealed off for considerable periods of time. One of the perceived weaknesses of Blue Streak was its use of cryogenic fuels.

It is also noticeable that the proposed IRBM bears a striking likeness to the firm’s original submission for the Small Satellite Launcher that was to become Black Arrow (fig. 4). It appears likely that the brochure was dusted down and re-used when the satellite launcher was first suggested. But before that, let us return to the idea of using Black Knight itself as a satellite launcher. There were several serious studies made for converting Black Knight into a satellite launch vehicle before the final Black Arrow design.

The first and most obvious idea was to consider adding solid boosters to Black Knight, both as additions to the first stage (strap-ons) and as upper stages. A family of solid fuel motors, named after birds, had been developed at RPE Westcott for the Skylark sounding rocket. A study was made by Tony

Fig. 2 The IRBM proposed by Armstrong Siddeley, using four large Stentor motors.
Derivatives of the Black Knight Technology

Fig. 3 The engine bay of the proposed IRBM.

Fig. 4 Bristol Siddeley’s proposed small satellite launcher, the rival to Black Arrow. It would have used the same engine as the proposed IRBM.
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Waterfall at RAE which considered a basic Black Knight with two Raven strap-on solid boosters, and with a Rook second stage, Cuckoo third stage [11]. Again, the Gamma 301 would have to be rated at 25,000 lb thrust. Such a combination was thought to be able to put a payload of 100 lb in a 200 mile circular orbit, although it was felt that this could be doubled with design ‘tweaks’. The programme was costed at £1.5m over two years. However, this design would have represented the end of the line: it could not have been developed very much further, although it does have the merit of simplicity!

During 1961, there was great interest shown at the RAE in the use of liquid hydrogen as a propellant. Liquid hydrogen engines had long been the subject of research at RPE Westcott [12] (figs. 5a and 5b). HTP/kerosene was felt to be a mature technology; further liquid fuelled ballistic missiles seemed extremely unlikely after the Blue Streak cancellation (except for the brief flurry of excitement during the Skybolt cancellation (see below)); and interest was now being concentrated on the Blue Streak Satellite Launch Vehicle. The RAE were currently working with Saunders Roe on a liquid hydrogen third stage for BSSLV, and an obvious related project seemed to be to add a liquid hydrogen stage to Black Knight [13].

At the outset, however, it was admitted that Black Knight as it stood, even with a liquid hydrogen second stage, could “not launch a payload into orbit with any degree of confidence”. To do this, firstly the Gamma 301 would be uprated to 25,000 lb thrust. The first stage would be extended to carry 11,689 lb of HTP and 1462 lb of kerosene (for comparison, BK 08, the heaviest vehicle at that time, carried 10,416 lb HTP and 1300 lb of kerosene). Stretching the tanks is a relatively cheap and easy modification. The second stage would then carry 1500 lb of oxygen and 900 lb of hydrogen. This is not a stoichiometric ratio, which would be 4:1. Using excess hydrogen, particularly in film cooling in the rocket motors, does not impose such a performance penalty as might be expected: the low molecular mass aids the specific impulse.

In addition, a “third stage solid propellant motor of about 450 lb weight with performance and charge/total weight ratio similar to that of the Scout “Altair” motor” would be added. It was noted that the “Cuckoo motor as it exists is about the right size, but its case weight is excessive compared with comparable U.S. motors such as “Altair”” [14]. What would have been needed is the Waxwing design

![Figs. 5a and 5b Testing liquid hydrogen rocket motors at RPE Westcott.](image)

that was later used for Black Arrow, and which had a very efficient mass ratio. This would have been possible with the technology of the time.

The design looks distinctly odd in one of the proposed configurations, where the diameter of the vehicle remains at the original 3 foot diameter of Black Knight (fig. 6). This results in a launch vehicle of 59.5 foot height - a height/width ratio or fineness of 20:1. There is a variant of 4 foot diameter shown at the same time [15], but when the design was passed to Saunders Roe for more detailed analysis, the 3 foot vehicle was the design analysed in terms of bending moments and the like [16]. This means that the 2400 lb of fuel in the second stage take up as much space as the 13,100 lb of fuel in the first stage! This points up one of the drawbacks of liquid hydrogen as a fuel. Figure 4 illustrates the vehicle.

Other design studies were made with the same
Derivatives of the Black Knight Technology

1. Jobs and American dollars. Was the point to push along British rocketry technology? If so, then the comparison becomes pointless. All small satellite launchers are going to be able to launch small satellites, so there is little point in comparing one with the other except on cost grounds. But the designs were being pushed ahead with no consideration being given to the nature of the payload. It is all very well to make a satellite launcher - providing you have a satellite to launch. In the end, neither of these vehicles ever made it past the drawing board, mainly due to a lack of funds but also partly due to the lack of a requirement for a satellite launcher.

2. Launcher Ideas in Search of a Mission

The last launch of Black Knight came with BK25 in November 1965, and with it the end of the Gaslight and Dazzle programmes. Gaslight and Dazzle had been joint UK/US/Australian programmes studying re-entry phenomena using Black Knight and the well instrumented range at Woomera. The first few Black Knight launches had succeeded in their task of verifying the re-entry head design; later launches were intended to look at other phenomena that took place both during the launch phase and during the re-entry phase. A follow-on programme to Dazzle had been planned [18], designated Crusade, and schedules for launches up to BK30 had been made. But the original Black Knight, even in its two stage...
configuration, could not achieve a sufficiently high speed for the required experiments, so the “54 inch Black Knight”, as it was generically called, was proposed (fig. 9). Design studies for this vehicle had been well in hand much earlier than 1965, however, and long before this vehicle could become operational, another crisis had hit the British deterrent with the cancellation of Skybolt in December 1962.

RAE immediately made a suggestion that the intended 54 inch Black Knight be considered as an alternative missile: ‘Quick calculation indicated that at least 1500 n.m. would be achieved using a Skybolt warhead boosted by a two-stage Black Knight configuration, the first stage being increased in power along the lines already discussed in relation to the Dazzle programme; guidance would be inertial, derived from recent T.S.R.2 development.’ (C.J. Stephens DGW(B) at RAE) [19]. Hasty cost estimates were made - £50m for R&D and £100m for deployment in silos - but the idea was not followed through, since almost immediately after Skybolt Polaris became available. A later paper [20] notes that two cases were considered, both based on the 54" Black Knight with a sea level thrust of 25,000 lb. The first set of calculations involved using HTP/kerosene with a vacuum SI of 250, and the second using UDMH/N_2O_4 with an SI of 280. A two stage - both liquid configuration was considered, using an 800 lb re-entry vehicle. The maximum range was calculated as just over 1000 n. m. with the HTP/kerosene combination, and 1500 n. m. with the more energetic combination. No further design work was started on the missile, as the gap between Skybolt cancellation and the Polaris agreement was so very short.

There is no doubt that the UK could have developed an indigenous Blue Streak substitute using the well established HTP technology as developed in Stentor and Black Knight at almost any time from 1958 onwards. However, such a weapon would not have addressed the apparent problem that had led to the Blue Streak cancellation: that of fixed and so vulnerable launch sites scattered around the English countryside. The main factor that had led to the cancellation of Blue Streak - even if it were silo based - was the calculation that 300 3 megaton warheads could take out all the silos. One possible means of tackling this problem would have been to make the weapon mobile, but in the UK context this would not be easy.

The 54 inch Black Knight design left the tank
length almost unchanged, which would have roughly doubled the weight of fuel. In addition, there was to be a solid fuel second stage specifically intended for the vehicle: Kestrel. The original Black Knight was a single stage vehicle, but to give greater re-entry velocities, a solid booster was added as a second stage, with the novelty that it pointed downwards! The booster used was the Cuckoo, designed originally for the Skylark rocket. Cuckoo I burned for 4.1 seconds, with a mean thrust of around 3,750 lb; Cuckoo II burned for 10.0 seconds, with a mean thrust of 1700 lb. Cuckoo II could give a velocity increment to the re entry test vehicle of up to 7,500 feet per second, although carrying it aloft inevitably reduced the first stage speed. Kestrel was designed to give a mean thrust of 5,400 lb for 10.0 seconds. This would now have given it the capability for much greater re-entry velocities.

Indeed, as far as satellite launchers go, the enlarged Black Knight did remove some of the limitations of the original 36 inch vehicle. It must be said, however, that the drawings are often seen for this vehicle, with the original 36 inch engine bay, and the tanks flaring out to 54 inches, does not look an attractive design, but a brochure from Saunders Roe in April 1964 does show a detailed design which is of uniform diameter. The engine is now designated the Gamma 303, now uprated to its maximum thrust. One advantage of this was the increased combustion pressure increased the sea level SI, as the counter pressure of the atmosphere became less significant.

However, the new and enlarged Black Knight, together with its new solid fuel second stage, the Kestrel, gave rise to further suggestions for satellite launchers. A study carried out by the Computing Department of Saunders Roe for the Low Orbit Vehicle for Experimental Research, or LOVER, a name that must have had its origins in some in-joke, is just such a project [21] (Fig. 10). The Saunders Roe simulation involved an almost unmodified Crusade type vehicle, with the first stage enlarged Black Knight lifting off vertically and pitching over to send the Kestrel solid stage up to act as an apogee motor. At apogee the Kestrel then gives the payload sufficient velocity to achieve circular orbit. However, this would be a payload of around 60 lb at a height of around 150 nautical miles. This, by itself, is not really adequate other than as a demonstration.

All these studies point up the basic problem with either Blue Streak or Black Knight as first stages of a satellite launcher: their thrust/weight ratio. Initially designed for a lift-off acceleration of 1.3g, or 0.3g from the launch pad, they were singularly ill-equipped for second and third stage matching. For a reasonably efficient vehicle, the first stage should only be a half or perhaps two thirds of the lift-off mass, implying that the lift-off thrust should be almost doubled. With Thor and Ariane, this was done with strap-on solid boosters. The original design of the 54 inch Black Knight would have made this impossible. And there were no really suitable solid boosters in the UK in the early 60s. Such solid fuel boosters would have needed a thrust of several thousand pounds for at least thirty seconds. The length of time of thrust is necessary for the first stage to burn off sufficient fuel to reduce the weight of the vehicle to a point where the sustainer engines can then take over.

Given the American support to Dazzle and Gaslight, and presumably to Crusade, then it might have been thought that the enlarged 54" vehicle was a foregone conclusion. Accordingly, two projects were indeed submitted for approval by the RAE in 1963: Black Arrow and the Crusade vehicle. But again, budgetary constraints meant that only one of these could be funded, and, of the two, the RAE eventually chose Black Arrow. The choice was no doubt helped by the offer from Westland (who now owned Saunders Roe) and Bristol Siddeley (who had taken
over Armstrong Siddeley) to pay up to £1 m of the development costs [22]. This offer, although it delighted the then Aviation Minister, Julian Amery, was not to come to fruition for a variety of reasons.

Although the previous designs for satellite launchers had come to nothing, the RAE was still keen to go ahead with a launcher programme. The previous designs described had been, in the end, too small and not capable of a great deal of further development. The new vehicle would have to have a larger first stage than the original Black Knight. Bristol Siddeley submitted a brochure for such a launcher, which, from its description, sounds like the IRBM proposal from 1960 brushed down and revamped [23]. That having been said, it was a sound idea. The vehicle would have 4 PR27 chambers in the first stage, giving a lift off thrust of 100,000 lb and a weight of 70,000 lb. The second stage would have been powered by the Gamma 303 at 25,000 lb thrust, and a small liquid third stage was also proposed.

This, however was thought to be too expensive: the RAE costings priced the Bristol Siddeley submission at £11,470,000 as opposed to the RAE design at £2,915,000. The Bristol Siddeley design was also larger, and felt to be too large: one of the points of Black Arrow was to be a cheap alternative to Europa, whose launch costs for small satellites made it hopelessly uneconomic. But it was also recognised that the Black Arrow design, with 8 chambers, took the Gamma engines as far as they could go: the design could not be subsequently developed further.

Whether these costings were legitimate, it is difficult to say. The RAE had subsequently to admit that scaling up Black Knight was a more difficult operation than they had anticipated. They also came to realise that Black Arrow was still too small: by the 1970s, its capacity of around 200 lb in low Earth orbit was quite inadequate. Black Arrow could be extended by parallel staging - liquid add-ons were suggested, but solids seem much more logical. However, as mentioned, Black Arrow was at the limits of its developmental capacities: even substantial solid boosters would have been hard pushed to improve the payload by the necessary amount to launch anything but the simplest of satellites.

4. Victims of Short-Sighted Politicians

There is also a further oddity to the Black Arrow design: the first stage is made to be exactly 2 m in diameter, whereas all the other dimensions are still imperial, with the second stage diameter being 54” - a legacy of the Crusade vehicle [24]. It also gives Black Arrow a somewhat odd, squat appearance. The reason for this decision lay in the ELDO design: Blue Streak had been given an interface to match the 2.0 m diameter Coralie French second stage. If Europa had failed, or if the RAE were given the opportunity, then the Black Arrow stage could be neatly fitted on top of Blue Streak without any further modification! [25] It was the BSSLV or Black Prince all over again. Indeed, such a study was carried out in 1968 in order to provide an answer for a Parliamentary Question from the Conservative member for Banbury, Neil Marten, one of the few space enthusiasts in the Commons. And lo and behold, a design was costed with Blue Streak, Black Arrow second stage (with only 4 chambers and 1 turbopump) at £1.5m. This strikes one as again being distinctly optimistic. Such a vehicle could have placed around 750 kg in a 500 km polar orbit/1800 lb in a 200 n. m. polar orbit. Extending the nozzles of the thrust chambers would improve the performance; now 930 kg was predicted as against 1130 kg for ELDO A. With a third stage, the payload increases to 2000 kg [26]. It is probable, however, that the question was “planted” by Marten after a visit to Farnborough, as a way of letting the necessary calculation be done, and to draw attention to the idea.
However, as mentioned, Black Arrow had been given the go ahead at the tail end of a Conservative administration. The Wilson administration came in with the intention of cancelling, or at least, critically reviewing, a large number of the expensive technological programmes of the time, many of which were military in origin. Thus, TSR 2 and the rest went. ELDO and Concorde survived only because of their European dimensions, and even ELDO was dropped in April 1968. Among all these projects, Black Arrow was small fry, and was put on hold, with a drip feed of finance being renewed on a three monthly basis. When eventually the programme was given a go ahead on a very reduced scale in 1966, two years on, the decision produced a three page letter of protest from the then Chancellor of the Exchequer, Jim Callaghan, reminiscent of the letters that a Tory Chancellor, Heathcoat Amory, had written so many years previously about Blue Streak.

There was, however, a political fear that a decision to cancel Black Arrow would be seen as a one too many technological bridges burned, and this was to be the justification used from then on by the RAE at all the innumerable Black Arrow reviews that were to plague Farnborough for the next five years. This was the last British rocketry project left. Cancel this, and all is gone. Once gone, it is gone for good, as we know. But the Treasury line was different:

(i) “It is claimed that the launcher would be of value in giving UK scientists and technicians experience of injecting satellites into orbit and controlling them, and would also enable us to test satellites and components in an actual space environment. But why should we in fact wish to give UK scientists and technicians this experience? What satellites is the UK going to be putting up? And for what reasons? No decision has yet been taken in regard to a programme of communication satellite and development. Ministers have not yet even been invited to consider the possibility of such a programme. Nor has any military requirement for a UK satellite launching capability been stated. The indication are that no such requirement will arise”.

(ii) “It is suggested that possession of a small satellite launcher will enable us the better “to compete for contracts for space projects”. I must remind you that the Working Party ... concluded that export prospects in the space field were relatively quite small .... It might be as well if you were to specify what contracts we are more likely to get if we have a small satellite launcher. I should myself be very surprised if there was anything significant. If there isn’t, I suggest that you would do better to drop this particular argument”.

(iii) “... I do not myself understand how the development of a small launcher on the basis of “proven techniques” will have much relevance to ELDO activities on, say, high energy upper stages. Doubtless you can explain this. In any event, however, Ministers have yet to reach a final decision on UK policy towards ELDO: it is possible, to say the least, that they will ultimately take the view that we should aim to withdraw from ELDO activities. It is also possible that the attitude taken by the Italians and others at the recent ELDO conference will lead before long to the collapse of the organisation. It cannot therefore be assumed at this stage either that ELDO will continue to exist or that, if it does, the UK will continue to participate in it, or will wish to influence its activities.”

F.R. Barratt in Treasury Chambers to Walter Abson at the Ministry of Aviation, 28 April 1965 [30].

This, more than anything, points up the reason for the demise of Black Arrow and British rocketry. The Treasury were not prepared to wear it. But the cancellation of Black Arrow did lead to one prediction coming true: once you are out of the launcher business, you are out of it for good.

References

9. for example P.R.O. DEFE 7 1392.

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