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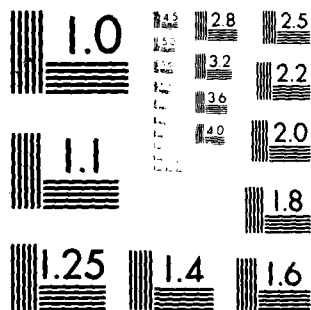
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ROYAL AIRCRAFT ESTABLISHMENT

THE ROYAL AIRCRAFT ESTABLISHMENT - 100 YEARS OF RESEARCH

by

A. J. Smith

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THE ROYAL AIRCRAFT ESTABLISHMENT - 100 YEARS OF RESEARCH

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A. J. Smith

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1 THE EARLY YEARS

The birth of the Establishment can be said to have occurred when the War Office was persuaded by Captain J.L.B. Templer to allocate £150 - the first Air Estimate - for the purpose of building a balloon at Woolwich Arsenal. The satisfactory outcome of this venture - a balloon of some 10000 cubic feet capacity - led to the formation in 1878 of the Balloon Equipment Store, the embryo organisation from which the RAF and RAE both directly grew, see Figs 1 and 2. The successful use of observation balloons in various military exercises in the 1880s led to the expansion of the Balloon Equipment Store and its removal first to the School of Military Engineering at Chatham in 1882 and later to Aldershot in 1890 to facilitate close co-operation with the Army.

By 1902 attention was turning toward airship development and although work was hampered by lack of funds, 1905 saw the Balloon Factory on the move once more to a new, and officially temporary site at Farnborough, where space for airship erection and flight testing was available. Colonel J.E. Capper succeeded Templer as Superintendent and was joined by two of the great pioneers of early British aviation, S.F. Cody and Lieutenant J.W. Dunne. The beginning of the Establishment's work on powered aircraft was marked in 1907 by the first flight by British Military Airship No. 1 (NULLISECUNDUS) illustrated in Fig 3.

In 1908 Cody - ex cow puncher, Indian fighter and Wild West showman - constructed a biplane designated as Army Aeroplane No 1 and made the first officially recorded flight in Britain by a power driven, man-carrying aeroplane on 16 October 1908 being airborne at Farnborough for 496 yards (Figs 4 and 5). Cody thus became the first test pilot of the Establishment, however both he and Dunne left the Factory soon afterwards when the War Office concluded in 1909 that the aeroplane had no military value and due to the enormous expense involved withdrew financial support. However Cody continued to work on the Farnborough airfield in a semi-private capacity until August 1913 when he was killed when the wings on his aeroplane buckled at a height of 200 feet.

In 1909 the Establishment, now carrying the designation of His Majesty's Balloon Factory as a consequence of Royal patronage in 1908, entered a new phase with the arrival of M. O'Gorman as the first civilian Superintendent, and work officially concentrated on airship development. The Balloon School was separated from the Factory, being renamed the Air Battalion in 1911 and the Royal Flying Corps in 1912 (with Headquarters at Farnborough until 1915). In 1910-11 two new aircraft, the SE1 and BE1, were designed and constructed by the Factory. Officially this work was covered by War Office instructions for the repair of a Bleriot monoplane, and a Voisin biplane, although in each case the only surviving feature of the original aircraft was the engine! Thus was begun the series of military aeroplanes which was to form the majority of RFC equipment in 1914-15 and also serve to evolve the basic principles of design, construction, inspection and testing of aircraft which are among the major contributions of RAE to aeronautical engineering. Under the designation of the Army Aircraft Factory in 1911 and the Royal Aircraft Factory in 1912 the organisation began to develop on subject orientated lines,

a theme which has persisted to the present day, and F.M. Green and Geoffrey de Havilland joined as Chief Engineer, and Designer and Test Pilot respectively. In 1908-14, the poor quality of aero-engines was a serious handicap and a vigorous research programme began under F.M. Green which led ultimately to the highly successful RAF series of engines. Under Captain H.P.T. Lefory, Royal Engineers, pioneering work on the use of wireless in airships and aircraft led to successful transmission of artillery spotting reconnaissance reports by wireless from a BE1 aeroplane in January 1912. The concept of load safety factor and the basic principles of aircraft stressing were also established at this time.

2 WORLD WAR I

The declaration of hostilities in August 1914 finally released the Treasury funds necessary for aeronautical development, but too late for adequate preparation and equipment of the RFC for the early stages of the war. The only British types suitable for production were the Factory's BE, FE, and RE designs and the urgent need for their further development resulted in certain functions being transferred to the Testing Squadron of Central Flying School, Upavon and the Inspection Department of the RFC. The factory was expanded rapidly and O'Gorman gathered together a team of brilliant scientists and designers, a list of which reads like a "Who's Who" of pioneers in British scientific history, including such names as F.W. Aston, E.T. Busk, R.H. Mayo, H.P. Folland, H. Glauert, A.A. Griffith, S. Keith Lucas, F.A. Lindemann (later Lord Cherwell), B. Melvill-Jones, G.I. Taylor, G.P. Thompson and many others. In the period 1914-18 more than 500 aircraft of 30 different types were built, the majority in prototype form for mass production by the newly created and largely inexperienced Aircraft Industry, which manufactured some 1800 BE2 aircraft (Fig 6) in the early war years, and later about 4000 RE8 artillery reconnaissance aircraft, and finally more than 5000 SE5A fighters (Fig 7) which were highly successful from 1917 onwards. In 1916 the Government determined that the Factory should concentrate on its present day functions of aeronautical research and development, leaving the manufacturing aspects to Industry which was reinforced by the dispersal to it of a number of senior staff from the Factory, many of whom played a prominent part in the subsequent development of British aviation. At Farnborough rational design procedures and requirements were codified in a six page pamphlet issued in 1916 which was the forerunner of the present-day AvP970 now extending to three large volumes and defining the requirements for British military fixed wing aircraft and helicopters. Also in 1916 work was in hand on 'Aerial Target' (Fig 8) - the forerunner of the V1, guided weapons and cruise missiles. The concept was not properly developed at this time, being taken up again by the RAE when a proper autopilot became available. Full scale flight research became closely linked with theoretical work as typified by E.T. Busk's application of the theories developed by G.H. Bryan, leading to the demonstrations of the principles of aircraft spinning and recovery with which the names of F.W. Gooden and F.A. Lindemann are associated. In 1918 the RFC was reformed as the RAF and the Factory renamed as the Royal Aircraft Establishment to avoid confusion of initials, and this change effectively marked the close of an era of which Sir Roy Fedden later wrote "There is no doubt that history has shown that this

was a unique place, and you can hardly turn anywhere in British aviation without finding that the good things that were done on aircraft between the two wars stem almost entirely from engineers who had been at this remarkable place and who were inspired by an outstanding leader".

3 THE INTER-WAR YEARS

In the inter-war period RAE was no exception to the general trend of retrenchment and industrial depression, but despite these handicaps the foundations for later development were laid, particularly in the area of propulsion, where many innovations in piston engine design were made. In 1926 Griffith made the first practical proposal for the use of gas turbines for aircraft propulsion, almost 20 years before the ultimate realisation. Work on pilotless radio controlled aircraft (Fig 9) led steadily towards application to guided weapons, and to the development in 1930 of the Automatic Pilot Mk 1 known as 'George' which became standard equipment on both military and civil aircraft for many years. Co-operation with Industry had grown until it became standard practice for aircraft firms to develop their designs with the help of the expertise and facilities at RAE. New facilities were added to keep pace with the increasing performance of aircraft, including a spinning tunnel opened in 1931 and a 24ft open jet tunnel for full scale testing in 1935. In 1938-39 design and construction of a pressurised high speed tunnel began; from 1942 this facility played an important part in the development of all British high speed aircraft. A vital contribution was the reconstruction of RAF radio communications, both the ground stations and in the air, where the universally used medium wave equipment was replaced by a new VHF multi-channel R/T system which proved to be of crucial importance for fighter control during the Battle of Britain and in later tactical operations.

In this period the RAE also began to make a significant contribution to Aviation Lighting. In 1926 E.S. Calvert was doing work to improve aircraft navigation lights, whilst in 1927 the techniques for floodlighting grass airfields were being evaluated, and the view was expressed that "night flying is unsafe if the visibility is less than 1200 m"¹.

The use of neon lamps for airfield beacons was investigated and the visual range of contact lights at Heston (London) and Ringway (Manchester) airports was measured. Work by N.E.G. Hill and others² led to the development of British Standards for signal colours, which in turn were influential in the drafting of the CIE regulations still in international use today. In 1938 the RAF expansion programme involved the provision of permanent runways and the RAE was busy deriving suitable lighting patterns and equipment.

4 WORLD WAR II

At the outbreak of World War II, RAE was again expanded rapidly and again reinforced by many of the country's leading scientists. The scientific and technical output was as versatile as it was effective in contributing to the war effort, many special researches being carried out under extreme urgency and requiring close contact with operational experience. A vital activity was the flight testing of aircraft and equipment both of

the Allies and captured machines (Fig 10) including work on detailed performance improvements in crucial areas such as maximum speed and manoeuvrability. Stabilised bombsights for high and low altitude bombing and an automatic dead-reckoning navigation system for accurate navigation independent of vulnerable ground aids, were developed and adopted by the RAF and USAF, as was the highly successful gyro gunsight which proved to be one of the major air weapons of the war (Fig 11). Experiments with a camera-equipped Spitfire demonstrated the practicability of fast high altitude reconnaissance aircraft and led to the formation of the RAF Photographic Reconnaissance Unit, subsequently described as the "indispensable hand-maid of Allied Staffs on every front" - this work also contributed to the widespread post-war use of aerial survey techniques. Other activities included intensive development on the take-off and landing problems of naval aircraft, the techniques and equipment required by the Army Airborne Forces, bomb ballistics, and sea rescue of aircrews, such examples and many others went to the making of RAE's record of war service, much of it achieved in very close collaboration with the appropriate specialised areas of Industry.

5 THE POST-WAR PERIOD

In the immediate post-war lull all RAE work on piston aero-engines ended and the staff of the turbine division combined with Power Jets Limited to form subsequently the present day National Gas Turbine Establishment as the UK Government centre for research and development in the field of gas turbine engines and their related systems. 1945 saw the formation of the Blind Landing Experimental Unit, first at Martlesham Heath and later at Bedford, to begin the development of equipment initially for military aircraft, and culminating with a high integrity automatic landing system for the Trident and other transport aircraft, capable of satisfying the stringent requirements of the civil airworthiness authorities (Fig 12). During 1945-46 a number of exhibitions of wartime aeroplanes were staged at RAE providing the first large scale public displays of jet aircraft, and in 1948 the SBAC show came to Farnborough for the first time.

A new period of military tension followed rapidly on the heels of a hard won peace, and the atomic warhead, guided weapons and new forms of propulsion heralded an era of high speed flight, necessitating the provision of new facilities particularly for aerodynamics, structures and guided weapons testing. The latter requirements were met initially in 1947 by the establishment of a sea range at Aberporth and a land firing range at Larkhill which eventually became an RAE outstation in 1958. The major development however, was at Bedford where a complex of powerful new wind tunnels was opened during the period 1951 to 1960, including in 1957 the 8ft x 8ft subsonic and supersonic tunnel with a drive power of 80000 hp, which has subsequently made major contributions to virtually every aerospace project in which there has been UK participation. Other developments at Bedford included provision of a large and fully instrumented airfield having unrestricted approaches, and facilities for catapult and arrester development.

In the most recent 30 years of its history RAE has added immeasurably to its achievements across the whole spectrum of aerospace activities but, for reasons of security, and brevity, many topics must be omitted from this account, and only a very

small sample of the less sensitive developments can be mentioned. In the field of aviation lighting the familiar 'tapered ladder' effect utilised in airfield approach lighting systems was originated at RAE, successfully demonstrated on the Berlin Airlift in 1949 and subsequently standardised by ICAO for use throughout the world (Fig 13); an example of the way in which the RAE has always played a leading role in the work of the ICAO Visual Aids Panel. In addition to the approach lighting pattern mentioned above the RAE has been responsible in whole or part for the development of inset runway lighting, high intensity taxiway centreline lighting, STOL lighting and the VASI. Significant contributions to the understanding of the inter-relation between lighting aids and fog have also been made both for landing and ground movement control. The recent introduction of PAPI (Precision Approach Path Indicator) shown in Fig 14 typifies a continued pre-eminence in the field of airfield lighting aids.

Visual landing aids for ship-borne operations have also been an area of active interest for the RAE. In this context the Establishment made significant contributions to the development of the mirror landing system, line-up cues and visually secure flood-lighting. The most recent naval activity has been the development of a suite of aids to support Sea Harrier operations (Fig 15).

The steam catapult, the angled deck and the hydro-pneumatic arrester are all developments for the safe operation of carrier-borne aircraft to which RAE made major contributions. In 1954 the Establishment was responsible for the inquiry into the Comet disasters and established new standards in accident investigation, and new methods for the extensive fatigue testing of pressurised aircraft which were widely adopted and are exemplified today by the complex thermal fatigue test currently in progress on a Concorde airframe at Farnborough, verifying the safe life in advance of airline experience. Perhaps the best known of the recent innovations in materials technology is Carbon Fibre Reinforced Plastic which was first developed at RAE in the early 1960s and is finding increasing application on military and civil aircraft and for a variety of diverse non-aerospace applications. During the 1950s, research and development on missiles laid the technological foundation for the successful emergence of a new UK guided weapon industry. An offshoot of this work included the highly successful Skylark upper atmosphere sounding rocket, developed originally at RAE and subsequently by Industry. Some 350 successful launches have been made since 1957 in many parts of the world ranging from Norway to the Argentine. Later work on ballistic missiles provided the basis for a UK Space programme with the development of the Black Arrow rocket and the science research satellite Prospero which was launched in 1971. RAE also played a leading role in the development and operation of a number of research satellites launched from 1967 to 1974 as part of both UK and collaborative programmes, and the British Defence Communications Satellite, Skynet, launched in 1974. More recently the RAE has been heavily involved in the computer analysis of earth resources images received at our terminals (Fig 16). Through the 1950s and 1960s flight research with specialised vehicles ranging from the Rolls-Royce 'Flying Bedstead' and Short SC-1 (Figs 17 and 18) to predecessors of the Harrier (Fig 19) explored the new flight regime of VTOL. The introduction of what was for their

time novel configurations, such as the Lightning interceptor and Concorde, was aided by exploratory work with research aircraft including the Short SB5, the BAC 221 and the HP 115. Significant contributions were also made to the development of electrically signalled controls which were first flown successfully in the mid-1950s, and flight instrumentation was enhanced by the introduction of the Head Up Display. Amongst a wealth of achievement in aerodynamics the most significant single development in recent years was the conception in the mid-1950s of the slender wing aircraft with controlled flow separations, leading directly to the design adopted for Concorde.

Spectacular multi-national ventures such as Tornado (Fig 20) with its weapons systems, and Concorde (Fig 21) provide an illustration of the contrasting nature of the various aspects of the research and development programme which supports them. RAE contributions to both projects have ranged from elegant intellectual hypotheses to design refinement via thousands of hours of development in massive test facilities, to equally vital if more down to earth research on basic topics such as the properties of materials adhesives and fasteners, the accuracy and integrity of avionic systems, and a host of other factors which affect the safety of the airframe and the provision of a suitable environment for the occupants of a vehicle capable of travelling at around 1400 mph in the stratosphere.

6 THE RAE TODAY

The RAE is the Air Systems Establishment of the Ministry of Defence (Procurement Executive) (MOD(PE)) with overall responsibility for the conduct and co-ordination of research and development on all aerospace activities with the exception of engines and radar. RAE also provides support for civil aviation, funding for this being provided predominantly by the Department of Industry (DOI). In the many cases where individual items of basic research serve both Defence and Civil interests the programmes are jointly funded.

The primary functions of the Establishment require it to maintain and develop expertise over a wide range of disciplines that are fundamental to aerospace technology. This expertise is deployed in a variety of tasks in support of the Services, Government agencies and Industry, extending from the research and conceptual states of aerospace projects to the evolution of new operational techniques and the solutions of problems as they arise in service. Throughout, particular emphasis is placed on the rapid and effective transfer to Industry of the knowledge and expertise stemming from research at the Establishment. This liaison is aided by the part which RAE plays in stimulating and monitoring extra-mural research by Industry under contract to MOD and DOI. All of these exchanges underpin the contribution made by the Establishment in response to the requirements of MOD(PE) project directors during the design and development stages of new aircraft and weapons, where RAE provides a level of support that varies from project to project in the range from the provision of technical advice to a co-ordinating role, which in the weapons sector can extend to monitoring during development, and technical supervision of evaluation and acceptance. Once equipment enters service the Establishment plays an equally valuable part in contributing to the maintenance of operational

effectiveness, both in the identification and solution of the teething problems that are inevitable with advanced systems of an innovative type, and also in adapting and modifying the equipment for new roles.

Although there are many applications for which RAE provides the full range of support to the Services and Industry, there are also many instances in which the expertise of RAE is complementary to that of other research and development establishments within MOD(PE) and there are especially close links with several of these establishments extending to the use of each other's facilities. A particular strength of the RAE derives, however, from the accumulated skills and experience available from within its own resources across the broad spectrum of interests that befit its standing as the largest research and development centre in Europe.

Relationships between the Establishment and the academic world are also very close. Research Councils form one of the bonds, another being university research agreements sponsored by MOD and DOI and monitored by RAE. There are also direct formal links maintained with the universities of Reading, Southampton and Surrey. It is noteworthy that many professors of aeronautics and related subjects were formerly at RAE for some part of their careers.

On the international scene, RAE participates in the development programmes of multi-national projects as well as in collaborative research, and is often the technical agency for the exchange of information covered by government-to-government agreements.

A characteristic feature of aerospace technology is the reliance that must be placed on massive major facilities for testing and calculations. RAE maintains a range of such facilities, both for research and as a national resource on which the UK Industry is dependent for the development of the majority of its aircraft and weapon projects. Research in flight is equally necessary, and this is satisfied by maintaining at RAE a fleet of aircraft, nearly all of them specifically adapted for the purpose.

The Establishment is accommodated at six sites, with the largest elements being located at Farnborough and Bedford. To maintain the effectiveness of such a large and diverse organisation the scientific staff is grouped into technical departments. The majority of these departments have a strength of about 100 scientists, which experience has shown is an appropriate number for a senior scientist, as head of department, to control and inspire. The organisation is not static or rigid, a feature illustrated by recent restructuring of departments (Fig 22). The RAE is one of the world's foremost aerospace research centres. Its main characteristic is that it is large enough to allow a broad attack to be made on major problems while maintaining sufficient independence at lower levels so that initiative is not stifled. The chief aim is to ensure that the Armed Services have the most efficient and cost effective airborne systems in order that they may continue their role of national defence and aiding the preservation of peace.

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<u>No</u>	<u>Author</u>	<u>Title, etc</u>
1	H.N. Green	The atmospheric transmission of coloured light. RAE/E & I 720 (1932)
2	J.E.G. Hill	Tests on the recognition of coloured light signals which are near the limit of visibility. RAE/E & I 1159 (1939)



EARLY HISTORY OF THE RAE

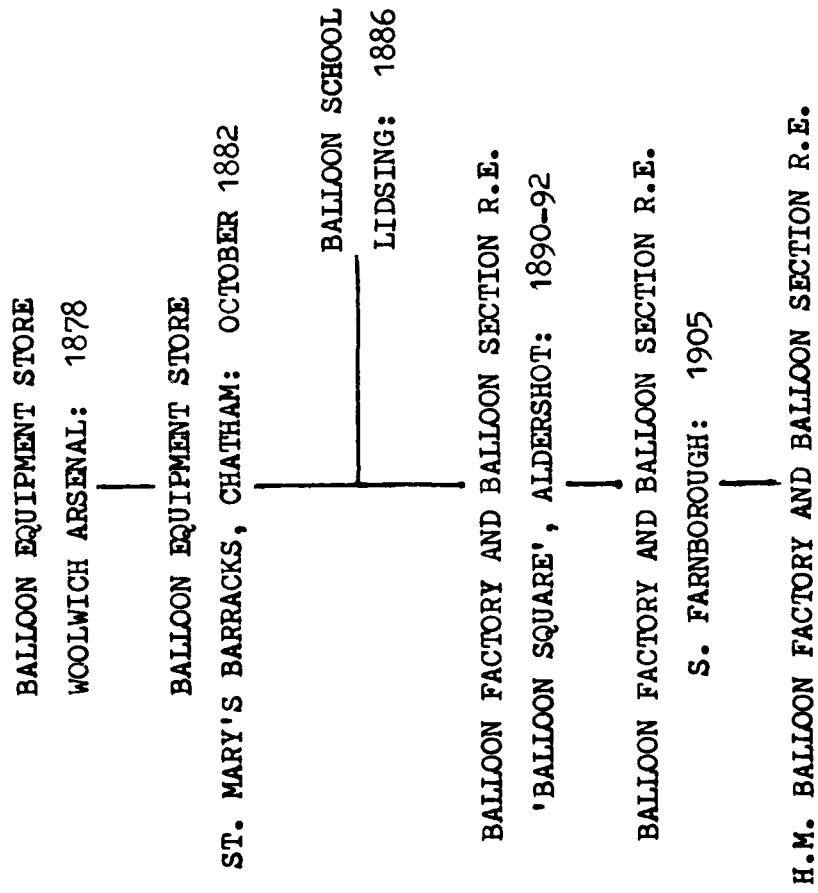


Fig 1 Early history of the RAE

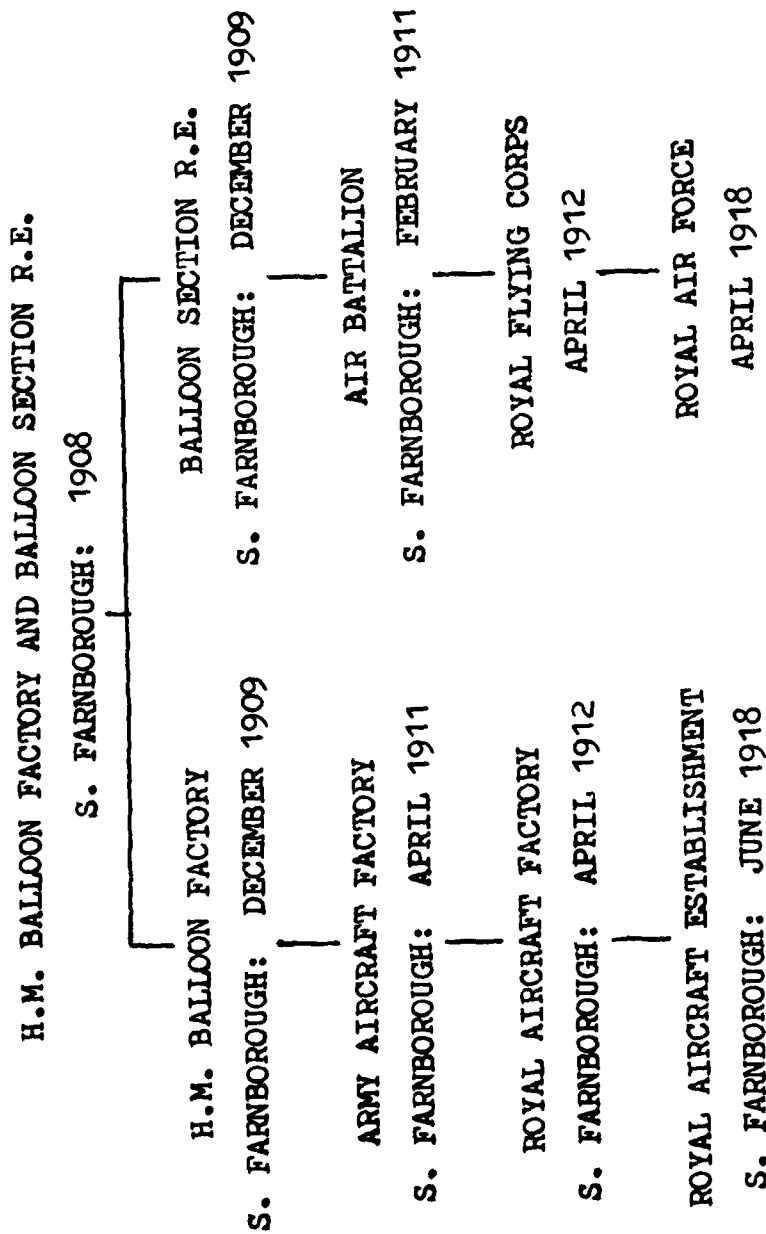


Fig 2 HM Balloon Factory and Balloon Section RE

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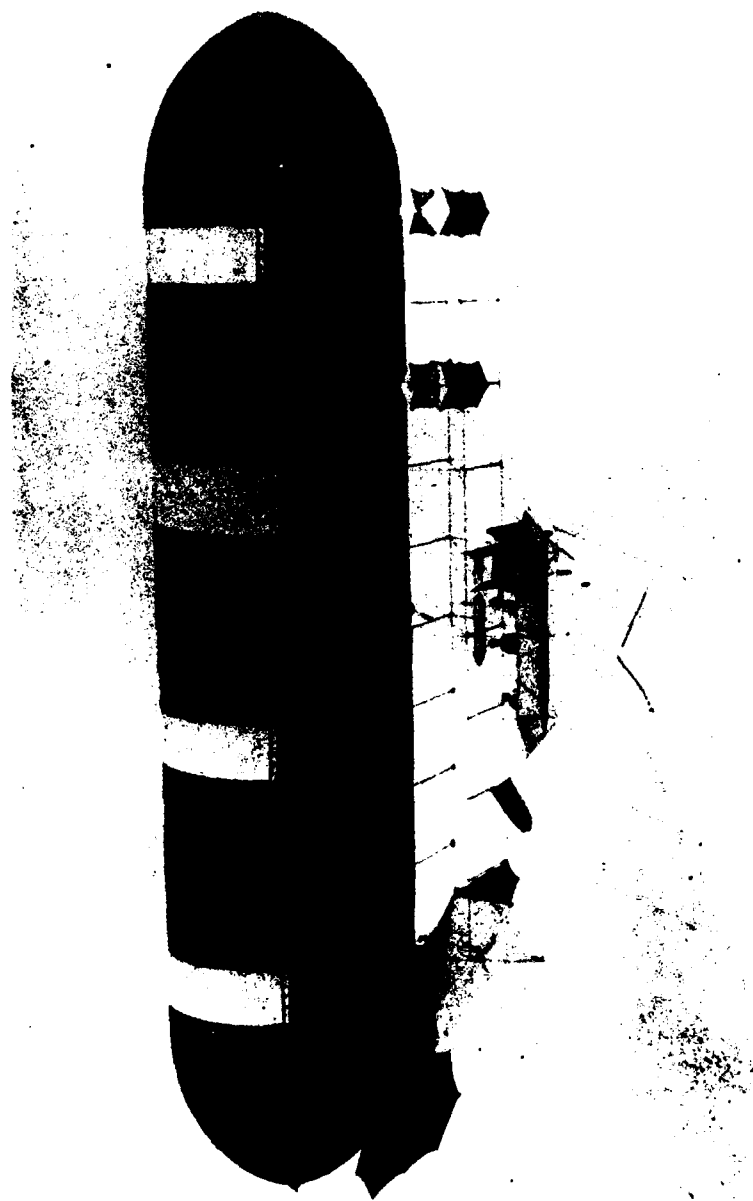


Fig 3 Nulli Secundus

Fig 4



Fig 4 Cody's biplane



Fig 5 Cody at the controls of his aircraft

Fig 6



Fig 6 BE2

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Fig 7 SE5(a)

Fig 8

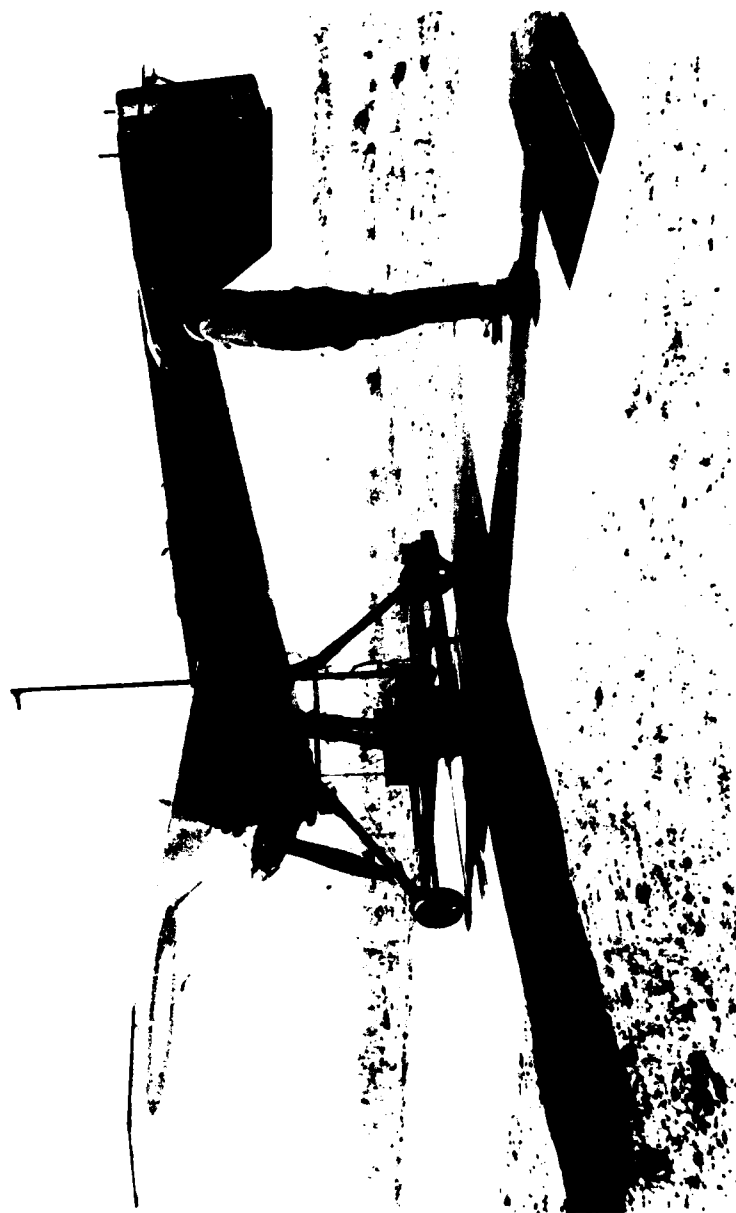


Fig 8 Aerial target

Fig 9

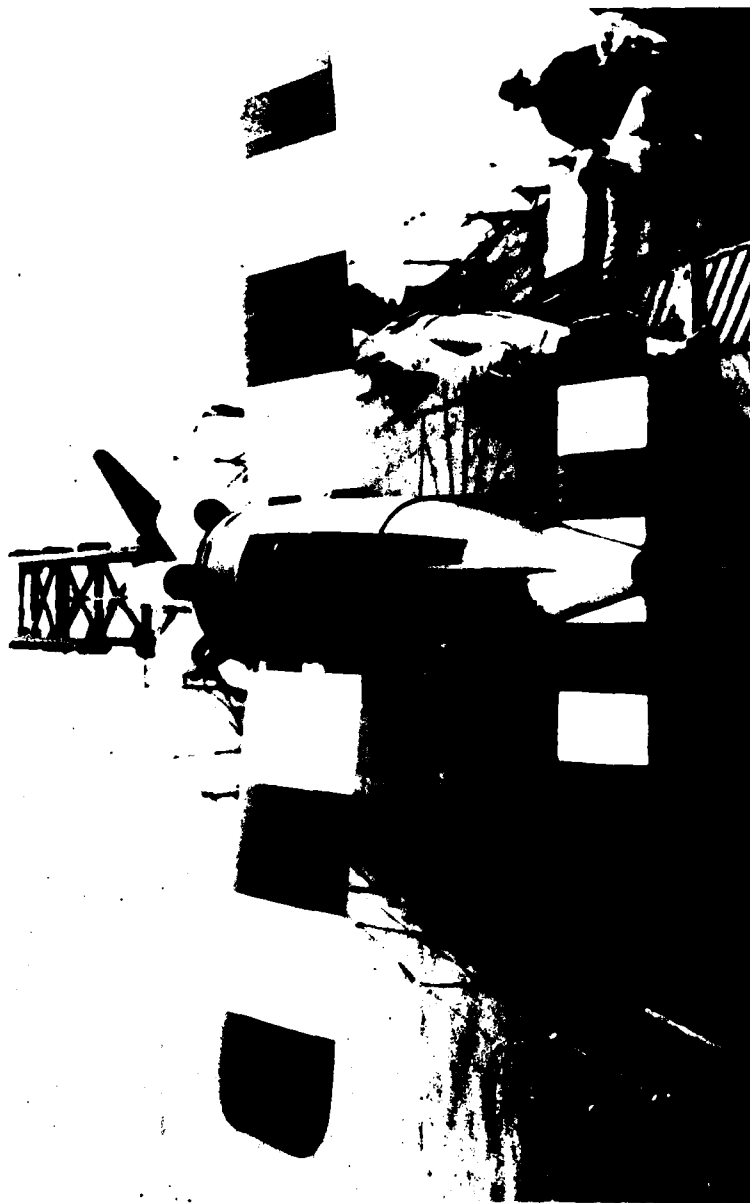


Fig 9 Larynx

Fig 10

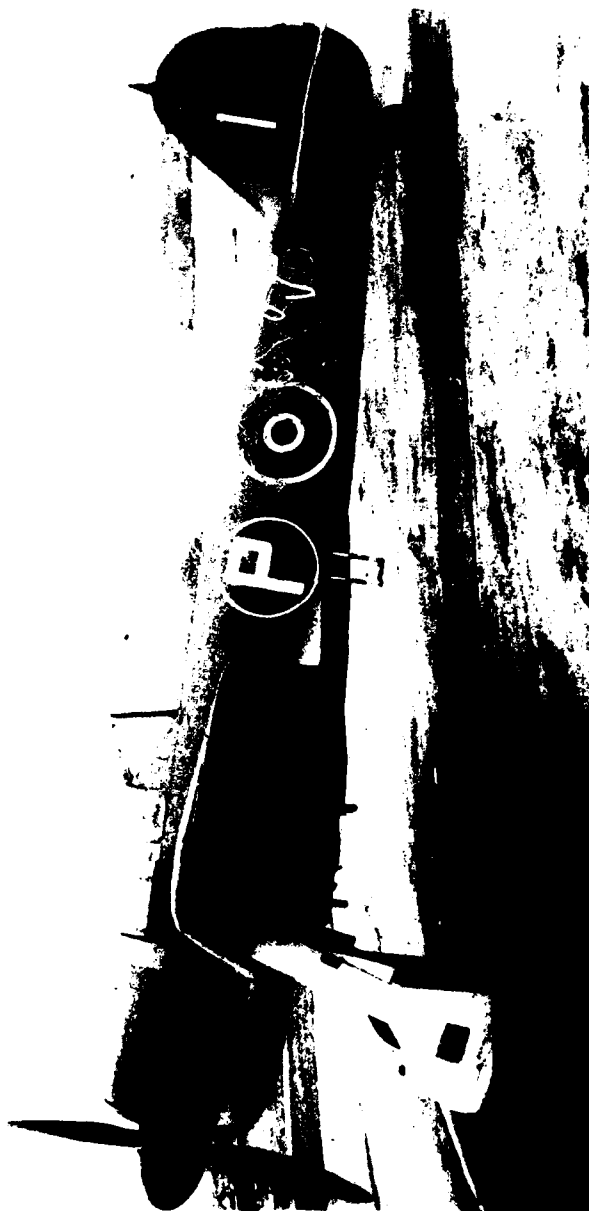


Fig 10 Captured Fw 190 (1943)



Fig 11 Gyro gunsight development

Fig 12



Fig 12 Fog landing

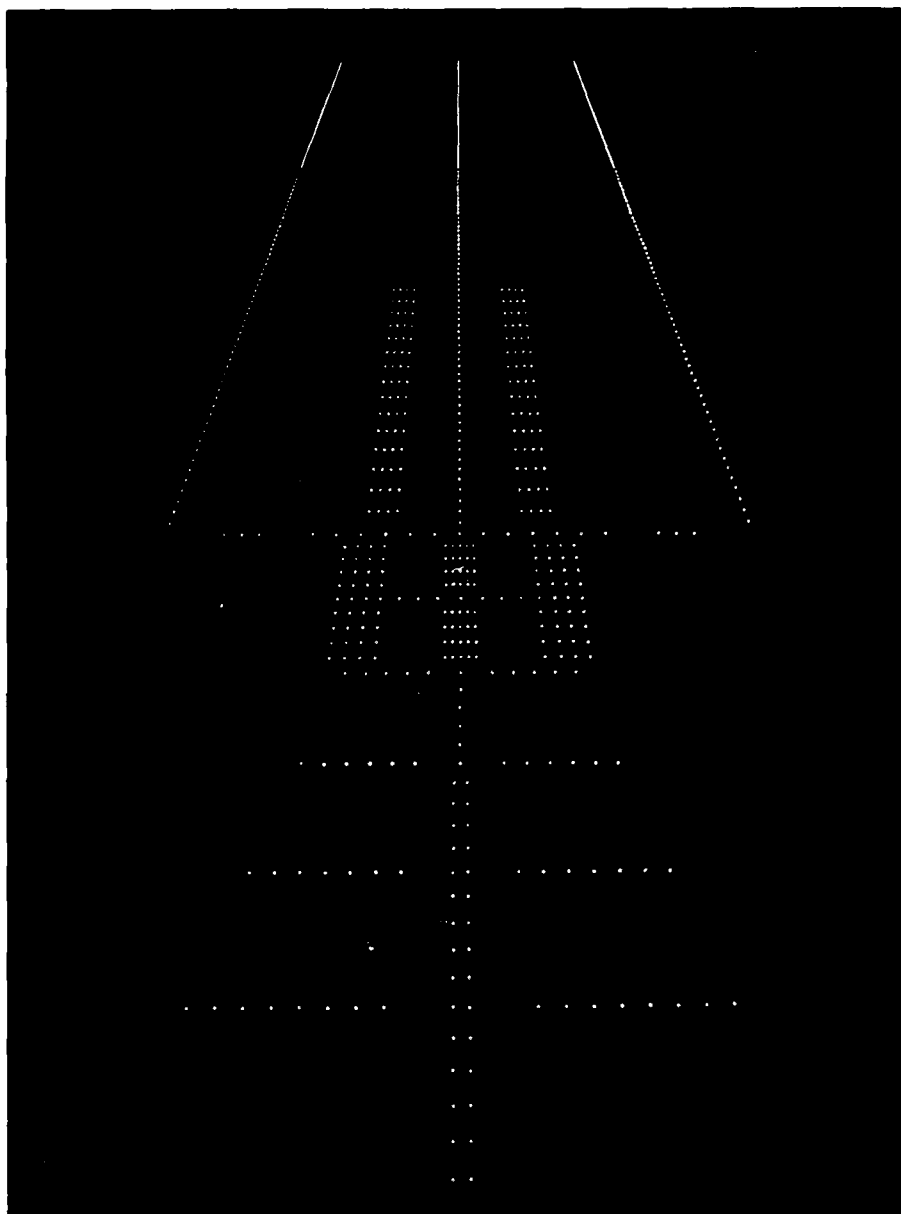


Fig 13 Airfield lighting patterns

Fig 14



Fig 14 Typical PAPI installation

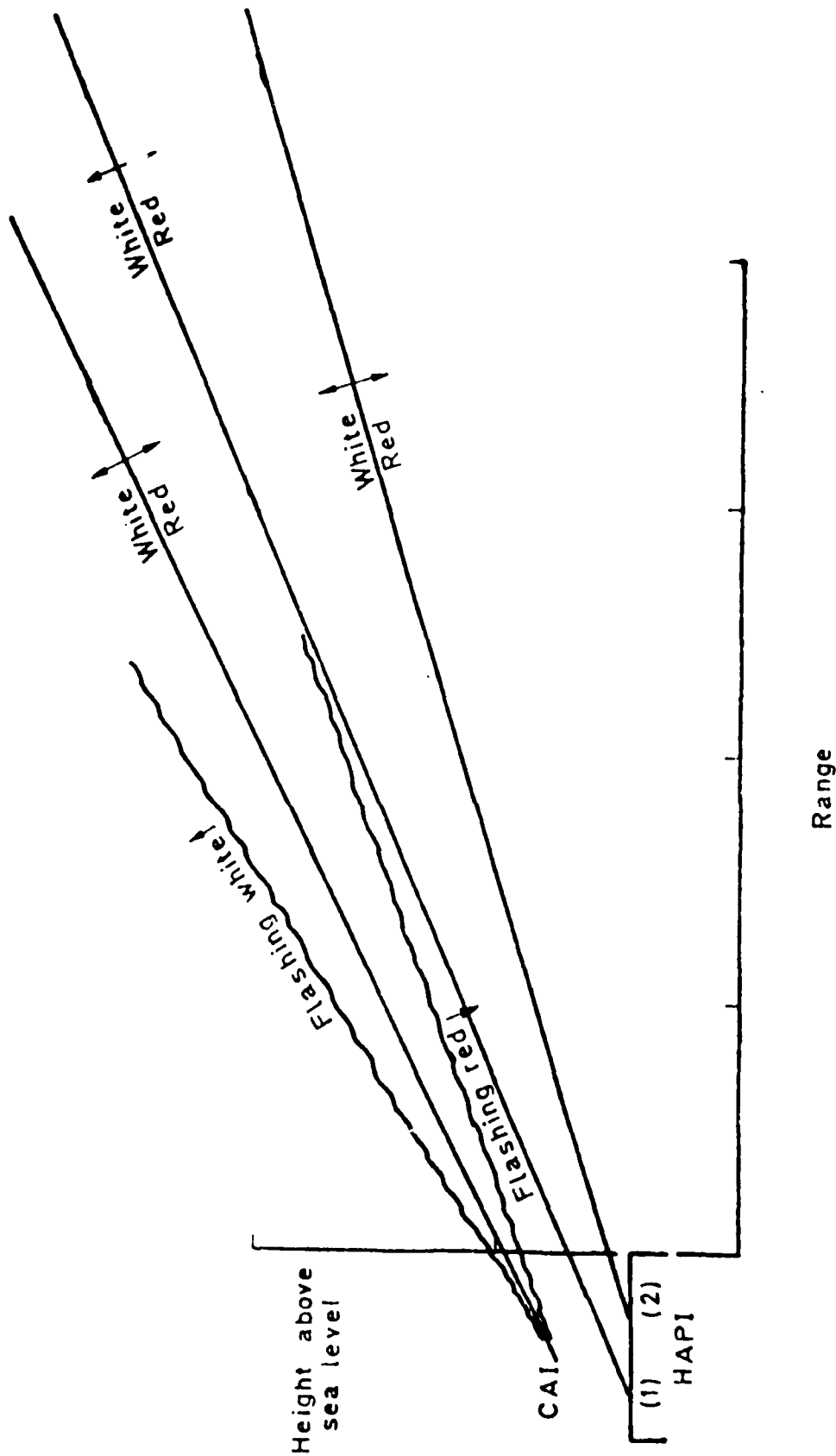


Fig 15

Fig 15 HAPI/CAI

Fig 16

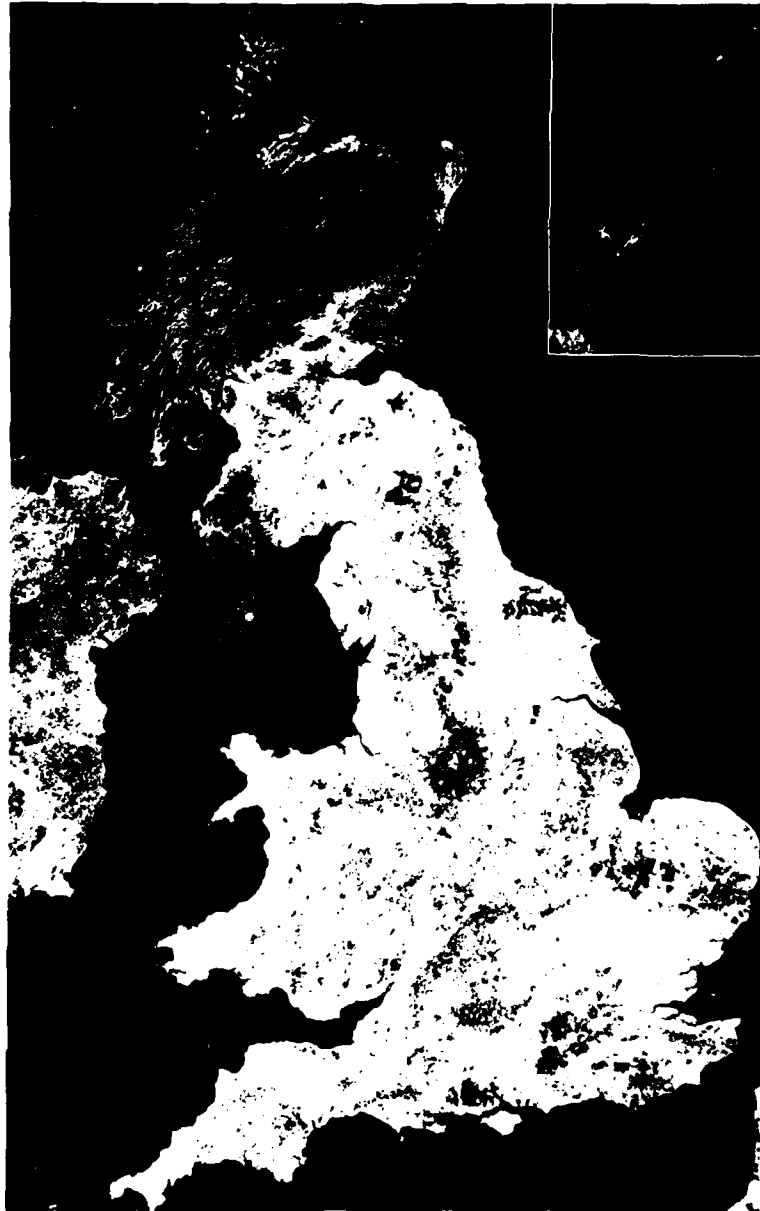


Fig 16 Landsat image, Earth resources

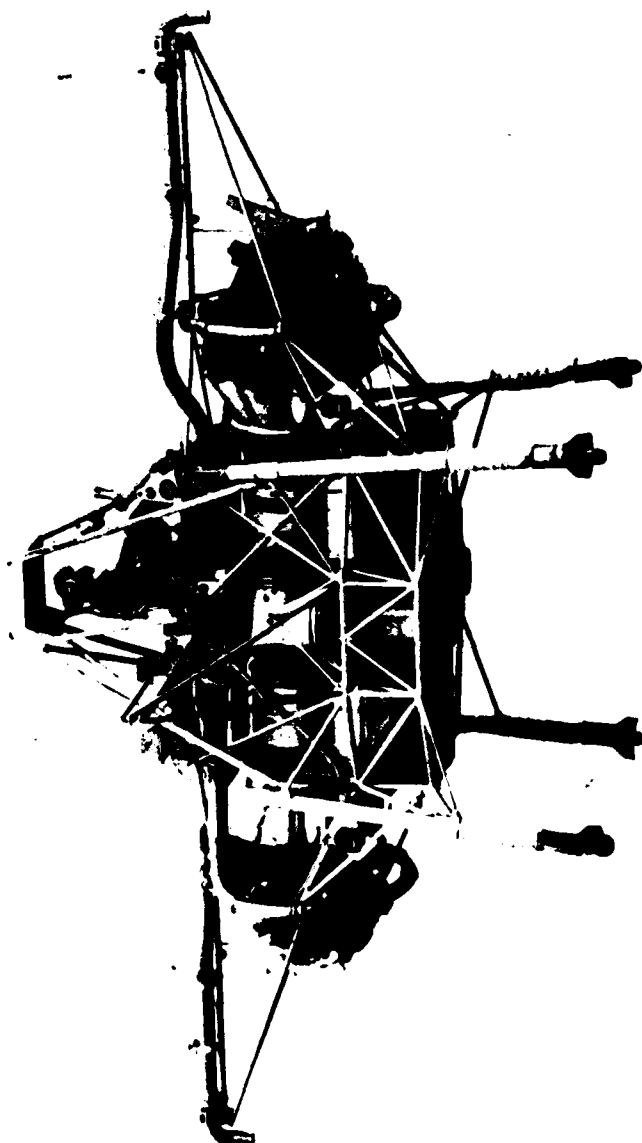


Fig 17 The Flying Bedstead

Fig 18

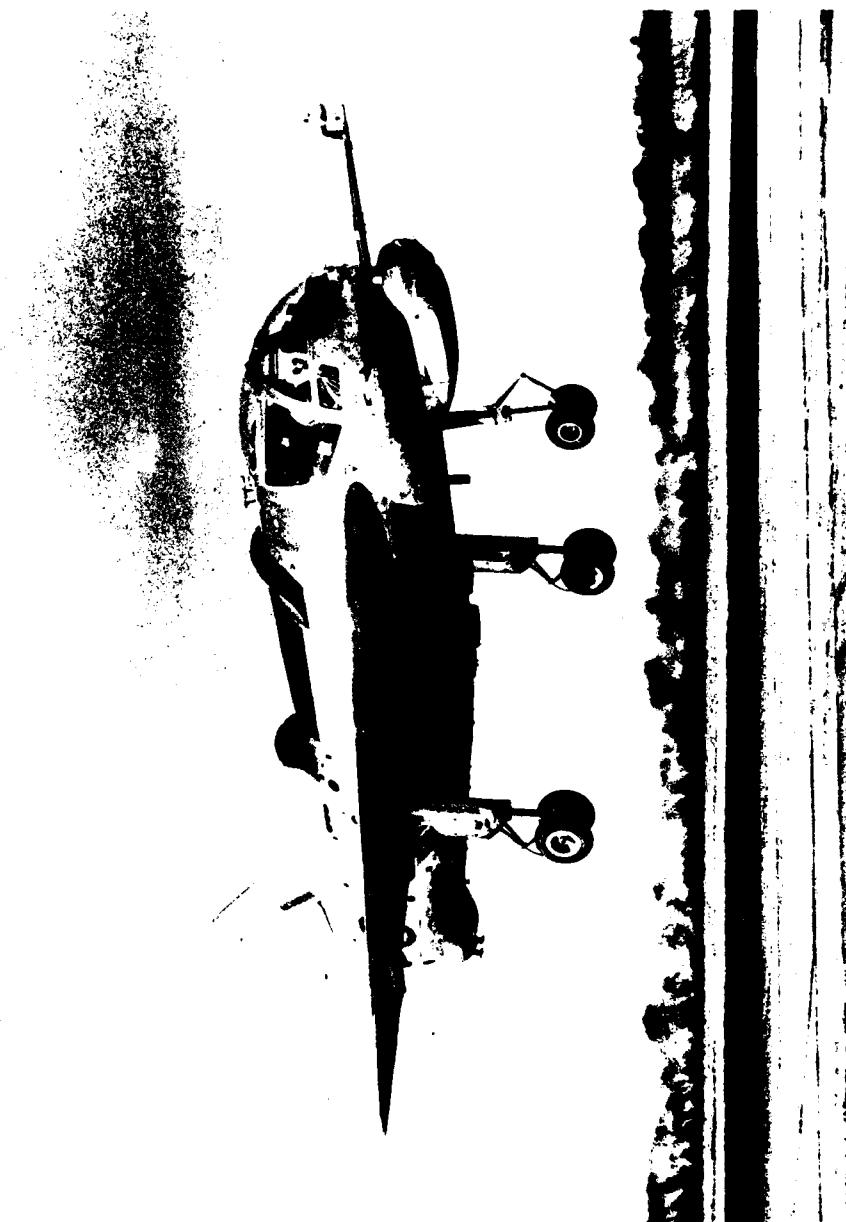


Fig 18 The SC-1

TN PS 432 C17250



Fig 19 The Harrier

Fig 20



Fig 20 The Tornado

TN FS 432 C17252

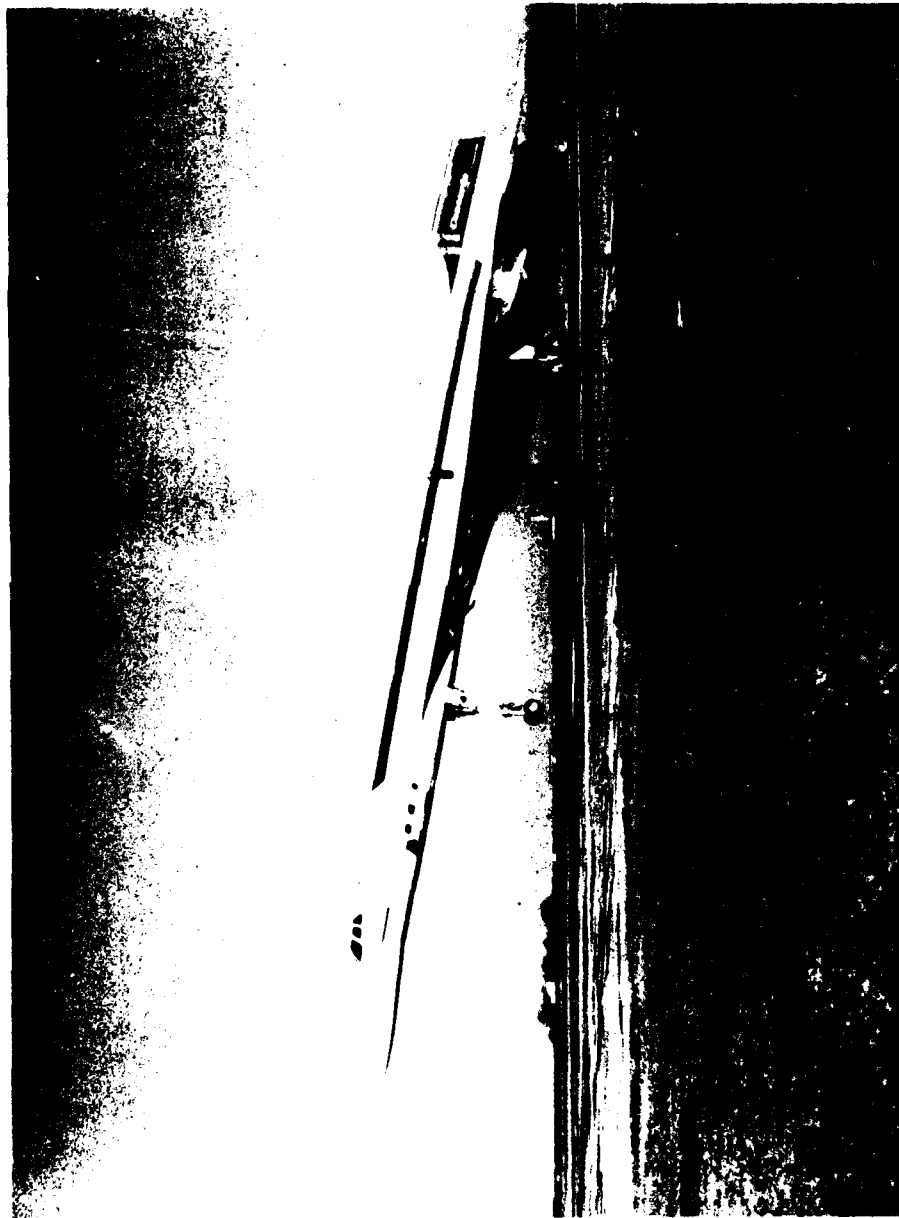


Fig 21 The Concorde

Fig 22

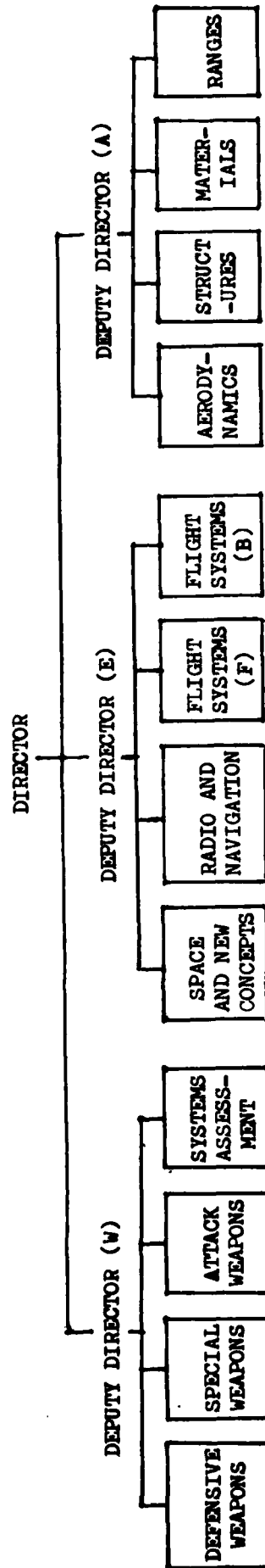


Fig 22 Structure of RAE - R & D departments

REPORT DOCUMENTATION PAGE

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