RCEA
(SUSSEX)

An Association for Retired Professional Engineers

NEWSLETTER March 2020

President's Message

Welcome to the March Newsletter.

We have completed our 2019/2020 session of talks with very good attendances which is encouraging.

The season of visits and outings starts in April with an outing to the Hassocks Garden Centre, including a talk on 'the history of lawnmowers' with optional lunch. The committee has worked hard to create an interesting programme for you, and it would be encouraging if you support the events.

Our activities will be kept under review and may be cancelled in the light of new advice from the Government. Individuals are of course free to make their own decisions in any case.

The Barn at Field Place has proved its value on those days we have used it. Your committee considered that despite the cost, it would be worth using it as a norm, but we have not been able to change the venue at present.

The microphone and amplification arrangements at recent meetings has improved, so thanks are due to Glyn.

We have added the link for Membership Mojo to our web site under About Us, Membership. This enables you to make changes yourself to the data we hold about you. It is https://membermojo.co.uk/mm/signin_email

Derek Webb
March 2020

PROGRAMME OF EVENTS April 2020 – October 2020

16th Apr	**Thursday**	**Coffee - at Spotted Cow, Angmering**
20th Apr	**Monday**	**Outing - South Downs Heritage Centre, inc. talk on the history of lawn mowers and (optional) lunch.**
30th Apr	**Thursday**	**Coffee - with Partners at Swallow's Return**
15th May	**Friday**	**Visit - Gatwick Aviation Museum**
21st May	**Thursday**	**Coffee - at Spotted Cow, Angmering**
23rd May	**Saturday**	**Visit - Culham - repeat of 2019 visit. Places not guaranteed.**
28th May	**Thursday**	**Coffee - with Partners at Swallow's Return**
18th Jun	**Thursday**	**Coffee - at Spotted Cow, Angmering**

25th Jun	**Thursday**	**Outing - Sheffield Park - Waterlily Festival**
2nd July	**Thursday**	**Coffee - with partners at Swallow's Return (note change of date)**
20th July	**Monday**	**Visit - Ford Materials Recycling Facility**
4th Aug	**Tuesday**	**Visit - Hovercraft Museum, Gosport and Fort Nelson.**
20th Aug	**Thursday**	**Coffee - at Spotted Cow, Angmering**
27th Aug	**Thursday**	**Coffee - with Partners at Swallow's Return**
15th Sep	**Tuesday**	**AGM and Talk: Converting 160 tons of WW2 concrete into a 6 bedroom floating home, Mike Wooldridge**
17th Sep	**Thursday**	**Coffee - at Spotted Cow, Angmering**
24th Sep	**Thursday**	**Coffee - with Partners at Swallow's Return**
13th Oct	**Tuesday**	**Talk – HS1, Crossrail and HS2 - A Traction Power Perspective, Louise Moore, Vanda Engineering Ltd**
15th Oct	**Thursday**	**Coffee - at Spotted Cow, Angmering**
29th Oct	**Thursday**	**Coffee - with Partners at Swallow's Return**
TBC	**TBC**	**Visit – Ceres Power, Horsham**

All Talks and Meetings will commence at 2.30 pm and be held in the Chichester Room, Field Place, Worthing unless another venue or time is indicated.
Timings for visits and outings will be as printed in the detailed description of the activity.
Coffee mornings commence at 10.30 am.

We apologise for only being able to publish a short list of our forthcoming events. This is simply due to the difficulties we now face in booking speakers and visits far ahead. As you know we sometimes have to cancel/rearrange talks and visits, often at short notice. We suggest that members should increasingly rely upon our website for up to date details of events.

Website of the RCEA

Our website, **www.rceasussex.org.uk** carries the very latest information on all of our events.

New Members and Speakers for Talks

The RCEA needs new members and speakers to ensure that we can continue as a thriving organisation. Please think of appropriate people you know and encourage them to come along to our talks and hopefully join the RCEA.
We also need more speakers to give talks to us on Tuesday afternoons from September to March. We are aware that many members have the knowledge from their working careers to provide interesting talks. If you are willing to give a talk please let us know. Speakers from outside organisations are increasingly harder to find and often seek payment for their services.

New Members

S J Hilton, Open University, Maths & Science – Worthing

RCEA Insurance

Members need to be aware that the insurance policy that the Association holds is solely for the protection for the assets and liabilities for the Association as an entity. The policy does not provide cover for personal injury or loss to individual members. Members attend the Association's events at their own risk, although under some circumstances there may be some cover from the insurance arrangements of the venue owner.

Newsletter Entries

If you would like to provide an article for inclusion in a future newsletter it would be very welcome as we are always looking for new material in addition to reports on previous talks and visits/outings. From feedback from our members we know that the newsletter is particularly appreciated by those who are no longer able to get to our meetings and visits, so if you are able to contribute in this way it would be much appreciated. Articles should preferably be Microsoft Word documents, although we can usually convert both text and pictures (even photographs) into a suitable format. Accompanying pictures are best supplied as separate files which will be embedded within the text during editing.

Brief Details – Talks, Visits and Outings April – October 2020

Talk and Visit
Monday 20th April 2020 - South Downs Heritage Centre, Hassocks, BN6 9LY

The South Downs Heritage Centre is located within South Downs Nurseries and Garden Centre so there are ample opportunities to browse the horticultural collections and perhaps take home some plants.

The talk, which will start at 11:00am, is on the **development of the lawnmower** from the first steam driven devices to the present day and will be given by Clive Gravett, an acknowledged expert. He has published a book on the subject "Two men went to Mow" and the profits go towards his charity, 'The Budding Foundation' which supports disadvantaged children.
The talk will be followed by the meal (if required) in the same function room as the talk before the museum tour. You will then be free to explore the garden centre at your leisure.
The guided tour of the museum and the talk will be £5, payable to the RCEA by cheque with the application form. The meal cost will be payable to Garden Centre cafe on the day. You can browse the attached menu and order your meal on the day of the visit or skip the meal if you wish.

Reply slip has been omitted as this visit is now cancelled.
Contact Ivan Farrow: 07971 184207, email ivan_farrow@yahoo.com

Visit
Friday 15th May – Gatwick Aviation Museum at 11:00am

The Gatwick Aviation Museum at Vallance By-Ways, Lowfield Heath Road, Surrey RH6 0BT houses a number of historically important aircraft from the Cold War era, including an Avro Shackleton Mk 3, a rare Blackburn Buccaneer S1, an English Electric Lightning FS3 and a de Havilland Sea Vixen. Several engines are also on display, from piston engines including the Rolls-Royce Merlin and the Armstrong Siddeley Double Mamba to gas turbines from the Rolls-Royce Nene to the Olympus, Pegasus and Spey. The museum also gives a history of Gatwick Airport's role from the Second World War onwards. We hope to have one of the museum's volunteers available to guide us round the exhibits but, because of the uncertainties linked to the coronavirus pandemic, this will be subject to change. Cost of entry is £7.50 per person, payable to the museum on the day.

Reply slip is at the end of this newsletter.
Contact Perry Eastaugh: 01903 788858, email perry.eastaugh@icloud.com

Visit
Saturday 23rd May – Culham Centre for Fusion Energy

Following the very successful visit to Culham last year I am organising another visit this year. Unfortunately, the demand for tickets is such that they were all allocated within a couple of hours of the date being made known. Consequently, I have only been able to get 5 places on the reserve list and therefore they cannot be guaranteed. However, they usually have cancellations.

We would like to make you aware that there will be a significant amount of brisk walking during the tour (3-4 km of walking and standing) so it is advisable to wear comfortable shoes. Please also note that open-toe shoes are strictly forbidden in one of the experimental areas, so please ensure ALL visitors wear covered footwear.

Visit to Culham (cont'd)

A brief programme for the event is as follows:
Arrival - tea and coffee will be served
Introductory talk on fusion
Followed by a 2 hour tour of JET and MAST fusion experiments

If I have already confirmed receipt of your reply slip you do not need to respond.

Reply slip has been omitted as this visit is now cancelled.
Contact Ivan Farrow: 07971 184207, email ivan_farrow@yahoo.com

Outing
Thursday 25th June – Water Lilly festival, Sheffield Park

Sheffield Park is a large area of Capability Brown-landscaped grounds with lakes owned by the National Trust in East Sussex. The nearby house is privately owned and not open to the public. For several years now Sheffield Park has held a festival between June and July when the water lilies are in bloom. The natural lilies are supplemented by large artificial ones and a floating pontoon enables visitors to 'walk' out onto the lake. This event attracts large numbers of visitors (many from overseas) and this year we have been fortunate to secure a guided tour of the park and lakes. The visit starts at 10:30am with a guided tour of between 1 and 2 hours.

Following the guided tour, visitors are free to further explore the grounds and/or to seek food and drink in the tea rooms which are located just outside the main entrance. Visitors can re-enter the gardens after visiting the tea rooms without additional charge.

Reply slip is at the end of this newsletter.
Contact Malcolm Hind: 01403251719, email malcolmhind@msn.com **before 20/6/2020.**

Visit
Monday 20th July – Visit to the Ford Materials Recycling Centre (change of date)

We are planning a visit to the Materials Recycling Facility (MRF) at Ford at 10.00am on 20th July. The visit will include a short presentation in the Education Centre, followed by an opportunity to see the MRF's state of the art technology from their viewing platform. Finally, there will be a Q&A session. The visit is expected to last for about 2 hours. Please note that visitors need to climb stairs to reach the viewing platform, so the visit is not suitable for those with limited mobility. Also, anyone with a pacemaker will not be able to go on the visit because large magnets are used in the separation process. **The visit is only open to residents of West Sussex**. It is limited to a maximum of 14 people, so priority will be given to RCEA members. Please note the early cut-off date. This is because Ford require details of all visitors, including medical information, in order to confirm the booking.

Reply slip is at the end of this newsletter.
Please make sure you give your FULL NAME when completing the reply slip.
Contact Perry Eastaugh: 01903 788858, email perry.eastaugh@icloud.com **before Monday 20th April.**

Outing

Tuesday 4th August – The Hovercraft Museum, Lee-on--Solent and Fort Nelson, Fareham

We have arranged an outing to the Hovercraft Museum (the world's largest collection of hovercraft) at Marine Parade West, Lee-on-Solent PO13 9NS, starting at 11.00 on Tuesday 4th August. The museum has an impressive array of hovercraft, including SR.N4 *The Princess Anne*, a BH7 military hovercraft, three hovercraft that appeared in the James Bond film *Die Another Day*, examples of SR.N5 and SR.N6, an ex-Royal Marines hovercraft LCAC22 and two examples of the Hover Hawk, the first light production hovercraft in the world. The visit will start at 11.00 with refreshments and we will be taken on a guided tour of the exhibits which will last about 2 hours. (You can then stay on to see more if you wish).

Otherwise, the plan is that we drive then to Fort Nelson, Portsdown Hill Road, Fareham PO17 6AN (about 20 minutes from the Hovercraft Museum and close to the M27 for the return). We will be able to explore some of the 19 acres of ramparts, fortifications, tunnels and ammunition bunkers, and view some of the biggest guns ever made, including a section of Saddam Hussein's 'Iraqi Supergun' and an 18" railway howitzer, as well as more decorative guns such as the 'Furies' bronze cannon from 1773 and a Burmese bronze 'dragon' cannon of 1790. There is also a chance to see what life was like for the average Victorian soldier at Fort Nelson, with displays of the barrack accommodation, the garrison kitchens and the hospital. Because the arrival time for this part of the visit will be flexible, we have not arranged a guided tour. People can spend as much time as they wish (or omit it altogether).

Reply slip is at the end of this newsletter. Applications **before Saturday 25th July please.**
Contact Perry Eastaugh: 01903 788858, email perry.eastaugh@icloud.com

Talk and AGM

Tuesday 15th September 2020 – Converting 160 tons of WW2 floating concrete into a 6 bedroomed luxury houseboat

Mike Wooldridge (member)

A freehold mooring plus an associated houseboat came up for sale by auction in Shoreham Harbour (west arm) in 1997. After arranging a family loan, the speaker and his wife bought said lot as an investment and also an interesting project. The talk will cover the assessment of the existing houseboat and the process of finding a replacement which took the form of a WW2 concrete barge capable of carrying 200 tons of petrol. The barge was moored in Torpoint Marina and had to be towed up the English Channel to its new home. Finding a suitable towing vessel, arranging insurance, opening the seized-up Shoreham footbridge, waiting for the right tide and weather window, and creating a suitable mooring system will all be covered.

Then followed the process of getting planning permission (since proven to be unnecessary), building a new top deck cabin, cutting port holes, casting window frames, fitting out and connecting to all mains utilities. The boat is now occupied by the speaker's youngest daughter and family.

The talk will also cover research which showed that the barge was one of 200 built by the same engineers (Mouchel) and constructors (Marley, Wates) who also built (part of?) the WW2 Mulberry Harbours.

Talk

Tuesday 13th October 2020 – HS1, Crossrail and HS2 - A Traction Power Perspective

Louise Moore, CEng MIET Vanda Engineering Ltd

From the UKs first high-speed railway to its latest and a bit in between!

This presentation will consider the new railways that have been (or will be) constructed over the last 20 years in the UK. It will cover the challenges encountered and solutions developed in terms of traction power for:

- High Speed 1 – which has now been operation for 15 years
- Crossrail – which is currently in the integrated testing and commissioning phase
- High Speed 2 – currently in the tendering stage for Railway Systems

An overview of each project will be given including high level scope and key requirements and then go on to discuss the various stages of a major project using traction power examples from the three projects.

The stages discussed will include scope development, through procurement, design, installation, testing, commissioning and handover.

Our speaker, Louise Moore, will be giving this presentation from an Engineer's viewpoint.

Visit
Date to be decided – Ceres Power, Horsham

Paul Barnard, Director of Special Projects at Ceres Power, was our speaker at the 2019 Cooch Memorial Lecture last November and gave us a fascinating insight into fuel cell technology. We have asked if it would be possible for a group of us to visit their factory in Horsham. Paul has recently contacted us to say that, in principle, they would be willing to host a visit but, given the current health situation, they would prefer not to fix a date until things have settled down. Numbers are likely to be limited so, at this stage, we are asking for expressions of interest. As soon as a date can be agreed, you will be informed.

Reply slip is at the end of this newsletter.
Contact Perry Eastaugh: 01903 788858, email perry.eastaugh@icloud.com

Reports

Talk
Tuesday, 10th December 2019 – "National measurement standards for medical ultrasound and underwater acoustics"

Dr Roy C. Preston, retired Senior NPL Fellow, (member RCEA)

Roy's talk addressed the programme of research and development at the UK's National Physical laboratory (NPL) in two main areas. The first being medical ultrasound measurement standards from the start in 1978 to the present time, and the second underwater acoustics measurement standards from late 1980's to the present time. Thanks were expressed to Dr Bajram Zeqiri and Stephen Robinson at NPL for providing some of the display material. A major message of this talk was that the work in medical ultrasound achieved success and world-wide recognition through the development of the membrane hydrophone and its calibration based on optical techniques.
NPL is the UK's national standards organisation and got involved with medical ultrasound in 1978 following rapid developments of diagnostic ultrasound in industry and medical physics departments who needed reliable measurements of the ultrasonic fields. The project was initially led by Dr Keith Shotton with Alison Livett and David Bacon and in 1980 Roy took over responsibility.
Over the years, medical uses of ultrasound in the 1 MHz to 20 MHz, and now beyond, have been numerous and include:

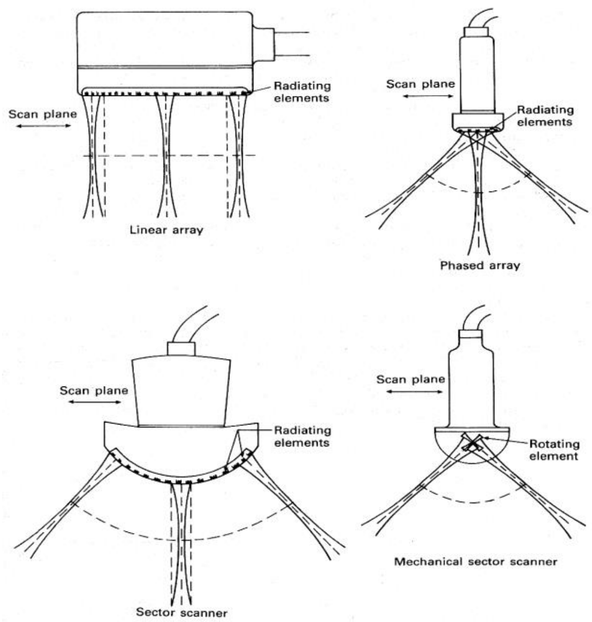
- Diagnostic imaging
- Foetal heart-beat detection
- Blood flow measurement
- Physiotherapy
- Lithotripters – breaking kidney stones
- HIFU (High Intensity Focused Ultrasound) – cancer treatment
- And many others

The ultrasound can be continuous wave, tone burst or pulsed. For measurement of the acoustic output of these systems, all characterisation is undertaken in water where the speed of sound is 1500 m/s, hence the wavelength of ultrasound ranges from 1.5 mm to 0.075 mm over the 1 MHz to 20 MHz range.
In ultrasound, there are only two acoustical quantities realised by National Measurement Institutes which are now supported by International Key Comparisons:

- Acoustic power
- Acoustic pressure

The power output of an ultrasound transducer can be measured using a radiation force balance which measures the force the ultrasonic wave exerts on a surface. NPL has established a primary standard radiation force balance shown opposite that is used mainly for international comparisons.

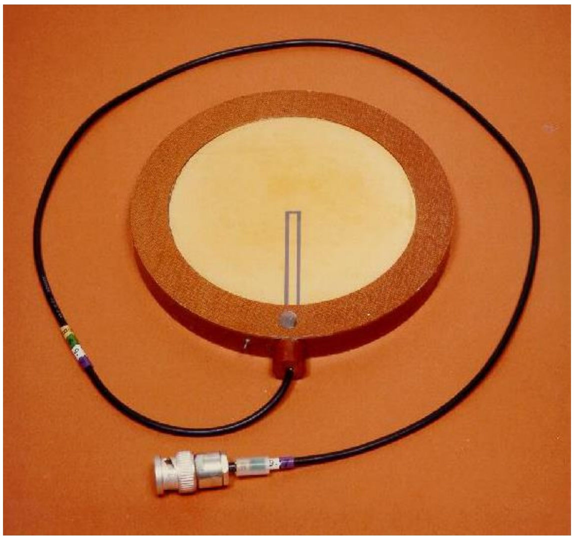
The real progress NPL made was in the development of methods of measurement of the ultrasonic fields and the calibration of the measuring devices. Measuring ultrasonic fields emitted by medical ultrasonic transducers and more complex scanners presents many challenges.



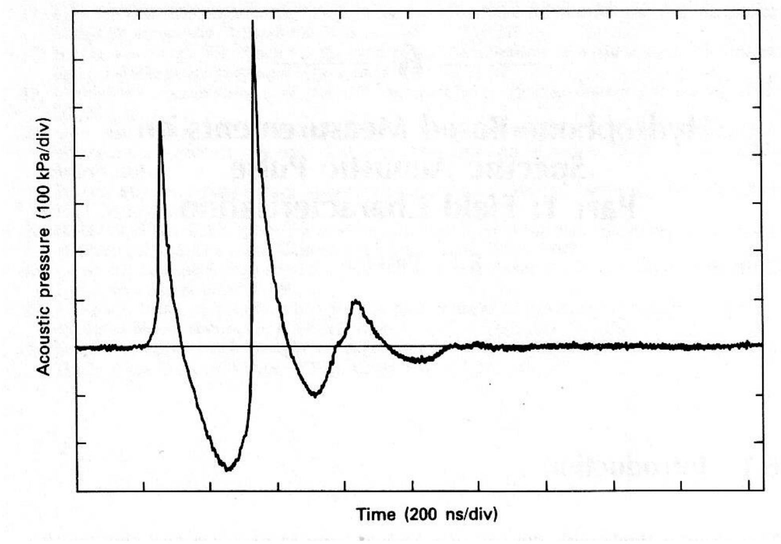
Hydrophones were developed with small active areas to measure the spatial and temporal distribution of the ultrasonic fields generated by the different types of transducers used in medical ultrasonic equipment. Shown opposite are schematic diagrams of different types of medical ultrasonic scanner transducers.

In all cases, the measurements are made in water tanks with the transducer and hydrophone supported on co-ordinate positioning systems to enable optimisation of the hydrophone signal and mapping the fields.

There was a need to develop reliable measuring hydrophones which had a smooth and reasonably flat frequency response, stable sensitivity which is theoretically predictable. This was achieved through the development of the piezoelectric polymer (polyvinylidene fluoride - PVDF) membrane hydrophone in a collaborative programme between NPL and Marconi Research Centre, Chelmsford.



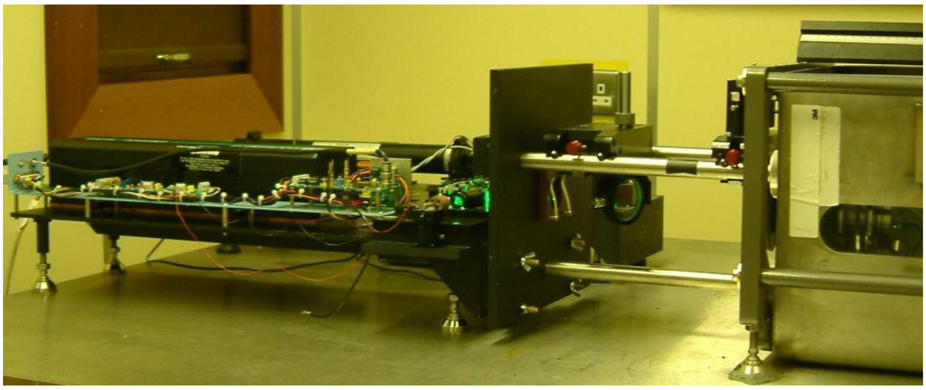
The membrane hydrophone provides an acoustically transparent device with an active element diameter of typically 1 or 0.5 mm. A bilaminar configuration, as shown opposite has two layers of 25 µm PVDF film to give a frequency response to over 20 MHz. Other devices used for the standards programme were made from thinner PVDF giving them response to higher frequencies.



Early results showed the acoustic pressure waveform measured at the focus of diagnostic ultrasonic transducers to be non-linear, as shown opposite. Maximum positive and negative acoustic pressures were typically 8 MPa and -4 MPa respectively. These findings caused alarm worldwide and it was only after the publication of a seminal paper by David Bacon at NPL that acceptance of the results was gained. The ability to predict non-linear waveforms and the theoretical performance of the membrane hydrophones were key to this acceptance.

Another supporting factor was NPL's work on the absolute calibration of the hydrophones using optical interferometry, developed jointly with AERE Harwell, to provide direct traceability to the System of Physical Units (SI).

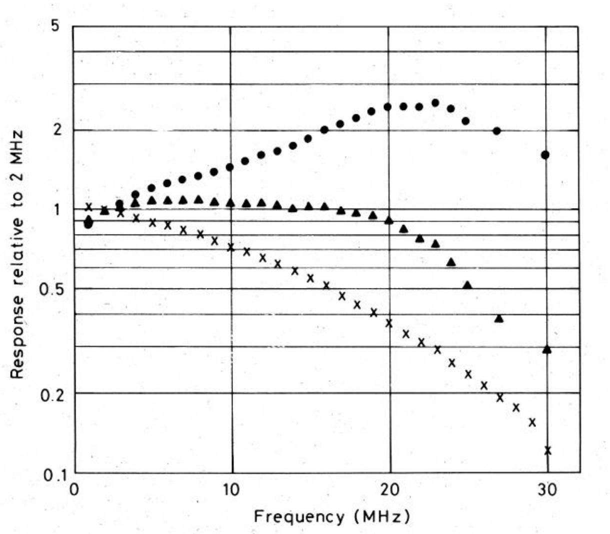
The method involves a 3 or 5 µm thick optically reflecting pellicle placed in an ultrasonic field and using the laser interferometer, shown opposite to measure the small displacement amplitude of the pellicle caused by an ultrasonic wave, typically a few nanometres, from which the acoustic pressure can be derived.



The pellicle is then replaced by a membrane hydrophone with its active element at the same point as the laser measurement was made and the output of the hydrophone measured to enable its sensitivity to be determined and for it to be used as a secondary standard device.

Systematic studies of the performance of the calibration method have been undertaken and now yield uncertainties typically from 2-3% at 1 MHz to 10% at 15 MHz. Future developments will involve extending the calibration method to up to 60 MHz and above.

For the calibration of other hydrophones against the secondary standards, the type of non-linear waveform shown previously is utilised. A 1 MHz transducer is driven hard to generate a non-linear field containing higher frequency harmonics every 1 MHz which allow comparison of the sensitivities of a device to be calibrated with the secondary standard.

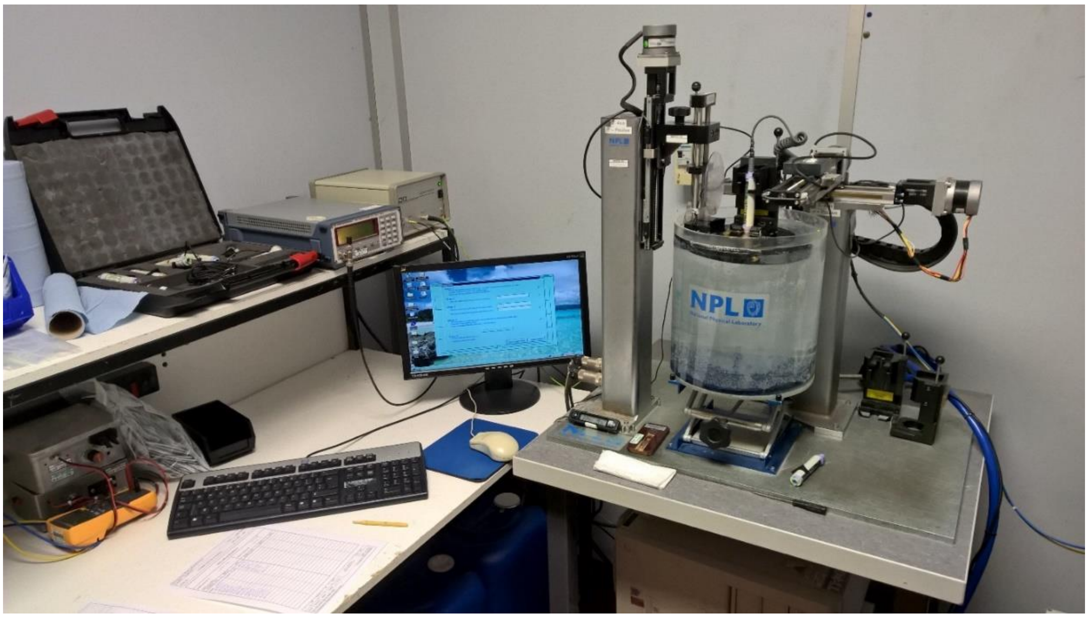


The results shown opposite are for a 25 µm bilaminar hydrophone (circles) and when combined with a matching amplifier (x) gives a flat and smooth frequency response (triangles).

Measuring the acoustic output of medical ultrasonic equipment is the basis for providing the clinical user with useful information on safety. The two main interactions between ultrasound and human tissue during diagnostic ultrasound examinations are tissue heating and mechanical effects such as cavitation. The relative importance of these two interactions depends on the type of tissue between the transducer face and the site of interest to the clinician.
Most ultrasound scanners now provide safety information to the clinician in the form of Thermal and Mechanical Indices displayed on the screen during scanning.

The operator selects the tissue type being scanned and can keep the displayed indices below recommended maximum levels. All displayed indices are calculated from free-field measurement data using hydrophones and power measurements using radiation force balances and NPL's calibration of hydrophones underpins the world's medical ultrasound industry.

In 2002, NPL developed a simple system, the later development of which is shown opposite for Huntleigh Healthcare to monitor every foetal heart-beat detector they make and over the years, 600,000 probes have been measured.



Underwater acoustics

During the late 1980's there was a growing UK need for national measurement standards in underwater acoustics and an evaluation of calibration needs was undertaken by contacting and visiting many companies and organisations.

A new standards programme was established at NPL involving the development of measurement and calibration facilities. Two open tank facilities with precision positioning systems were established for operation and free-field calibration of hydrophones and transducers from 250 Hz to 500 kHz.

A large 100 tonne acoustic pressure vessel (APV) shown opposite was acquired from the USA capable of operating at hydrostatic pressure up to 7 MPa (70 bar, equivalent to ~700 m depth). The facility allows variation in water temperature and pressure cycling.

Acoustic measurements can be undertaken in the frequency range 2 kHz to 400 kHz. An important role of the APV is in the testing of acoustic absorbing and anti-reflection panels used in military applications. This installation has now established itself and is used to undertake much work for research purposes and for commercial companies.

An open water facility is also operated by NPL located on a local reservoir. A floating calibration laboratory on a large raft, shown opposite operates in over 20 m deep water and allows testing and calibration of underwater acoustic devices in the frequency range 40 Hz – 350 kHz.

NPL validates its measurement standards by extensive uncertainty evaluation and international comparison exercises. Technical guidance is provided on-line on topics such as the speed of sound in sea water and sound absorption. Training courses are also given.

Research into optical methods of calibration and standards for ocean noise monitoring are also on-going areas of research and study.

The UK National Physical Laboratory leads the world in medical ultrasonic and underwater acoustic measurement standards. A success story which has established the UK as a very influential player on the international scene.

Roy Preston

Talk.
Tuesday 14th January 2020 – "Operation Overlord, D-Day 6 June 1944"

Dudley Hooley, Director, Tangmere Military Aviation Museum

As members have enjoyed hearing Dudley Hooley's talks before, we knew that he would attract a good audience, but were rather caught out when 64 members and guests turned out on a rather wet day in January to hear him speak about Operation Overlord. Fortunately, we had been relocated to the barn at Field Place, and after rushing around for extra chairs, tea and coffee, Dudley began his fascinating insight into Operation Overlord. This article is a very much condensed version of the extensive and fascinating material that Dudley presented.
He began by talking about the military leaders who played a key role in Operation Overlord, the codename for the Battle of Normandy, the Allied operation that launched the successful invasion of German-occupied Western Europe during World War II.

General Eisenhower, Supreme Allied Commander Europe is at bottom centre, with ACM Tedder, Dep Supreme Allied Commander Europe on his right and Gen Montgomery, Commander 21st Army Group & Allied Ground Forces for Overlord on his left. From left to right at the top are Gen Bradley, Commander 12th Army Group, Admiral Ramsey, Naval Commander-in-Chief of the Allied Naval Expeditionary Force for the invasion, ACM Leigh Mallory, Commander-in-chief of the Allied Expeditionary Air Force and Gen Bedell Smith, Eisenhower's Chief of Staff

Preparations for D Day

D Day was the day when the invasion of France would begin. An enormous amount of preparatory work, construction and training had to be undertaken first. Since it was clearly impossible to avoid some news leaking out beforehand, it had been necessary to enact a series of deceptions to convince the Germans that the invasion of Europe would take place at Pas de Calais rather than the beaches of Normandy. The Pas de Calais area offered a number of advantages over the chosen invasion site, such as the shortest crossing of the English Channel and the quickest route into Germany. As a result German command, particularly Rommel, took steps to heavily fortify that area of coastline. The Allies decided to amplify the German belief in a Calais landing.

Montgomery, commanding the Allied landing forces, knew that the crucial aspect of any invasion was the ability to enlarge a beachhead into a full front. He had only limited divisions at his command, 37 compared to around 60 German formations. The deception's main aims were to give the impression of a much larger invasion force to achieve tactical surprise in the Normandy landings and, once the invasion had occurred, to mislead the Germans into thinking it was a diversionary tactic with Calais still the real objective. A key element of the deception was Operation Quicksilver, which entailed the creation of the belief in German minds that the Allied force consisted of two army groups, 21st Army Group under Montgomery (the genuine Normandy invasion force), and 1st U.S. Army Group (a fictitious force under General George Patton), positioned in south eastern England for a crossing at the Pas de Calais. German intelligence would (and did) deduce that the centre of the invasion force was opposite Calais, the point on the French coast closest to England and therefore a much more likely landing point.

To facilitate this deception, additional buildings were constructed, and dummy aircraft and landing craft were placed around possible embarkation points. Patton paid many of these a visit along with a photographer.

Contrary to popular belief, there was no use of other dummy vehicles, such as inflatable tanks (shown opposite) but these became a popular myth.

As early as 1942 it had become obvious that additional airfields would be required for the Allied assault on Europe, particularly during the build-up and during the actual landings. The need would be for rudimentary airfields that would require only basic facilities for day-only operations. These airfields, to be known as Advanced Landing Grounds (ALGs), would therefore need runways, refuelling and re-arming points and hard standings for the aircraft. The belief was that the ALGs would not be used during the winter months and therefore accommodation under canvas and in requisitioned nearby houses would suffice.

On 1 April 1944 Selsey ALG was re-opened and six days later the Spitfire IXs of No 485 (RNZAF) Squadron of No 135 Wing, No 84 Group, 2nd Tactical Air Force (TAF) moved in followed a few days later by No 222 (Natal) Squadron RAF and No 349 (Belgian) – both squadrons also equipped with Spitfire IX dive-bombers. The squadrons quickly settled in by setting up their dispersal areas. Large marquees were erected for the messes and six-man tents for the ground crews to live in. The Kiwis of No 485 erected their tents near the red-roofed St Wilfred's Chapel on the eastern boundary of the airfield. The pictures over page show the location of RAF Tangmere and a typical scene when in full operation.

Another important part of the D Day preparations involved a most unlikely person, a Sir Percy Cleghorn Stanley Hobart (shown opposite), an expert in military hardware, who devised a series of ‘Hobart Funnies’ based upon tanks, to be used on the D Day itself.

These included ‘swimming tanks’ (shown far right, flame throwers (below right) and path layers (below left).

On D Day itself the sea state off the Normandy beaches was much rougher than the swimming tank ‘skirts’ had been designed to accommodate, and most of them unfortunately sank before getting to the beaches, but the flame throwers, track layers and the bulk of Hobart’s other ‘Funnies’ were very successful and contributed in no small measure to the eventual success of the landings.

Another important preparation for D Day was the construction of several mini submarines named X craft. Each X craft was about 51 feet (15.5 m) long, 5.5 feet (1.68 m) in maximum diameter and displaced 27 tons surfaced and 30 tons submerged. Propulsion was by a 4-cylinder Gardner 42 hp diesel engine, converted from a type used in London buses, and a 30 hp electric motor, giving a maximum surface speed of 6.5 knots (12 km/h), and a submerged speed of 5.5 knots (10.1 km/h). The crew initially numbered three — commander, pilot and engineer, but soon a specialist diver was required, for which an airlock, known as a wet and dry compartment, was added. The pictures overpage show how compact the X craft were – certainly not an ideal home for those suffering from claustrophobia!

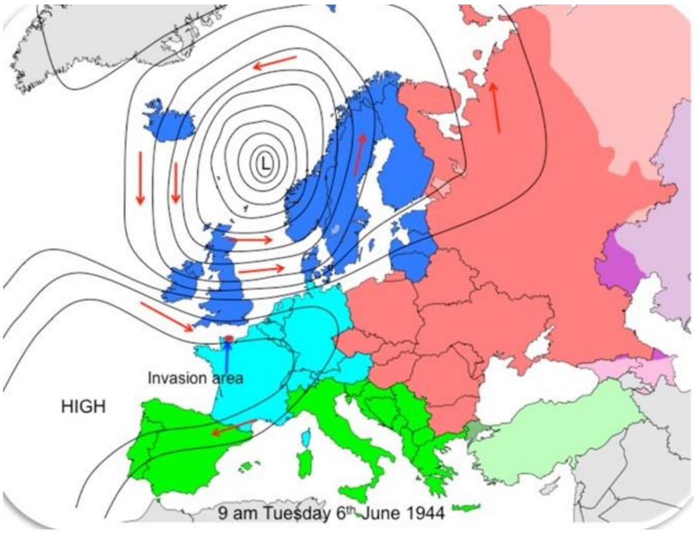
X-Craft were involved in the preparatory work for Operation Overlord. It was planned to take surveys of the landing beaches with HMS X20 spending four days off the French coast. Periscope reconnaissance of the shoreline and echo-soundings were performed during daytime. Each night, X20 would approach the beach and 2 divers would swim ashore. Soil samples were collected in condoms. The divers went ashore on two nights to survey the beaches at Vierville-sur-Mer, Moulins St Laurent and Colleville-sur-Mer in what became the American Omaha Beach. On the third night, they were due to go ashore off the Orne Estuary (Sword Beach), but by this stage fatigue (the crew and divers had been living on little more than benzedrine tablets) and the worsening weather caused the commander to shorten the operation, returning to England on 21 January 1944.
X20 and X23 acted as lightships to help the D-Day invasion fleet land on the correct beaches. The engineer, usually a Navy Chief Petty Officer, operated most of, and maintained all, of the machinery in the vessel.

The weather

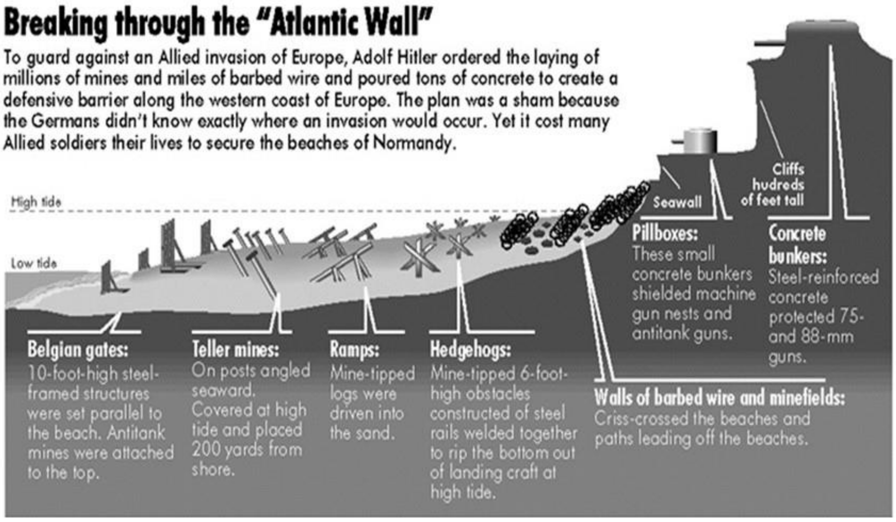
Despite all the preparations for D Day, the one variable not under the allies' control was the weather. Calm weather was critical for the success of such a massive sea borne operation. The ultimate responsibility for predicting the weather conditions at the Normandy beaches rested on the shoulders of the chief meteorological officer, Group Captain James Stagg (shown opposite). Stagg, who was born in Dalkeith, Scotland, had been commissioned a Group Captain in the Royal Air Force Volunteer Reserve and appointed the chief meteorological officer for Operation Overlord in 1943.

The original date scheduled for D Day was 5th June 1944, but Stagg had to advise Eisenhower the day before that in his opinion the weather forecast was not sufficiently good for the invasion to take place on this date, despite some American forecasters disagreeing with him.
The next day at 04:15 on 5th June, Stagg once more found himself in front of Eisenhower being asked if the mighty offensive could be mounted the following morning. After clearing his throat, Stagg began. 'Well, I'll give you some good news,' he said. 'Gentlemen, no substantial change has taken place since last time, but as I see it, the little that has changed is in the direction of optimism.'

The forecast that Stagg was relying on is shown opposite. As predicted, Stagg reckoned that there would be a break in the weather - enough to mount the invasion.
General Eisenhower then said quietly, 'OK. Let's go.' 'No one present disagreed,' he recalled, 'and there was a definite brightening of faces.' If his prediction was wrong, then his forecast would result in perhaps the greatest military catastrophe ever. Had D-Day not taken place on June 6, the ships that were already at sea would have had to return to refuel. For his invaluable services during the planning of D-Day, Stagg was appointed an Officer of the US Legion of Merit in 1945 and appointed an OBE at the same time. He was knighted in 1954 and elected as president of the Royal Meteorological Society in 1959.



The task ahead

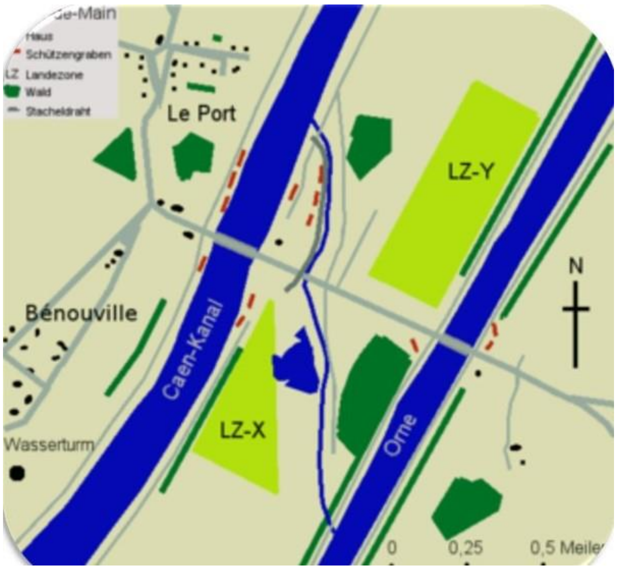


From intelligence received the allied commanders knew that breaking out from the beaches would be difficult and casualties would be high. But once this had been accomplished, it was equally important to ensure that vital roads and bridges in Normandy were secured by the allies to allow further progress and to prevent the Germans mounting a counter offensive once they realized that Normandy was the invasion point.

Two strategically important bridges spanned the river Orne and the Caen canal (the famous Pegasus bridge), and these had to be secured ahead of the landings on the beaches. The task of securing these bridges fell to the paratroopers.

As the bridges had to be secured ahead of the main invasion force's arrival, the operation had to be carried out before dawn – i.e. in the dark. Furthermore, it had to be carried out as quietly as possible, necessitating the use of unpowered gliders.
The map opposite shows the two designated landing zones X and Y – both quite small fields. The gliders had no engines, their pilots only had one chance to land in the correct place, in the dark, with no practice beforehand!

This operation has been described as one of the most outstanding flying achievements of the war.



The Airspeed AS.51 Horsa shown opposite was a British troop-carrying glider used during the Second World War. It was designed by R. J. Mitchell, developed and manufactured by Airspeed Limited using a number of subcontractors; the type was named after Horsa, the legendary 5th-century conqueror of southern Britain. It had a top speed of 242 km/h, was 20 m long and designed to carry 25 fully equipped troops in a rather tight space. Over 3,600 such gliders were eventually built.

On D Day all 6 gliders were overweight as they each carried 30 troops.

The picture opposite shows one of the gliders under tow behind a Halifax tug plane.

On a darkened airfield at 2230 hours on June 5, 1944, a reinforced company of British glide-borne infantry, D Company of the Second Battalion, Oxford & Buckinghamshire Light Infantry (Ox & Bucks), boarded gliders, prepared to start the invasion of France. Their commanding officer, Major John Howard, watched them in the night's dim light, shuffling forward under the heavy load of their weapons and equipment. He recorded, "It was an amazing sight. The smaller chaps were visibly sagging at the knees under the amount of kit they had to carry."

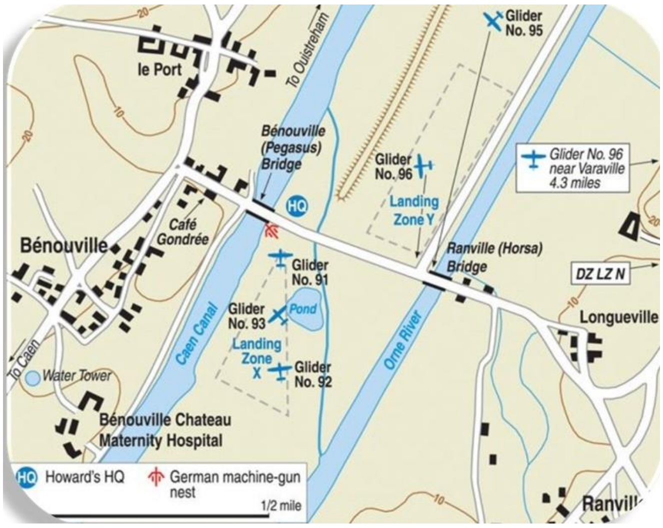
The first glider touched down on French soil at 00:16, followed by the others in close succession. The landing of the three 'coup de main' gliders on LZ-X was extremely rough (see opposite). The severity with which No.1 Platoon's glider came to a halt catapulted both pilots through the cockpit screen and left all the passengers unconscious for a few seconds. Howard's seatbelt had broken, and the impact threw him about the glider. He had hit his head on the roof, and this forced his helmet down over his eyes. When he regained his senses, Howard's first impression that he was either dead or at least blind, but he quickly discovered the problem and was relieved to discover that he could see again.

As No.1 Platoon went into action, Howard, with his wireless operator, Corporal Tappenden, set up a command post inside a trench near the perimeter wire. Howard watched No.1 Platoon as they went into action, and as the following gliders landed and reported to him, he directed them to their planned objectives, an alteration only being needed if something had gone wrong with the assault. Whilst he was standing here, Howard and Tappenden were fired on by a German rifleman, but all his shots went astray. The first news that came to Howard was that Lieutenant Brotheridge had been hit. Howard remarked, "It really shook me, because it was Den and how much of a friend he was, and because my leading platoon was now without an officer. At the top of my mind was the fact that I knew Margaret, his wife, was expecting a baby almost any time."

The bad news continued because all three of the platoon commanders at Bénouville Bridge had been hurt, and Brotheridge would die of his injuries. Howard was concerned about this and because Corporal Tappenden had heard nothing from Ranville Bridge.

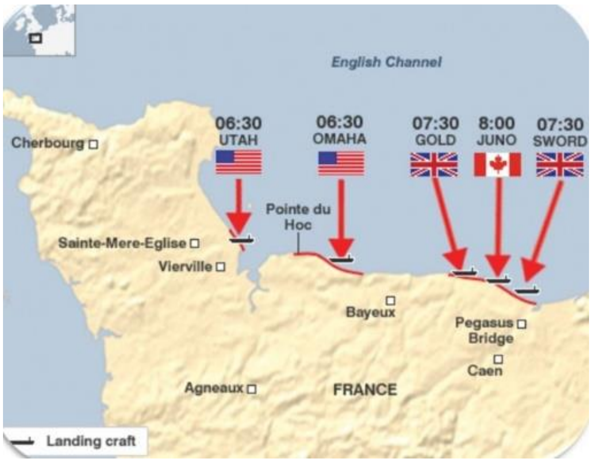
However, just as he received visual confirmation that Bénouville Bridge had been successfully taken, Tappenden tugged Howard's smock and passed on the news that Ranville Bridge had also fallen.

The skills of the glider pilots in landing their craft so near to their targets was incredible and contributed in no small measure to the complete success of this part of the D Day invasion.



D Day

H Hour was 06:30 on 6th June when the first wave of US troops landed on Utah and Omaha beaches in Normandy. Dudley described and illustrated in detail the assaults on each of the five beaches. As this is a very much condensed description of Dudley's talk, we have been able to include only a brief selection of pictures with illustrative text in this newsletter.



The five assault beaches

Getting Ashore from the landing craft

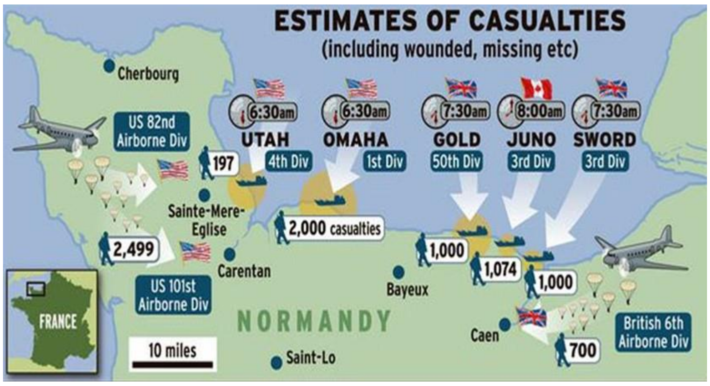
The beaches were a very dangerous place to stay for any length of time

German 155mm gun emplacement

Aerial bombing of strategic targets

Naval bombardment of beach defences from USS Texas

On D Day itself 156,000 allied troops landed in France, 6,939 vessels were involved, and within 5 days a total of 326,547 troops had landed supported by 104,428 tons of supplies.
Successful as Operation Overlord was, the allies paid a heavy price for the victory as shown in the two pictures below. There are few reliable statistics for German casualties, but figures range from 4,000 to 9,000.



Our thanks to our speaker, Dudley Hooley, for a very detailed account of Operation Overlord.

Malcolm Hind

Talk.

Tuesday 11th February 2020 – "Wealden Iron – the UK's First Industrial Centre"

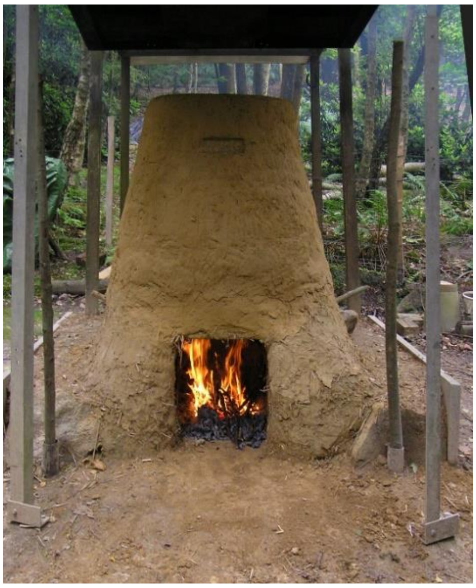
Dr Tim Smith, Hon Sec Wealden Iron Research Group

Our speaker, Dr Tim Smith, provided us with this résumé of his presentation which is reproduced in its entirety.

Kipling, a resident of East Sussex, captured the importance of iron in war in the first verse of his poem, 'Cold Iron':

Gold is for the mistress – silver for the maid –
Copper for the craftsman, cunning at his trade,
Good! said the Baron, sitting in his hall,
But Iron - cold iron - is master of them all.

The Iron Age starting around 800BC in Britain and iron production on the Weald continued through the Roman period, the Saxon period, Medieval times and into the early 19th century.
At first, small furnaces called bloomeries, constructed of clay and stone with air blown with hand or foot bellows, made iron. The fuel was charcoal from local coppiced wood and the iron ore was collected from stream beds and later dug from mine shafts and quarries.
We know of nearly 700 bloomery furnaces on the Weald and are finding more each year. Two of these bloomeries are shown in the pictures below. The one on the left is a reconstructed bloomery furnace of medieval type and the picture on the right shows an excavated medieval furnace.




This iron came out of these furnaces in a solid mass – not molten, but the waste material, called slag or cinder, flowed as liquid, like volcanic lava – see below left. Today, we find this slag as heavy lumps often with flow markings scattered across the Weald – see the picture below centre. The picture below right shows a sectioned bloom of iron.



This iron bloom had numerous cavities and contained slag. This was compacted and slag driven out by hammering while hot to produce a 'billet' which was sold to skilled blacksmiths to make into useful items such as horse and ox shoes – vital for transport – as well as farming implements and tools.

In the frequent times of war, knights' armour, arrow heads, spears, battle axes and even cannon - constructed like barrels, consisting of staves of iron held together with iron hoops - were in demand. This was known as the 'Direct Process' as the iron could be directly fashioned into useful implements.

The Blast Furnace

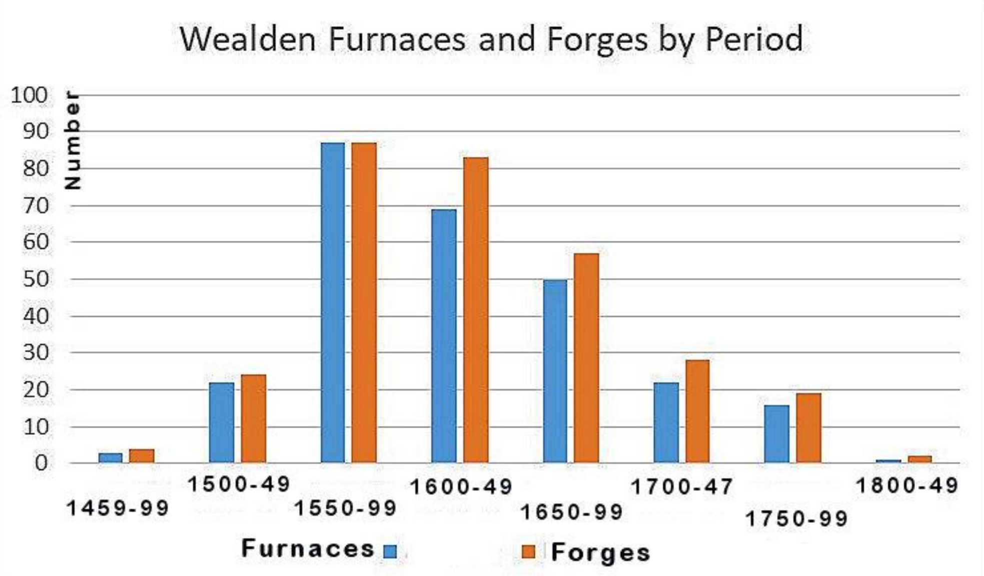
As the demand for iron increased, furnaces grew larger and taller and waterpower started to be used to drive the bellows and hammers to compact the iron. Unexpectedly not only molten slag flowed from these furnaces but molten iron too. The iron became molten because, just as in a bloomery, solid iron is first formed, and the higher up the furnace this happens, the longer it stays in the hot charcoal and furnace gases causing it to absorb more carbon.

The higher carbon content lowers iron's melting point from around 1500°C for pure iron to about 1200°C for 4% carbon iron, typical of blast furnace iron, temperatures easily achievable even in a small furnace. On solidification blacksmiths found this metal was hard and brittle and could not be hammered into shape.

We now come on to discuss the blast furnace – so called as it relied upon a blast of air being blown continually into the furnace near its base. The very first blast furnace to be built in Britain was on the Weald at Buxted in East Sussex.

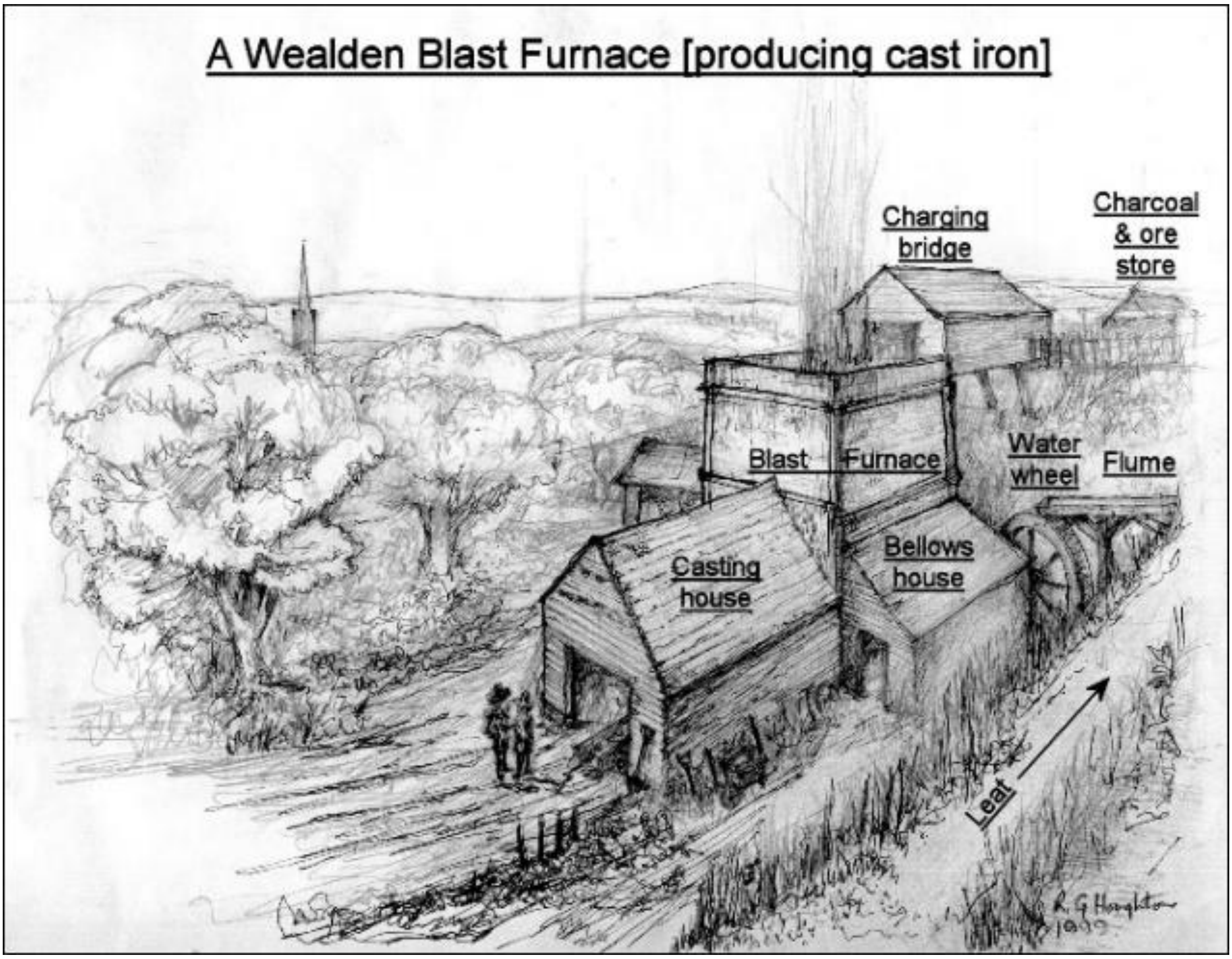
Experts in running these furnaces came from the low countries of parts of today's Belgium and France at the invitation of King Henry VII. The technology they brought was known as the Walloon process reflecting the area from which the ironworkers came. The first furnace was built in 1490 and iron was made on the Weald for the next 323 years, the last furnace closing in 1813. Some iron was cast direct from the furnace into moulds to make useful items such as fire backs, pots, salt pans and even grave slabs.

Over this 323-year period, the Weald boasted 119 furnaces and 109 forges. Peaking between 1550 to 1699, at any one time up to 80 furnaces and forges were in operation – see opposite. All are located between the North and South Downs. The closest ones to Worthing are Burton Forge, Knepp furnace, Shipley Furnace, and Pallingham furnace.



The only image we have of a Wealden blast furnace was cast on a fireback in 1636 – see left. This is part of the 'Lenard' fire back of 1636. Today, the evidence of their locations is from finding slag and the remains of bays (dams) that created the ponds required to drive the water wheel which pumped the bellows via a cam. A series of pen ponds generally fed the lowest pond below which the furnace was situated. Thus, without quantities of slag as evidence, a bay does not necessarily indicate the location of a furnace or forge.

From excavations and surviving sites of similar furnaces elsewhere, we surmise a layout of a furnace site as depicted below showing a Wealden 'Walloon' furnace.



Gunfounding

The Weald was the centre of England’s armaments industry for nearly 200 years supplying cannon and shot to the Government and merchant ships, and sometimes, illegally, to foreign powers.
The traditional Sussex rhyme:

‘Master Huggett and his man John,
They did cast the first can-non’

dates from around 1574 in the reign of Queen Elizabeth I. At various spells over this 200-year period, a total of 37 furnaces were equipped to cast cannon – a very demanding task - flowing metal direct from the furnace into a vertical mould set in a deep pit before the furnace. A central core provided a hollow cannon which was reamed out after casting to ensure a smooth and accurately dimensioned bore.

Shown left is a six pounder (shot weight) cannon measuring nearly 3m long and is one of two on display at Horsham Museum.
While reducing the work needed to finish the cannon, the use of a central core could result in porosity in the barrel wall which often caused the cannon barrel to shatter when fired.

The casting of cannon continued until 1775 when the Industrial Revolution brought in new, more accurate methods of boring cannon from a solid casting that Wealden gun founders could not match. The largest guns cast on the Weald were 32 pounders – known as Demi Cannon. (Strictly, a 'Cannon' was a 66 pounder while a Cannon Royal, the largest of all, fired a 74-pound ball).

Wealden furnaces were too small to hold enough metal to cast these larger guns. A finished Demi-Cannon weighed around 6384 pounds (2895kg) and would require close to 7000 pounds (3175kg) of metal to flow from the furnace as a 'gun head' had to be included at the top of the mould – the end of the barrel - to act as a reservoir of metal to feed shrinkage as the metal solidified. This was sawn off after solidification was complete.

The life of guns was relatively short with a maximum of 40 shots for larger guns and 55 for smaller before they were retired from service for fear of exploding due to progressive weakening. Retired or failed guns were either cut up and re-melted in the blast furnace or put to other uses such as quayside bollards. This ensured a sudden demand for replacement guns in time of war.

Round shot for cannon, previously labouredly chipped from stone, was in great demand during times of war. Little skill was needed to cast this, and many furnaces produced this commodity in varying standard sizes.

Shown opposite is a 4.5 lb proofing ball, one of many found at furnace sites where cannon were tested prior shipping to London for official proofing

Refining Forges

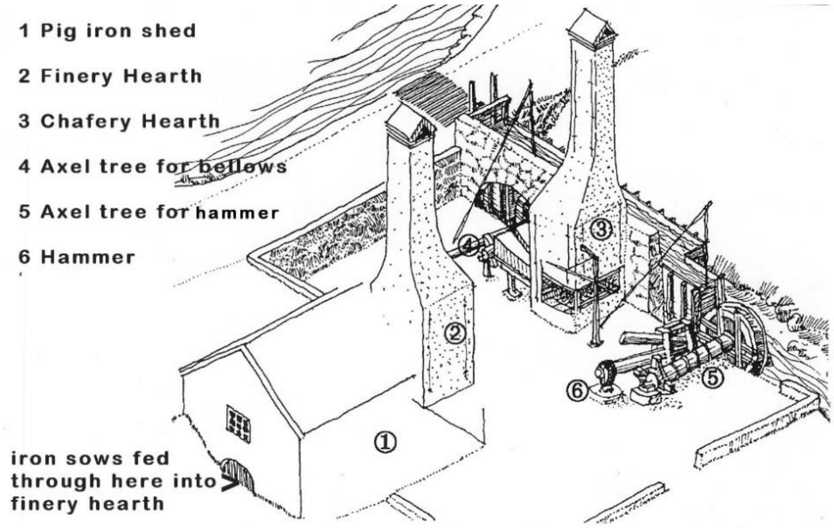
While cast iron is strong in compression, it is weak in tension, and cannot be forged to make the tools, horseshoes etc. for which the blacksmiths had previously used bloomery iron. A second process was required to make the iron ductile giving rise to the blast furnace – forge process being known as the 'Indirect Process'.

In the refining forge, the carbon content of the cast iron was reduced 40-fold, from around 4% to 0.1% or less. This was carried out in refining and reheating hearths and consolidation of the refined iron was by a heavy water powered hammer to produce a long bar of ductile (wrought) iron suitable for forging by the blacksmith.

At the blast furnace, iron for the forge was cast as a heavy 'sow' some 2-3m long and triangular or semi-circular in cross section.

A short length of such a sow is on display in Horsham Museum. Weighing well over 0.5 ton, these sows were carried to the forge for refining – probably by ox cart. The forge needed more water than the furnace and hence was often located on a nearby but different water supply.

The forge consisted of two charcoal filled hearths – one to refine (finery) and the other to reheat (chafery) the iron, each with bellows driven by water wheels, and a large helve hammer lifted by cams driven by a third water wheel. The picture opposite illustrates such a forge. The tip of the heavy sow was fed into the finery hearth through a hole in the back wall of the building. In the finery hearth, the tip of the sow was gradually melted off bit by bit, the air from the bellows oxidising the carbon, so lowering its concentration.



At intervals, a lump of hot refined metal was taken to the hammer for consolidation, then reheated several times in the chafery for further hammering into bar iron suitable for the blacksmith to use. Meanwhile, the sow was pushed a little further into the finery to continue the process.

Raw materials

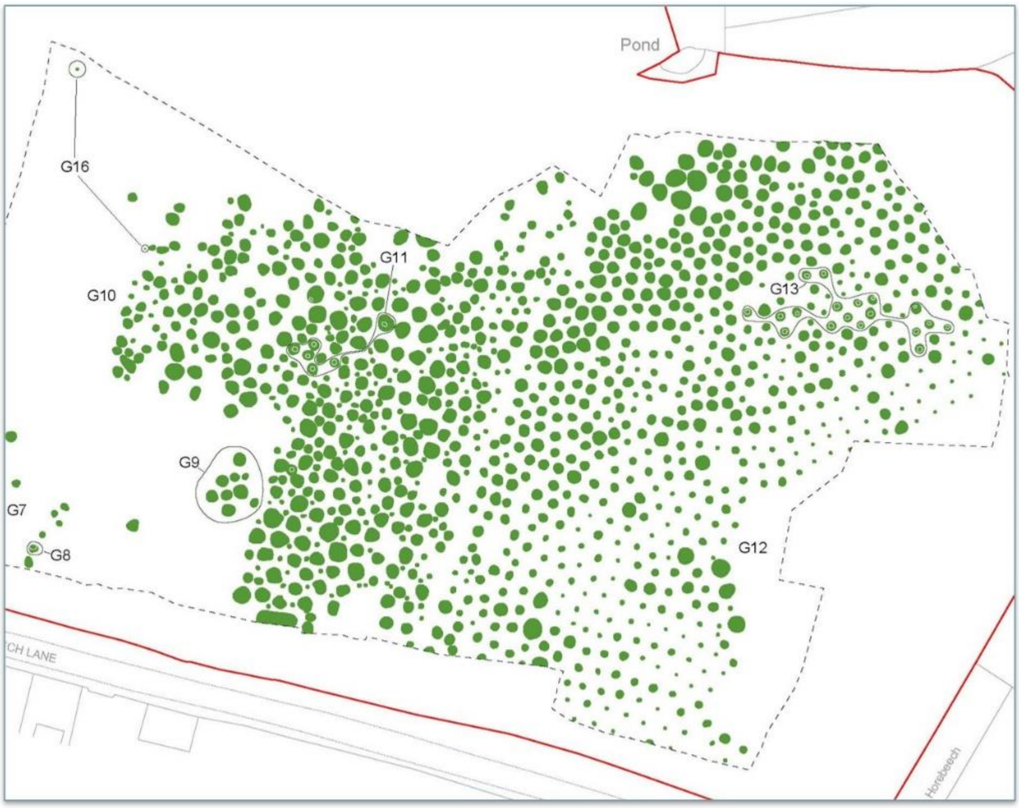
In addition to charcoal from coppiced woodland, roasted iron ore and flux, in the form of Cyrena limestone (Sussex marble) or chalk, was added to the blast furnace charge to improve the yield of iron and lower the melting point of the slag. In the bloomery process, much of the iron is lost to the slag as it combines with the silica present in the ore. The slag may contain 50% iron, more, than the raw ore itself, which, on the Weald, typically contains 40% iron, relatively rich compared to areas in the Britain later exploited, such as Northamptonshire and Cleveland.

Calcium in the flux combines with silica in preference to the iron, greatly improving the metal yield. Blast furnace slag contains only 1-3% iron distinguishing it from bloomery slag (~50% Fe) as being much less dense and often glassy in appearance – see below left.
Forge slag contains much more iron and hence is denser than furnace slag but often has a 'rusty' appearance unlike bloomery slag – see below right.

Mining ore

Most of the Wealden ore exists as siderite – an iron carbonate of iron. This occurs as layers at various depths at the junctions between clay and sandstone. Early miners probably found the ore in the beds and banks of streams. Bloomery sites are nearly always close to streams. This would be roasted in a pit prior to use in smelting to drive off CO_2 and moisture making the ore porous which aided reduction and friable which helped in breaking large pieces.

When the Romans came, they organised the industry from local demand to industrial export to the Continent. They dug quarries to extract ore on a large scale. Such 'mine pits' survive today, often in woodland as, after mining, such land was useless for agriculture.
In the Medieval period, landowners demanded that land mined should be restored for agricultural use. Hence, shaft pits were dug – small ones to explore for ore and larger ones to extract it from the various layers at differing depths. Once the ore was extracted, the pit was refilled from the spoil of adjacent pits, but the space between pits was never mined for the ore it contained, being unstable as too close to a filled in pit. Pit locations can often be seen in woodland as small hollows a few metres in diameter where the infill has settled. In other areas, the mined area was restored to fields.

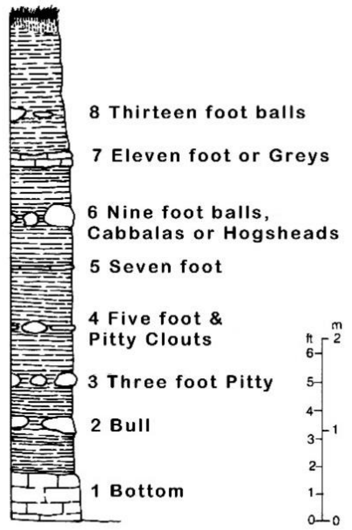


The picture opposite shows the pattern of mine pits recently excavated at Horley prior to a housing development. There are over 1000 in five acres. Note the linear gap towards the centre. Old maps show this as a field boundary indicating the prior use of the land for agriculture. The lack of any indication of the pits prior to stripping off the grass for housing development shows how well the land had been restored.

Sometimes ore pits are incorrectly called 'Bell' pits, but they do not open up at the bottom as bell pits in chalk do – such as the flint mines on the South Downs - as digging in clay does not support such side excavation.

The ores at various depths (see opposite) were given different names reflecting differing qualities of ore requiring careful blending of the mix charged to the furnace. In some documents, Ironmasters complain to the miners that they are extracting only the top, lower quality ores, and landowners complain that the top fill is all clay rather than restoring the topsoil.
For further information on the iron industry of the Weald please visit www.wealdeniron.org.uk

Here you will find not only descriptions but also a number of digitised publications and also a database of all known sites and persons related to the later water powered sites.
Coming soon – '*An Iron Trail through Knepp*' one of Horsham's Heritage Trail leaflets providing a self-guided walk through the Knepp Estate following the route the sows were taken from Knepp furnace to Shipley forge.



Ironstone seams in the Wadhurst Clay

Tim Smith

Tuesday, 10th March 2020 – "Development of Military Fast Jet Simulation".

Stewart Hilton

Stewart began his talk by taking us back in time to the 1960s when the Jaguar fast jet was in development.

The SEPECAT Jaguar (opposite) was a joint aircraft venture between Britain and France to produce a supersonic, low-level strike fighter. The maiden flight was on 8th Sep 1968, with the aircraft entering service with the RAF in 1973 and remaining in service until 2007.

This development programme also heralded the first military digital flight simulator to be manufactured for the RAF.

Fast Jet Simulators are the most technical demanding of all flight simulators due to the complexity of the systems, high speed, low level flight and flexibility in operation.

Full Flight Simulators

A full flight simulator is made up of several fundamental building blocks, a realistic crew environment (cockpit) and three key cueing elements (physical motion, visual and sound). All these elements must work in harmony to create a realistic real-time training environment that truly replicates the functions of the aircraft being simulated. The advantages of training aircrew on machines that provided the means to practice flight procedures without taking to the air is seen as essential by both the civil and military operators. In the early days there was little need for such devices as the very early aircraft had few controls and a fixed under carriage.

In the early seventies the requirements for producing a digital fast Jet simulator were very challenging. The Apollo space programme provided the perfect platform for the development of solid-state digital technologies and highlighted the need to provide training simulators for space exploration. The big challenge was to produce a machine that was capable of computing critical flight data in what is referred to as 'Real-Time'. The real change in capability came during the late 1960s and 1970's when requirements demanded by the customer pushed the capability of military on-ground training to another level. The early pioneering work was carried out in the United States driven by NASA (with the need to have a man on the moon by the end of the 1960's) and the cold war. Prior to this, military flight simulators had been analogue devices primarily used to familiarise aircrew with the controls, procedure training, and handling skills. Mission training was limited or non-existent. The only cueing provided was sound with a limited motion and in some cases a model based visual capability.

During the 1970s and 80s a lot of research was carried out regarding the effectiveness of synthetic flight training devices. Cranfield University and MoD Boscombe Down were very active in conducting studies on latency. The lag between motion and sight was of specific interest and these studies proved to be invaluable to the work carried out by the simulator industry.

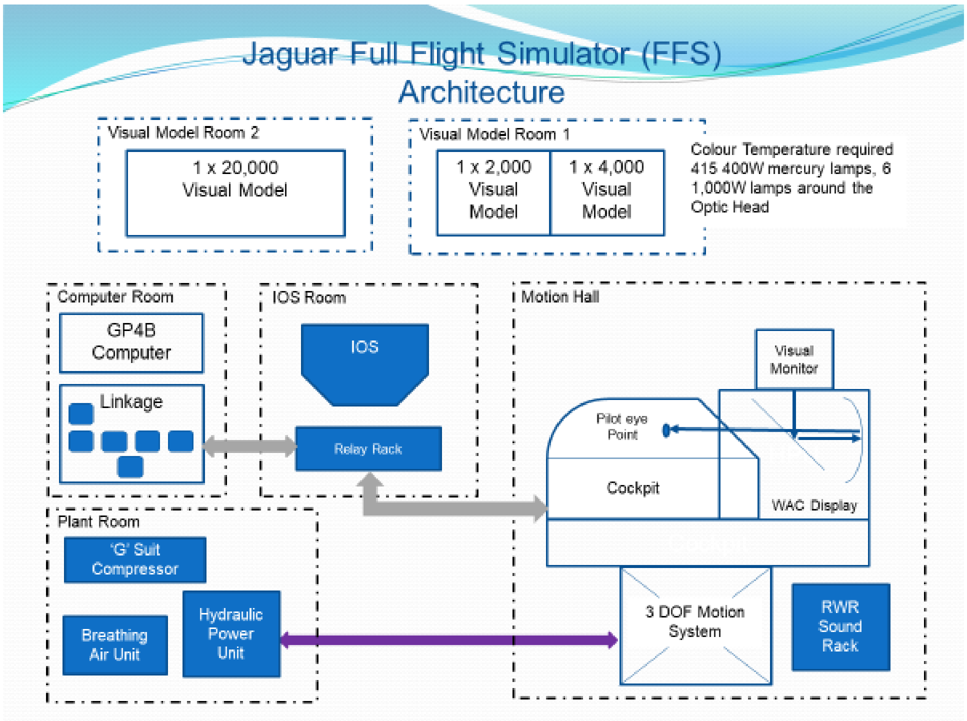
The only visual systems used during this period were model based (described later). These were extremely expensive due to the labour required to produce the large model boards required. Camera technology was also limited and required large colour temperatures to produce clear imagery. This was due to the small size of the optics used to simulate aircraft movement.

Training Requirements

The training requirements were fundamental to the design of the simulator and were derived from the training task list. It was obvious that not all training tasks could be performed on a flight simulator, but every effort was made to include as many as possible. As time moved on and technology improved the number of training tasks performed on a simulator gradually increased. Today civil training simulators can meet all the tasks required and 95% of military training tasks can be performed on military flight simulators. A sample of training requirements is listed below:

1. Familiarisation of the cockpit controls and instruments
2. The ability to take off and land by using flight instruments
3. The ability to practice all flight procedures pertaining to specific flight systems
4. The ability to communicate by radio and the use of radio aids
5. The ability to navigate using the aircraft's airborne navigational aids

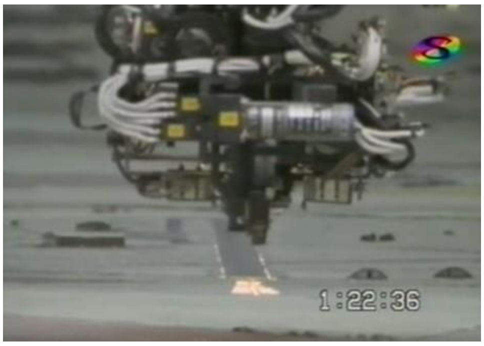
One of the most critical factors was to not produce any negative training effects, so fidelity was paramount. The cockpit had to be a true representation of the real article.
Turning our attention back to the Jaguar, the MoD contracted Singer Link Miles to manufacture 4 simulators to train aircrew on. Singer Link Miles had developed digital computer technology for several US military aircraft and due to the major advantages over the current analogue devices it was decided to use this technology for the Jaguar.



The Jaguar Simulator was a major step forward in technology, but by todays standard was still a quite crude device. The Jaguar simulator architecture is shown opposite. Although the computer was very capable of computing all the critical calculations for flight at the desired rate and driving all the associated hardware, there was no graphics capability.
Physical connection from the computer to the Cockpit, IOS, and Visual was via the Linkage. The Linkage took digital information from the computer and converted it into the format required for the external devices. It controlled the input and output of data from all the external systems.
The Linkage consisted of 6 cabinets: one Muffin, four Mini Links and the Synchro cabinet. The distributed data fell into 4 categories: Digital Outputs (lamps, circuit breakers etc.) Digital Inputs (Switches) Analogue Outputs (Instruments Gauges etc.) and Analogue Inputs (Potentiometers etc.). The Linkage was all TTL, the computer ECL.
The Muffin cabinet was the main interface to the computer and performed several tasks, one being the conversion of ECL to TTL and TTL to ECL. The Linkage utilised 16 bit words, the computer used 24 bit words plus the sign bit, so the Muffin cabinet took in two 24 bit words and converted them to three 16 bit words. It also had a sign converter. The 4 Mini Link cabinets controlled the flow of the digital and analogue information to the specific external devices. The Synchro cabinet produced the synchro output for all the analogue instruments; it took two AO words and produced a corresponding synchro output. Due to power consumption, most of the digital outputs had to be distributed via the Relay Rack situated in the IOS Room. There was no serial data; all inputs and outputs being individually wired from source to destination with lots of cables.

Jaguar Visual

The visual comprised three large horizontal models (shown opposite), each model having a different scale. The airfield model had the largest scale 1 x 2,000 (2K), the terrain model with a scale of 1 x 4000 (4K) being used for low level attack exercises. The largest scaled model was the navigation model 1 x 20,000 (20K). The Airfield and Terrain models were housed in the same room and the models were connected. The 20K Navigation model had a separate room. Colour Camera technology was still in its infancy and the Plumbicon tube used required a high colour temperature. The two models had to be lit with four hundred and fifty 400W mercury lamps in addition to the six 1,000W mercury lamps surrounding the optic head.



The colour camera was mounted on top of the Optical Head (see opposite). The Optic Head provided the simulation of heading, pitch and roll all controlled by the computer via the Linkage. At the bottom of the head was the servo-controlled pitch prism, 4mm in size. The whole head rotated providing the heading, roll being created though a dove prism mounted in the optical plane. The optic head was mounted on a huge XY gantry that traversed the model providing longitudinal and lateral movement across the length and breadth of both the 2K and 4K models. Horizon and visibility were produced by glass slides mounted in the optical plane.
The pilot's visual display was a single colour monitor mounted vertically above a collimator, utilising a beam splitter and parabolic mirror. The visual was repeated on the IOS and had the HUD image superimposed allowing the instructor to see exactly what the pilot was seeing.

Electronic Warfare (EW)

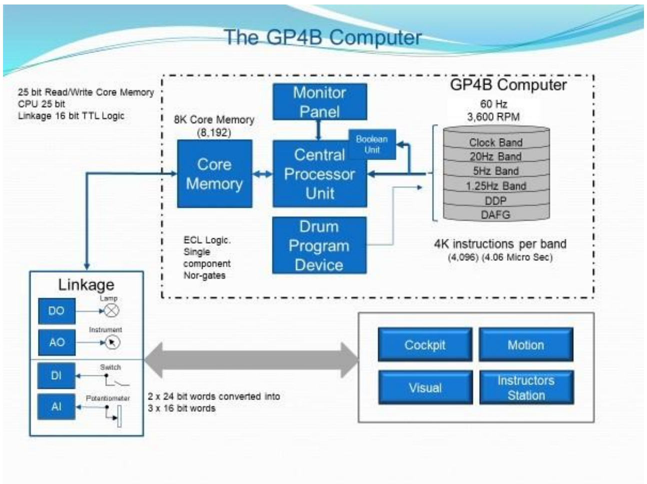
One of the requirements was the simulation of the electronic warfare environment. This was essential due to the workload experienced by the pilot having to interpret the threat correctly and take the correct evasive action. The simulation had to produce the PRF tones of the threats and drive the EW display mounted in the cockpit. Due to the sensitive nature of the threat information the system had to be designed to allow the customer to programme the threats on delivery of the simulator. White world data was used for test purposes.

The GP4B Computer

Dr. John Hunt was the man instrumental in the design of the GPM1 computer, later to become the GP4B (General Purpose Mark 4B) specifically designed to meet the challenge of flight simulation. The role of the GP4B computer was clearly critical to the success of the Jaguar simulator and is worthy of a detailed explanation, particularly for those who can recall the transition from analogue (and hybrid) computers to digital ones.

Prior to the late 60s, flight simulators were analogue devices. However, engineers were fully aware of the enormous advantages to be gained by using digital computation, especially in such areas as function generation, accuracy, all aspects of navigation, and in flexibility for change. The search was on to find an affordable computer which would meet the needs of real time computation for a full flight simulator. In the early sixties existing commercial digital computers were used to analyse the validity of mathematical models for the analogue computers currently used for simulation. As an outcome of this analysis, a fairly complete understanding of the required speed of computation had developed (i.e., the allowable time interval between successive computation cycle repetitions) to achieve acceptable solutions
The principal problem which dictated minimum time between repetitions arose from the necessity to provide a large number of repetitions per cycle in the solution of differential equations whose solutions represented a damped cyclic oscillation such as short-term pitch stability (angle of attack) and yaw-roll dynamics (Dutch roll). Attempts to reduce the number of calculations per cycle are known to result in a marked reduction in damping and a distortion of the computed cyclic oscillation frequency. A further but considerably less demanding consideration was to avoid human perceptible steps in the solutions, which problems did not exist in analogue computer design. The cost of a digital computer in 1961 that could come anywhere near meeting the requirements for a flight simulator was over two million dollars (IBM 9600/9604 family).
During the early 60s one of the major costs in the construction of a suitable real-time computers was the cost of Core Memory. Core Memory was the only Random-Access Memory (RAM) available at the time. It had an acceptable access speed (6 microsecond). Inexpensive drum memories with good capacity were available and represented a proven technology. Unfortunately, the access speed of the drum memories was far too slow. The slow computation rate was largely caused by the slow access time of the drum (read-write cycle).
Dr. Hunt began thinking about the possibility of separating the storage of true, constantly changing variables such as angular and linear velocities on the three aircraft axes, aircraft attitude direction cosines, altitude, etc. separately from fixed data and instruction code. The latter non-variables required at least one hundred times as much storage as the true, constantly changing variables. Recognizing that storage of only the true variables in random access core memory was economically practical, he concentrated on the possibility of using a massively parallel readout drum to deliver the instructions and related stored numerical constants in an orderly sequence, with the instructions and data being delivered from the drum right at the instance they were needed for computation. The drum was a read only device, written to only during the programming of the simulator.

The first Digital Computer designed by Singer Link Miles for Real-time programming was a drum computer, the GP4B. The main elements of the computer were housed in three 6-foot-high 19-inch racks.
Its architecture is shown opposite.
If you can imagine a vertical rotating drum approximately 24 inches in height with a diameter of around 18 inches coated in oxide on the outside making a surface like a magnetic tape. This drum rotated at 60 RPM (3600 Hz). The programme instructions were stored on the surface of the drum in a series of vertical bands, each band having 20 read/write heads arranged around the drum allowing the bits to be read in parallel making one 20 bit word. Each band could hold 4000*20 bit data words (instructions & fixed data). The drum had 20 of these bands, making a total of 400 read/write heads.



The drum could only spin in one direction, meaning that you could not perform any looping in the conventional sense. The computer had no operating system and all the instructions were written onto the drum in machine code. The 20 bands were read independently, depending on the information stored on the band. The sequence of instructions was read and performed at different repetition rates; 20Hz, 5Hz, and 1.25Hz. The critical motion calculations were assigned to the 20Hz band. The other programmes were assigned to the two slower bands according to their desired response times. The 5Hz instructions had four times as many bands as their 20Hz band and the 1.25Hz band had four times as many bands as the 5Hz band. There was also dedicated bands for specific activities (described later in the text). There was also a clock band (the master sync clock). The GP4B also had a separate Boolean processor that worked in parallel with the main accumulator. The instructions were numerical, such that the Add instruction was 02 followed by the address, and subtract was 04 followed by the address. (There were 2 digits for the instruction function)
The first 1K of memory was used for Boolean variables (i.e. 1 bit per variable, say Light on or Light off) The rest of the memory was used for variables and as a scratch pad.
There was a separate 8K core memory with the first 1K addressable as individual bits for Boolean variables (i.e. 1 bit per variable, say Light on or Light off). The rest of the memory was used for variables and as a scratch pad. The core memory word length was 25 bits to match the computer word length. Variables were not named and were directly addressed. Each computer word was made up of 25 bits, 24 magnitude bits plus 1 sign bit. Not twos complement but signed magnitude. As an example, the number 15 would look like 0x00000F Hex. The number -15 would look like 0x100000F Hex except Octal notation was used (0x00000017oct) because it looked better with 24 bits. There was one accumulator containing 25 8x8 inch Printed Circuit Cards, one for each bit of the accumulator. It didn't have any ICs, It consisted of discrete ECL NOR gates COTS components. All elements of the processor were made entirely of ECL NOR gates. ECL had the advantage of speed with a transition rate of only 1 to 4 nano seconds. The logic level between a 1 and a 0 was only 0.9 Volts. (0 = 1.7 Volts, 1 = 0.8 Volts)
Arithmetic was done as scaled fixed point. Everything was integer, but you had an imaginary radix point associated with every variable, so, every value was a crude approximation. If a variable with 6 imaginary fraction bits was multiplied by a variable with 4 imaginary fraction bits the result would have 10 imaginary fraction bits. In that case the answer would have 4 bits to the left of the imaginary radix point and 10 to the right. If that was then assigned to something that had 8 imaginary fraction bits, you would right shift by 2 before storing.
Other issues were where the program requires a branch, e.g. If (A=B) then C else D. Because the drum always rotated in one direction you could not jump to somewhere else. In fact, you must compute both C and D and select the answer based on the logical answer of A=B or not. Similarly, one could not easily perform loops quickly other than by waiting a cycle or else repeating the code.
There were no subroutines. For example, in a modern machine if you wanted the tangent of an angle you just call up the subroutine for a tangent and feed it the angle and it returns the tangent value. In the GP4B you would have to insert all the code for the tangent function every time you used it. There developed quite a rivalry between programmers for who could design a commonly used function the most efficiently.
The 25 bits of data had the first bit as the sign followed by a 24-bit integer with a user defined position for the number bits used by the fraction of the number. For example, if the user declared only 1 bit for the fractional part then the fraction could only be 0 or 0.5. If the user declared 2 bits for the fractional part then the fraction could be 0, 0.5 or 0.25 and so on. You can think of this as how many digits before and after the decimal point, although, of course, it was in Octal not decimal. Hence the binary number, say 1010 could represent 10, or 5 or 4.5 or 1.25 depending on where the user defined the imaginary point break between integers and fractions. Note the position of this break was not held in bits but just declared in the interface document so everyone knew where it was!

As an example:
Distance = Speed multiplied by Time, Speed is declared as 1 fractional bit
Time is declared as 1 fractional bit, Distance is declared as 1 fractional bit

So, if Speed is 2.5 and Time is 2.5 the result (6.25) requires 2 fractional bits (i.e. 01 in binary) but distance has only 1 fractional bit, so the resulting binary digit must be shifted right by the programmer to keep the declared format. Thus, the answer would lose the last bit and the answer would be 6 instead of 6.25. The users had to determine the accuracy required by each variable to account for this. At the other extreme it could be quite easy to multiply 2 numbers and after accounting for the position of the imaginary break point did not have enough bits left to hold the number. In other words the number overflowed. All this had to be catered for by the programmer. In modern computers with Floating Point processors this is not an issue.
The different instructions each took a different number of "cell" times (think of it as distance on the drum). So, an Add instruction may take two cell times whereas a multiply may take 9 cell times. To account for this time the programmer had to leave enough cells by inserting "No Operation" instructions. So, a multiply instruction would be followed by 8 No Op instructions. So, programme efficiency was paramount, especially on the Max rate bands. As mentioned above the system had a parallel Boolean Logic processor; consequently the smart programmer would insert Boolean Instructions into the No Op spaces.
Besides the "general purpose" aspect of the computer, it had other features that were decidedly not general purpose. Buried inside the computer was the DAFG (Digital Arbitrary Function Generator). This was a separate unit with its own programming. Basically, it was a fast hardware lookup table and interpolator. An array of values was stored on the drum that represented a curve from real world data acquired during flight testing, It had an associated input variable address and an output variable address, It would compare the input variable against the curve and put the answer into the output variable. It would do this as fast as possible, cycling through all the functions that you told it to. Let's say fuel consumption is a non-linear curve based on engine rpm. Maybe you have 20 specific data points on the curve that have been determined from real world measurements stored on the drum. The DAFG would look at the variable you told it was engine rpm, then automatically take the next stored value above or below dependent on direction of change. It would then, using the actual input value, perform a hardware derived interpolation and output the value for (in this case) fuel consumption into the accumulator.
The computer also had a Morse code generator built into it, the Digital Data Processor DDP. You put in a table of the latitude/longitude pairs of all the nearby airports and their call letters. The hardware would look at the current latitude/longitude and using geometry work out the closest airport. Then those call letters would be sent to the Morse code generator and the pilot would hear the call letters on his headset.
The computer had an extremely useful human interface unit consisting of digital readouts (not a monitor) of both the arithmetic computation and the DAFG. There was a keyboard to allow modification of instructions/data in real time. The Input/output system was by punched cards,

Computer Evolution

Significant as the GP4B computer was, we need to consider it in context with other developments:

1. Analogue Computers - Most flight simulators were analogue up to the end of the 1960s
2. The GP4B - The GP4B was the first digital computer used for flight simulation by the MoD (Jaguar)
3. Main Frames – Towards the end of the 1970's Main Frame computers became affordable and their performance was now suitable for running real-time programmes. Link Miles developed a real time operating system including a whole technology around the Main Frame called Advance Simulation Technology (AST) which was used on all civil and most military simulators through the 1980s.
4. Link Miles went back to the drawing-board in the late 1980s by producing their own real-time computer architecture called MST (Microprocessor Simulator Technology). It was an interesting concept. The idea was to produce a system comprising functional units called Major Functions that were self-contained and could be programmed in isolation from one another. These would be linked by a highspeed interface and when connected together would create the total computer and IO required for a full simulator. Link Miles worked very closely with Intel using their latest chip sets. It was a huge and bold undertaking due to the work involved. Not only was the hardware designed from scratch, but a full operating system had to be written too. The technical challenges were overcome, and several Civil simulators were manufactured using MST. Unfortunately, it was not cost effective, due mainly to the number of Major Functions required, and the components supplied by Intel. Before PC technology became available Civil simulators reverted back to common off-the-shelf technology.

5.Silicon Graphics – during the early 1990's Silicon Graphics were the pioneers of computer graphics and it was quickly realised by the simulator industry that the processing power required for graphic generation was ideal for real-time processing. Silicon Graphics machines were used on all the F16 FMS programmes from late 80s early 90s.

6.PCs – Personal computers were fast catching up and by the late 1990's they became the choice for all future real-time applications, civil and military. Tornado GR4 FMS, Typhoon FMS, and all Civil Simulators.

Tornado Simulator

The Panavia Tornado is a family of twin-engine, variable-sweep wing multirole combat aircraft jointly developed and manufactured by Italy, the United Kingdom, and West Germany. The maiden flight was on 14th August 1974. The aircraft entered service with the RAF in 1979 and remained in service with the RAF until April 2019.

Tornado GR1s were amongst the first aircraft in action during the Gulf war starting in January 1991, flying some 1,500 operational sorties divided almost equally between offensive counter air targets such as airfields and air defence sites, and interdiction targets such as bridges.

Several Tornado Simulators were produced during the period 1980 to 2010. The GR1, ADV, and the GR4. The GR1 was the first Tornado Full Flight Simulator built in the early 1980's. Due to the size of the contract it was jointly built by Singer Link Miles and Rediffusion Simulation.

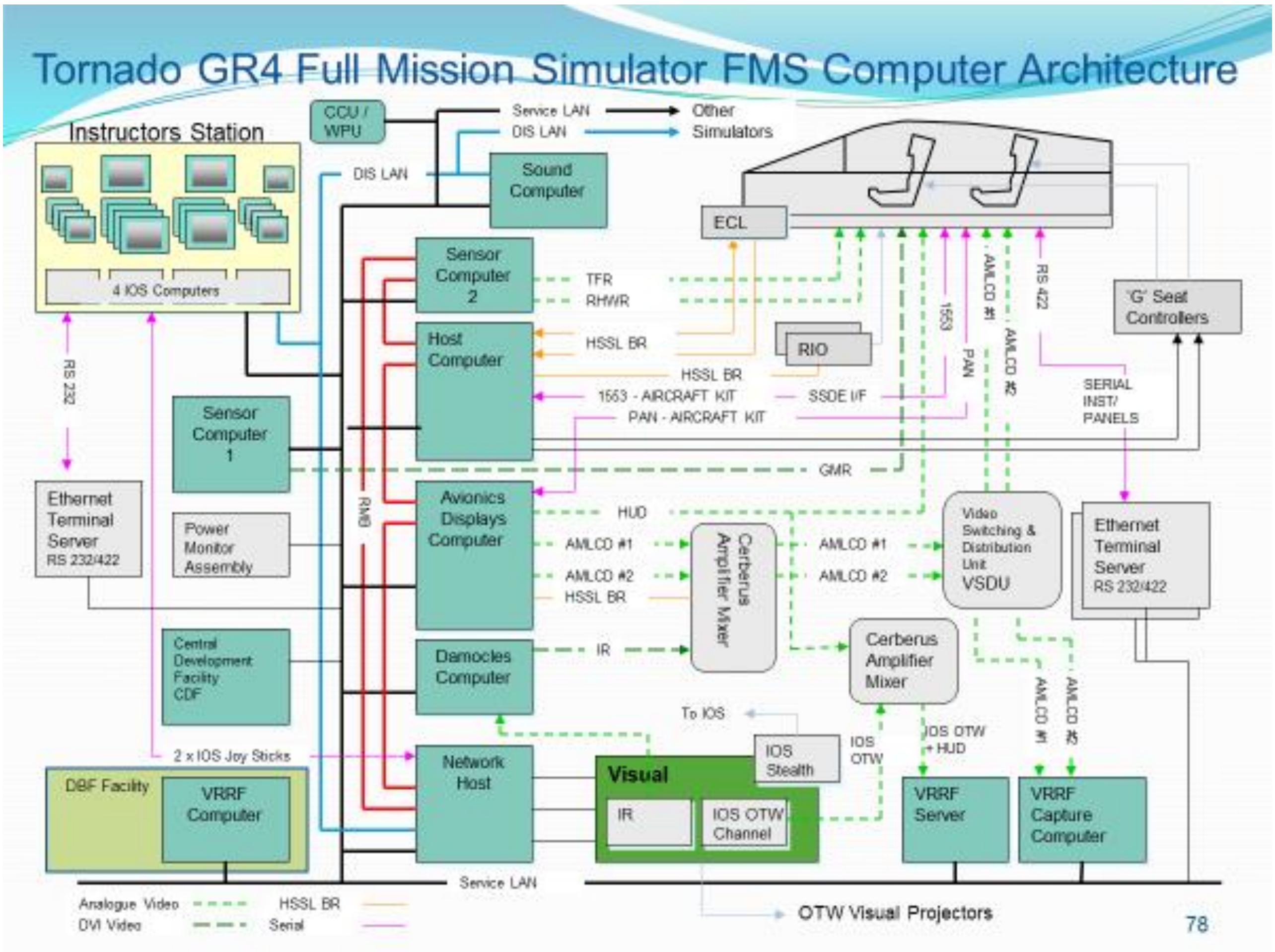
GR1 Simulator

The development of the Tornado GR1 simulator marked a significant step in technology from that used on the Jaguar. Computer technology had improved and although memory was still expensive it was solid state and far cheaper than the old core memory. Off the shelf mainframe computers were now used for the host computer. A real-time operating system had been developed that allowed flexibility in task prioritisation (tasks could be run at different rates dependent on their priority) it also had the ability to debug software in real-time. Singer Link Miles had developed a new Linkage technology AST (Advanced Simulation Technology) which was serial based and reduced the cable count considerably. Although the speed and performance of computers had improved significantly, they were still far short of what was required to meet all the simulator industry demands.
Graphics was in its infancy and could just about meet the graphics requited for the Instructors Operating Station (IOS). Real-time computer graphics for radar and visual simulation was over a decade away.
The mainstay of the GR1 was the radar and it was essential that a true simulation of the Ground Mapping Radar and the Terrain Following Radar was achieved. The simulator used the Link designed DRLMS (Digital Radar Land Mass Simulator). This was an enormous hardware pipeline processor consisting over 600 printed circuit cards PCB's and filled a complete container. The terrain data was stored on two 300 megabyte discs the larges discs available at that time. The GR1 had no visual as mentioned previously. Graphic based visual systems of the complexity require for fast jets was over a decade in the future. The RAF decided that a model based visual would be too expensive and not meet their training need. The other major training requirement was Electronic Warfare (EW). This was a challenge and again solved by a hardware solution. The solution involved stimulation of the actual aircraft EW processor with all the signals that would be encountered in a real operational environment, with the ability to programme these signals according to the information available.
Another point regarding the Tornado was a requirement by MoD to use where possible actual aircraft equipment. The simulator had a 3 degrees-of-freedom motion system, aural cueing and sound breathing air and 'G' Suit. The simulators were fully containerised.
A total of 142 Tornado GR-1s were upgraded to GR4 standard with deliveries starting in 1998 and were completed by the end of 2003. Compared to the GR1, the GR4 has a Forward-Looking Infra-Red radar (FLIR), a wide-angle Head-Up Display (HUD), improved cockpit displays, Night-Vision Goggle (NVG) compatibility, new avionics and weapons systems, updated computer software, and Global Positioning System (GPS). The upgrade also re-armed the Tornado with the Storm Shadow stand-off missile, Brimstone advanced anti-armour weapon, and the Paveway EPW LGB. New sensors include the RAPTOR and Vicon reconnaissance pods and an improved Thermal Imaging Airborne Laser Designator (TIALD) targeting pod.

The GR4 marked a major upgrade in aircraft capability, necessitating a similar upgrade in simulator design.

GR4 Simulator

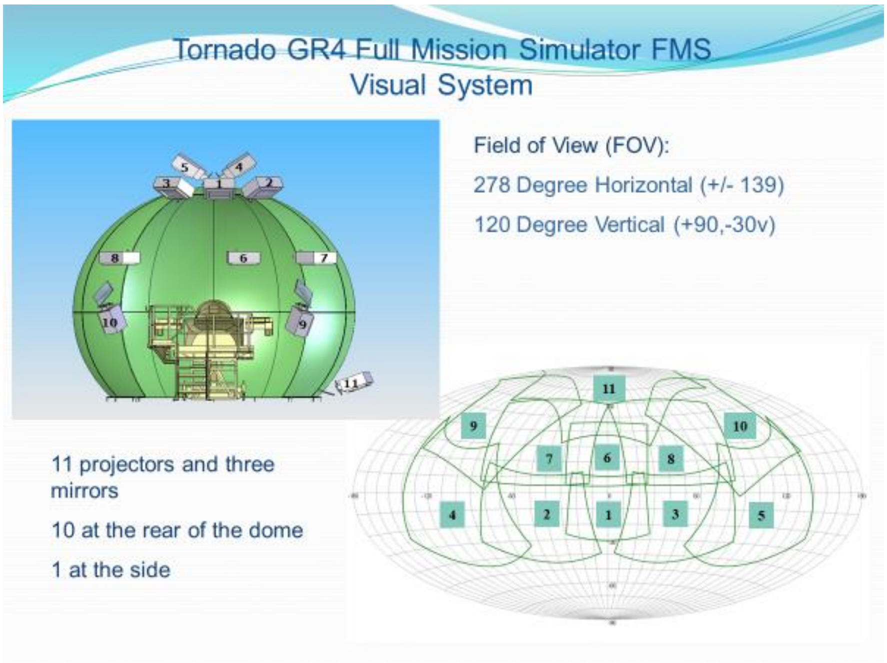
Shown below is the architecture of the GR4 simulator. The degree of sophistication compared to the earlier Jaguar simulator is immediately obvious, in particular the use of visual projectors and 'G' seat controllers which are described in detail.



GR4 Visual System

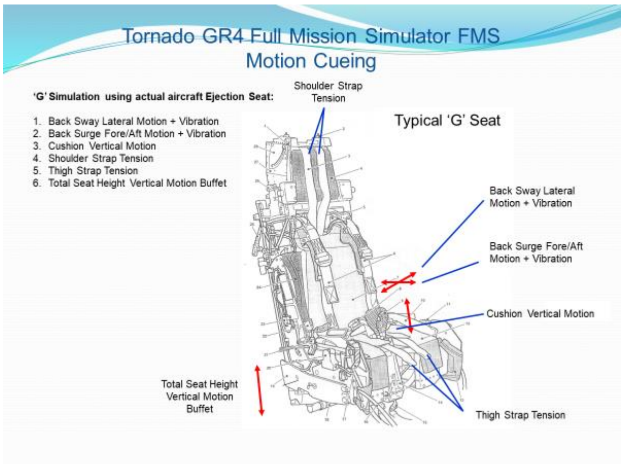
The visual system provides a visual representation of the environment for both military and civil simulators. Due to their complexity, military visual systems still require dedicated hardware and there is still room for improvement. They are extremely expensive costing several millions of pounds. There are several companies producing visual systems but the main three are CAE, Rockwell Collins and E&S.

Shown opposite is the GR4 Visual Projection system. The dome is 7.3m in diameter and provides an image having 10:1 contrast, resolution of 6,8,10 arc-min/OLP, luminance of 3ftL. The field of view is 278º horizontal (+/- 139º) x 120º vertical (+90º, -30º).
The resolution of the display is determined by the pixel count. To meet the resolution requirements for the GR4, 11 projectors with a resolution of 1400 x 1050 pixels were used. Regions were allocated different resolutions depending on the main areas of interest; the definition through screen was the highest resolution at 6 Arcmin.



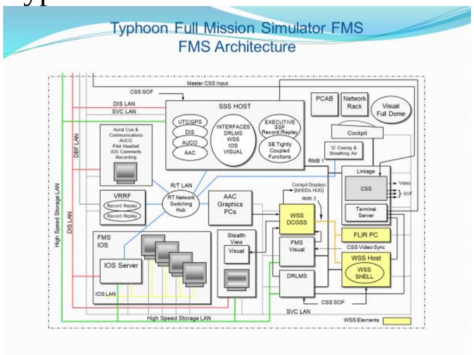
Visual cueing information is provided by the Image Generators (IGs) which provides the Out the Window (OTW) visual scene. The real-time control of this scene and all other IGs (stealth and IR) is via the Host Computer or Network Host. Control of all visual functions is via a dedicated visual interface. These include the following: Ownship position (height, speed and orientation {pitch, roll, heading}) weather effects, time of day, control of all CGFs, special effects and terrain impact. The IGs also takes initial data from the IOS at the start of a mission such as time of day which determines night/day dusk etc. Star and sun position are also modelled by the IG and this information is also communicated to the IG via the visual interface. The simulator models time of day and this is reflected by all the visual elements (OTW, IR, Stealth).
The Visual also provided infrared imagery for IR devices employed on the Ownship. This is a separate IG as the eyepoint, and field of view will differ from the OTW imagery. Dependent on the Ownship type there may be more than one IR IG. The Visual also employs an independent stealth IG. The visual database is used as the master and all other supporting databases are derived from it.
The Stealth IG produces an "independent observer" image. This image can be tied to any platform or allowed to free-fly through the database. The Sensor IG produces an “independent observer” sensor image.
The Visual Cueing software transfers data to the Visual Server using data packets in shared memory blocks within the Network Host global memory, with one block per IG. The transmission of these packets is controlled by the Visual Server via a raw Ethernet per IG. The IG uses these data packets as reference information to produce the visual images as described above. The Visual Cueing software is called from the Real-time executive at a rate of 50Hz. The iteration rate and synchronisation are controlled from the Real-time executive software.

GR4 ‘G’ simulation



‘G’ is provided by the ‘G’ Seat. The ‘G’ Seat is a modified ejection seat that enabled control of the shoulder straps by control for their tension, control of the back of the seat, back surge fore/aft motion and vibration, seat cushion control, vertical motion and control of seat height vertical motion and buffet.

Typhoon Simulator



Regrettably time ran out for Stewart to give us much detail of the Typhoon Simulator. However, he did show the aircraft itself (right) and the architecture of the simulator (left).

The future

Fast jet pilots are now training at a new test facility to help cope with the physical effects of accelerating when performing mid-air manoeuvres at high speed. The trainer is a centrifuge with a built-in simulator to enable aircrew to practice missions under high levels of G-force. It is located at RAF Cranwell in Lincolnshire and will be used to train hundreds of RAF and Royal Naval pilots. The facility replaces the current RAF's High G trainer in Farnborough, which dated from the 1950s and was little more than a seat at the end of a large spinning arm. The new centrifuge accelerates from zero to 9 G (about 60mph) in just one second, spinning 34 times a minute.

Our thanks to Stewart for such a detailed and interesting presentation on this subject.

Malcolm Hind

REPLY SLIP – Gatwick Aviation Museum at 10:30am on 15/5/2020

To: Perry Eastaugh, 33 Ruston Park, Rustington, Littlehampton, BN16 2AD
(01903 788858) email: perry.eastaugh@icloud,com

I would like to visit the Gatwick Aviation Museum at 10.30 on Friday 15 May. Please reserve me the following places:

Members ……………….Guests …………….

Name…………………………………………………………………

Address…………………………………………………………………….

………………………………………………………………………...

Telephone (mobile preferred):……………………………………………

Email address:……………………………………………………………………….

Applications before Saturday 9 May.

REPLY SLIP – Water Lilly Festival, Sheffield Park at 10:30am on 25/6/2020

To: Malcolm Hind, 7, The Castle, Horsham, RH12 5PX or email malcolmhind@msn.com with full details as below.

The visit starts at 10:30am with a guided tour for between 1 and 2 hours which involves considerable walking, largely on paths. A small number of self-drive mobility scooters are available to hire free of charge but must be pre-booked by calling Visitor Reception on 01825790231 Option 4. These mobility scooters are very popular, so early booking is advisable. Sheffield Park have asked for guidance as to the number of group members who are likely to make use of the tea rooms in order that they can staff accordingly, and that is the reason that this question is included. Costs for this outing are:

National Trust or RHS members - £4.00

Non - members (adults) - £15.00 Non - members (children under 18 years old) - £9.50

Car parking is free. Visitors opting to arrive/depart with the nearby Bluebell Railway should be aware that the walk to/from Sheffield Park will take approximately 15 minutes from the Bluebell Railway station.

I would like to attend the **outing to the Water Lilly festival at Sheffield Park and Garden, East Sussex, TH22 3QX on Thursday, 25th June, 2020 at 10:30am.**

Full Name…………………………………………………… Mobile telephone……………………………

Address……………………………………………..………………..……

…………………………………………………………………..………………

……………………………………………………………………….…...

Email address……………………………………………………….………..

Number of National Trust/RHS members…………Number of Non-National Trust/RHS adults………….

Number of Non-National Trust/RHS children……………………………………………………

Likely to use Tea Rooms? Yes No

Please include payment as a cheque payable to RCEA for the above. Payments are non-returnable after 1/6/2020 unless cancelled by the corona virus.

Applications by 1st June 2020 please.

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REPLY SLIP – Ford Materials Recycling Facility

To: Perry Eastaugh, 33 Ruston Park, Rustington, Littlehampton, BN16 2AD
(01903 788858) email: perry.eastaugh@icloud,com

I would like to visit the Ford MRF on Monday 20 July. Please reserve me the following places (priority will be given to members):

Members ……………….Guests …………….

Full name…………………………………………………………………

……………………………………………………………………...

Address……………………………………………………………………

……………………………………………………………………...

Telephone (mobile preferred):………………………………………………

Email address:……………………………………………………………………….

Applications before Monday 20th April please.

REPLY SLIP – The Hovercraft Museum, Lee-on--Solent and Fort Nelson, Fareham

To: Perry Eastaugh, 33 Ruston Park, Rustington, Littlehampton, BN16 2AD
(01903 788858) email: perry.eastaugh@icloud,com

I would like to visit the Hovercraft Museum at 10.30 on Tuesday 4 August, with the option of visiting Fort Nelson afterwards. Assuming we have more than 12 visitors, the cost of visiting the Hovercraft Museum will be £7.50 per person, including refreshments. If fewer than 12 people come, the cost will be £7.00 per person (£8.00 for anyone who is not a Senior), with refreshments extra.

The cost of parking at Fort Nelson is £3 per car, payable individually on the day. Entry to the Fort is free.

Please reserve me the following places:

Members ……………….Guests …………….

Name…………………………………………………………………

Address……………………………………………………………………

……………………………………………………………………...

Telephone (mobile preferred):………………………………………………

Email address:……………………………………………………………………….
I enclose a cheque for £7.50 per person, payable to RCEA. (In the event that fewer than 12 people sign up for the visit, £7 will be used to pay for entry and the extra £0.50 will be put towards the cost of refreshments). Applications are non-refundable unless the visit is cancelled because of corona virus.

Applications before Saturday 25 July please.

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REPLY SLIP – Ceres Power

To: Perry Eastaugh, 33 Ruston Park, Rustington, Littlehampton, BN16 2AD
(01903 788858) email: perry.eastaugh@icloud,com

I would like to express an interest in visiting Ceres Power when a date is agreed. Please reserve me the following places (priority will be given to members):

Members ……………….Guests …………….

Name…………………………………………………………………………….

Address………………………………………………………………………

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Telephone (mobile preferred):………………………………………………

Email address:……………………………………………………………………….

End of Newsletter