# FLIGHT TESTING THE TITANIC: RE-VISITING THE LOSS OF HIS MAJESTY'S AIRSHIP R.101

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## Abstract

His Majesty's Airship R.101 was a British airship built between 1926 and 1929; requiring a crew of at least 37 of whom an absolute minimum of 15 were required to be on duty at any time, and at 777ft with a gas capacity over 5 million cubic feet long it remains one of the largest aircraft ever flown – 3.6 times the length of an A380. R.101 also incorporated many aspects of new and under-development technology, including recovery of water ballast, semi-rigid construction, steel framework, wire cage gasbag retention, high rate of climb relief valves, multiple control rooms and aircraft Diesel engines. Following some major modifications, HMA R.101 was scheduled for a 74 hour multi-sector endurance demonstration flight from England to India in October 1930. Despite adverse weather, lack of testing of some recent design changes and one of five engines (later repaired and restarted) having failed, the flight was continued out of England and into France. Early in the morning of the second day of the flight the aircraft entered an uncontrollable descent, striking the ground at about 15 knots and 20° nose down. The initial impact appears to have been survivable, but the subsequent hydrogen fire killed 48 of the 54 persons on board, and destroyed the aircraft – also effectively ending all large airship development in the United Kingdom, despite a parallel "sister" project, the R.100, being well into its own flight test programme without significant safety related problems. The R.100 programme had highlighted deficiencies which would require rectification for further airship development including degradation of the gasbags and canopy and the lack of a commercially viable payload.

This paper will briefly describe the history of the R.101, but concentrate upon comparing the R.101 programme with both the more successful R.100, and modern best practice in large flight test programmes. It will show that modern good practice, if followed: including the "no-vote", modern CRM, realism about failing technologies, consideration of ergonomics, and the use of instrumented airframes, should have prevented many of the mistakes which led to the world's worst flight test accident. There are still however lessons to be learned from the loss of the R.101 for both flight test and overall aircraft programme management. This includes preventing political pressure from overriding good safety practice, ensuring that aircraft changes are properly evaluated before resuming a pre-planned flight test programme, not permitting safety critical programme decisions to be made by staff without the right knowledge base, and understanding and learning from other organisations' flight test and development lessons as well as your own.

## 1. Introduction

The idea for researching and preparing this paper came whilst preparing a previous paper on the history of atmospheric research flying (1), which proved a valuable tool in understanding historic good and bad practices in that field of work. The R.101 disaster regularly showed up as a background event in several contexts – the engagement of airborne meteorologists with airships, the prospects for air transport prior to WW2, the lessons to be learned about the management of a very large multi-player research flying programme, and the massive impact of a major flight test accident upon a whole research flying community.

In writing this paper, the objective has not been to create a full account of this very complex accident – that is best found in either the board of inquiry report from 1931(2) or in Masefield's very comprehensive book published in 1982 (3), whilst a less rigorous but informative "popular" account was written in the 1950s by Leasor (4); most recently a revised view of considerable factual information was written by Davidson (5). The objective instead is to bring a modern flight tester's perspective to this, and illustrate the lessons which are there for modern programmes to consider and use.

This paper is primarily about the events leading to the loss early on 5 October 1930 of the R.101 airship (Figure 1), which with a mass of about 150 tons and a volume in various modification states of 5,000,000 to 5,500,000 ft$^3$ was at the time the largest airship in the world, and remains one of the largest aircraft ever constructed. The aircraft was lost in a ground collision in France during the first leg of a planned 74 hour endurance flight to India.


Figure 1 The R.101C airship on mast at Pulham

## 2. The imperial airship scheme

In 1924 the Secretary of State for Air in the new (and Britain's first, but short-lived) Labour party (socialist) administration created, with all party support, a new strategic plan for the expansion of aviation in Great Britain and her Empire. This included development of various technologies and infrastructure, but was also built upon existing experience – which was at that time 72 years airship operating experience, but only 16 years of aeroplane operating experience. During that period, there had been 6 successful crossings of the Atlantic by air – three by aeroplane, carrying a total of 6 people, and three by airship carrying a total of 72 people. Whilst all airship attempts had succeeded, there had been a number of other failed attempts by aeroplane. So evidence pointed to airships, and particularly large airships, as the future of long distance air travel. However, the relative immaturity of both technologies was also recognised.

So was created the Imperial Airship Scheme, approved by the British Cabinet on 7 May 1924, to commence with a substantial programme of research conducted by universities, companies and the National Physical Laboratory (NPL), and also the dedication of one of several existing large state owned airships, the 2,000,000 ft$^3$ capacity/643ft long R.33 (Figure 2) - sister ship of the R.34 which, commanded by Major George Herbert Scott [6], had flown the first east to west Atlantic crossing in 1919 - to develop large airship operating experience through an extended flight test programme.

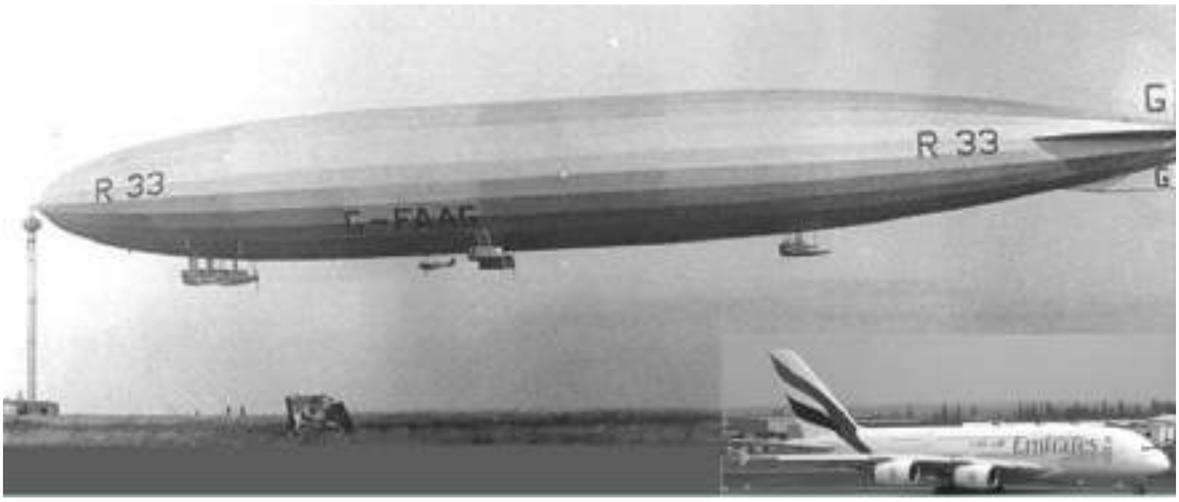


Figure 2 Airship R.33 showing a modern Airbus A380 to scale (aircraft suspended below the R.33 is one of several single seat models trialled for airborne aeroplane launch and about 20ft in length).

This was to lead to the development of two competing government funded airships, the R.100 (often referred to as the "Capitalist Airship") to be built by a corporate consortium under Chief Designer Barnes Wallis [7], and the R.101 (the "Government" or "Socialist" Airship) under Chief Designer Col. Vincent Richmond. Both were to be in the 5,000,000 ft$^3$ class with a nominal initial budget of £350,000 (about £21m at 2015 values), but the overall budget including infrastructure, flight testing and research was £2.4m (£145m today). These would be the two largest airships yet constructed. It is interesting to compare these costs to contemporary projects, which scale well to today – the construction cost of the Titanic (the world's largest ship when launched in 1912) was about 5 times in real terms the allocated cost of each of these airships; in the last few years the price of the 2009 *Oasis of the Sea,* currently the world's largest ocean liner, is about 3 times the current unit price of an Airbus A380. This is a crude comparison, and all figures ignore research and development costs, but broadly indicates appropriate allocation of resources.

By the end of 1929, both airships had flown: R.100, 12 hours[(8)] and R.101, 74 hours, and were installed in giant airship sheds dating from WW1 at RAF Cardington in Bedfordshire (these still stand and are in use in 2015 for a variety of purposes, including smaller modern airships) [(9)] (Figure 3). The R.33 had flown 800 hours, a number of these flights dedicated to science in support of R.100 and R.101 and reported back to both teams (although it appears that only R.101 staff had flown on board her, not R.100 staff [(5)]), as well as ensuring a cadre of highly experienced large airship flight testers, most of whom were Royal Air Force officers, available to both programmes. By this point 239 people had now crossed the Atlantic by airship with no unsuccessful crossing attempts, whilst of 27 crossing attempts by aeroplane, only 11 had succeeded, and 21 lives had been lost in the 16 failed attempts. So, the prescience of the 1924 Empire Airship Scheme, now managed again by Lord Thomson following the more secure return to power of the previously short lived Labour government under Prime Minister Ramsay MacDonald. Both airships were scheduled to continue testing through 1930.

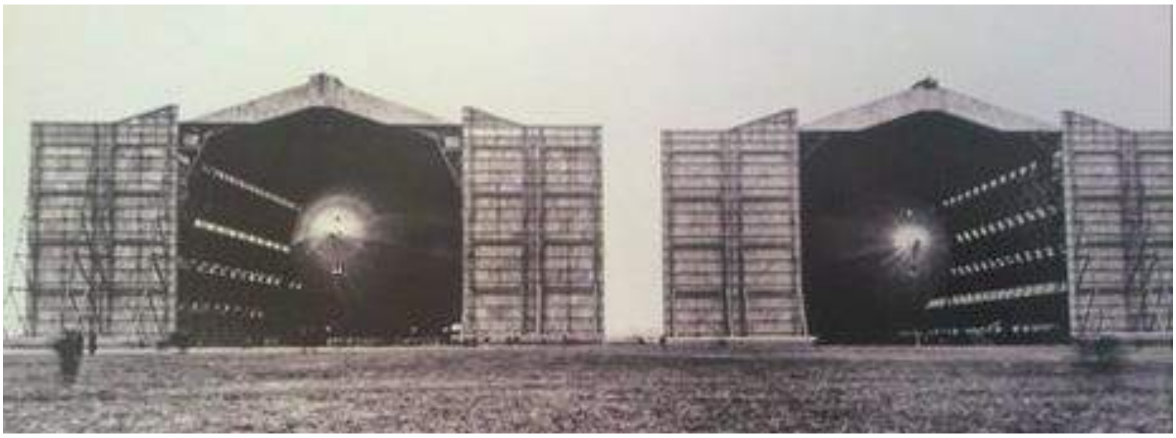

Figure 3 R.100 and R.101 airships in their sheds at Cardington: late 1929 or early 1930

## 3. Technology issues with the two airships

Neither airship was trouble free during their development and testing. An original plan had been to use large Beardmore compression-ignition (Diesel) engines running on a Hydrogen-Kersosene mix, then later heavy oils – this had particularly been to avoid the flash risk of more volatile petrol based fuels in the tropics that were a primary destination for imperial routes. However, the capitalist team rapidly determined that these were unsuitable on grounds of high mass, and saved both money and mass by use of second-hand Rolls Royce Condor petrol engines. Under the more direct instruction of the Air Ministry and Directorate for Airship Development, the socialist team were not permitted to do this, and continued with the Beardmore engines. The result was an installed engine mass in the R.100 of 6 engines totaling about 10 tons, whilst in the R.101 of 5 engines totaling about 20 tons. Hollow bladed steel propellers on the R.101 also proved highly problematic during ground testing and were eventually replaced in the flight vehicle with more conventional wooden propellers.

Figure 4 Beardmore Diesel engine at the Science Museum, London
(height floor to top of engine approximately 5ft)

Both airships had a lower length to thickness ratio than previous airships, based it is believed partly upon the original work of the brilliant but unpopular (perhaps because of cultural objections to a capable woman in a male profession) Hilda Lyon, and similarly used fewer but stronger structural frame members than previous airships [10, 11, 12]. Very large teams of engineering mathematicians, known as "calculators", were actively engaged in both teams [12, 13]. Much higher structural reserve factors were mandated on both designs (in response particularly to the loss of HMA R.38 which broke up in a turn over the river Humber) and the stressing practices were remarkably close to what is now the modern norm [2, 14].

Based upon operating experience, two further new technologies were introduced. These were pressure relief valves in gasbags to deal with unexpected large rates of ascent (a design case of 4,000fpm was in use although this was reduced to 2,500fpm in the R.100) such as might be experienced near a thunderstorm, and which had led to the loss of the USS Shenandoah on September 3rd 1925, and water recovery scoops in the upper surface permitting ballast recovery to allow more control options (the ballasted airship would be able to continue to fly despite being heavier than its aerostatic lift due to aerodynamic lift in forward flight).

The R.100 used a single control car suspended below the airship. The R.101 used two, a main control cabin within the airship from which there was no outside view, and a second steering cabin suspended 20ft below it. In either case, there were multiple levels of personnel involved in controlling the airship – for example the captain would give an instruction for change of thrust to his engine coxswain, who would then transmit that to his engine drivers located in the engine cars (nacelles in modern terminology) – the efficient communication strategies required to manage this, particularly in emergencies, do not appear to have been considered in either case. Both had options to dump ballast and fuel in an emergency – in the case of the R.101, the dumping of fuel was achieved through “can opener” type cutters that would permanently damage the fuel tanks in disposing of excess fuel.

Whilst the R.101 had heavy oil engines, she also used smaller petrol engines as starter motors. This was recognised at the time as a short term and poor strategy given the desire to avoid petrol fuels and the associated flash risk, so a programme was ongoing to replace these with hand-started small Diesel starter engines.

For the gas bags, both airships made extensive use of goldbeaters skin, a thin membrane material made from bullocks intestines (15). This had been a major strategic material for Germany during WW1, to the point that the occupied territories in Poland, Austria and northern France had been banned from making sausages so that the skins were available for Zeppelin manufacture. In Britain, goldbeater's skin had been used to make the gas bags of balloons for the Royal Engineers at Chatham from 1881–82 (16). Different techniques were used on the two airships for restraining and transferring loads from the giant hydrogen bags – but in the R.101 particularly there was a very major problem with chafing, leading to leaks in the R.101B configuration (see below) in the order of 50-90,000 $ft^3$/day, and even in the last R.101C configuration of 20-30,000 $ft^3$/day. There were fears that leaking hydrogen had the potential to pool within the top of envelope, amplifying any pitching motion, and holes around the nose were provided to ventilate the area and reduce potential for hydrogen pooling.

The airships were also covered with linen, which was then shrunk and tightened onto the airframes using nitryl-butrate dope. This was a well understood technology, used on aeroplanes since 1908 in Britain, and earlier elsewhere. However, in an attempt to shortcut manufacturing times, the R.101 team had experimented with pre-doping; this had been a failure, causing a very understrength envelope, with some parts referred to in contemporary accounts as “rotten”.

In summary then, these airships were major technological testbeds, to at-least as great an extent as any modern project. Some of these technologies were causing problems, requiring design decisions and changes.

## 4. R.101 A, B and C

The first configuration of the R.101 is referred to here and in some other texts as R.101A. This had 5,000,000 $ft^3$ $H_2$ capacity and a mass of about 150 tons. This airship could fly, but had insufficient spare payload to permit either long range or the carriage of a significant number of passengers. After an initial 74 hours of testing therefore, a programme of work was implemented to create the R.101B. This let out the hydrogen gasbags to create about another 5,000 $ft^3$ of $H_2$ capacity, whilst also removing a lot of excess equipment to reduce the empty mass.

R.101B however, proved an extremely poor airship – leaking gasbags, failing skins, and still an inadequate disposable payload led to an aircraft that was poorly controllable and underperforming. A decision was made to therefore make a significant modification to the airship, to the final R.101C build standard. This was done between July and September 1930, the start of the work being delayed by a political imperative to display the airship at the Royal Air Force display at Hendon. The largest part of the work was introduction of a new 45ft extension, increasing the total $H_2$ capacity by 500,000 $ft^3$ (Figure 5). Substantial resources were allocated to this task; in the order of 162,000 design man-hours, and 437,000 manual labour man-hours. It is interesting to note that these large figures indicate that the task was being treated with utmost seriousness, but also that the fact these figures are known is indicative of the level of interest in costs – R.102 and R.103 were being considered, and it will have been important to consider the likely effort required to create those.

Figure 5 Gas bag within R.101 structure (the photograph shows a test bay mounted on the door of the airship shed at Cardington).

The R.101C conversion was completed very late before the planned flight to India. R.101's lead captain, Flt.Lt. Irwin [(17)], a highly experienced Airship pilot with considerable test flying experience had developed a plan requiring a 24 hour endurance test including significant periods at high speed (~80mph), followed be the airship being hangered for a full structural inspection before any further flight. This was truncated to a 16hour 51minute (off-mast) flight on 1 October 1930, with no subsequent inspection work and the airship being then immediately prepared for the flight to India. The aircraft, in this form, was unproven either in severe weather conditions or at high speed.

## 5. The intrusion of politics and ambition into flight test practice (Macdonald and Thomson)

The Imperial Airship Scheme was in large part the brainchild of Lord Christopher Thomson, conceived prior to the first short-lived Labour government of 1924, put in place then, and continued by another Secretary of State for Air since. In 1929 Labour returned to power with its first stable administration under Ramsay MacDonald (Figure 6), where Thomson continued to actively support the scheme. Thomson was also MacDonald's strongest friend and ally in government.

Plans had been in place for some time that the R.101's endurance test flight to Ismailia in India and return would be scheduled to return before the end of the Imperial conference in London, a massive prestige event for the British government which would include debate about the future of aviation within the empire. Some-time before (probably early in 1929), private correspondence indicates that MacDonald had indicated to the Indian born Thomson that he might be nominated as the next Viceroy of India – the supreme ruler of the largest territory in the British Empire, in the name of the King. It is clear therefore that Thomson, a very highly respected and powerful man with near-absolute control over the airship programme, had extremely strong reasons for the R.101 to arrive in India on time, and with

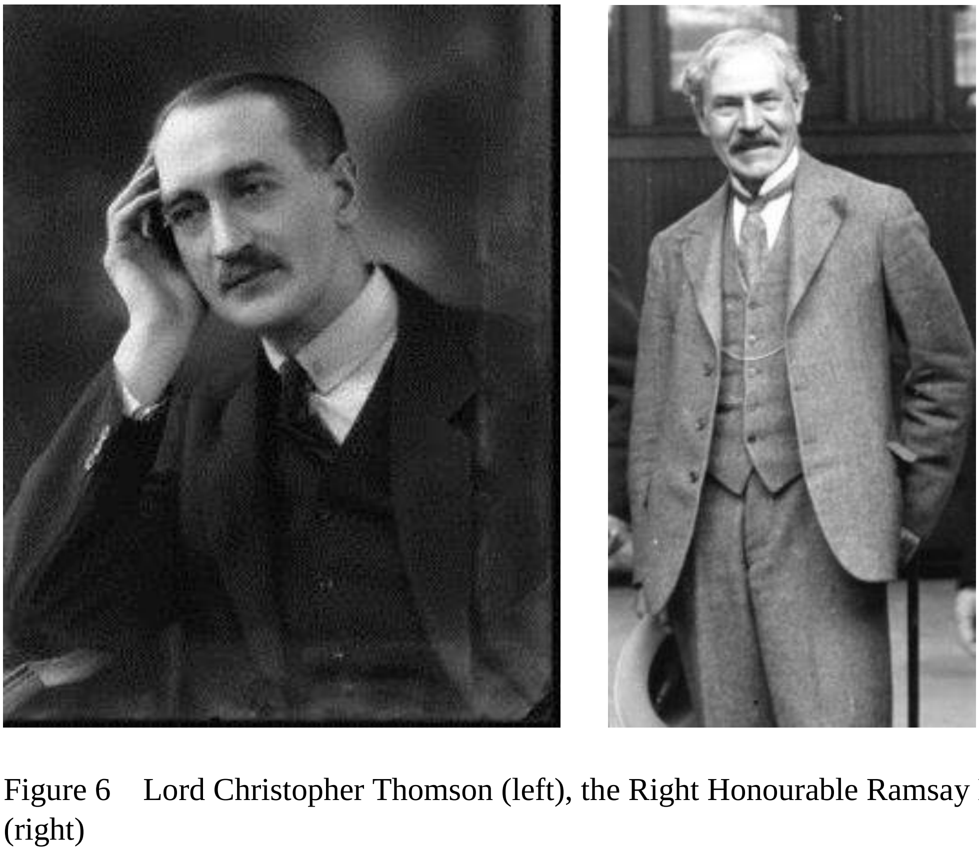

Figure 6 Lord Christopher Thomson (left), the Right Honourable Ramsay MacDonald (right)

him in it.

Additionally, the Labour government was insecure, under significant attack from various parts of British society, and very keen to achieve a major achievement for socialism – R.101 had great potential to be that achievement. Various historians, particularly Leasor [(4)] indicate that

Thomson and MacDonald were therefore the only people with sufficient authority to cancel the flight. This was probably untrue in theory, but had become so in practice.

The apparent consequence then is that the political imperative, understood clearly by all concerned, was that this flight must go ahead. One consequence of this, clear through various correspondence is that although substantial concerns about the safety of the airship and the wisdom of proceeding were held by various competent personnel at Cardington and to a lesser extent the Air Ministry in London, each time these were passed up the command chain they were watered down – so that by the time anything reached Thomson, it was at best an expression of mild concern. This has been remarked to be a very similar precursor to the circumstances of the Challenger Disaster over 50 years later [(18)]. The difference here is that most of those intermediate levels of authority were also on board the R.101.

## 6. The Titanic, and the Vickers Vulcan

It is tempting to analyse an accident such as R.101 in the context only of modern understanding – for example modern understanding of Crew Resource Management, and the well known Feynman chapters in the Challenger report [(28)]. Alternately one can discount the circumstances as “they simply didn’t know any better”. Therefore it is useful to look at what would have been in the professional consciousness at that time.

The loss of the Royal Mail Ship Titanic (Figure 7) is a very well-known accident today, being the loss of the world’s then largest ocean liner, due to a combination of inadequate safety provision, and foolhardy process through a field of icebergs by an overconfident captain. This accident had occurred only 18 years previously and would have been far more in the consciousness of professionals working in transport and in safety critical industries. In this context it should also be recalled that most airship pilots came from a naval background.

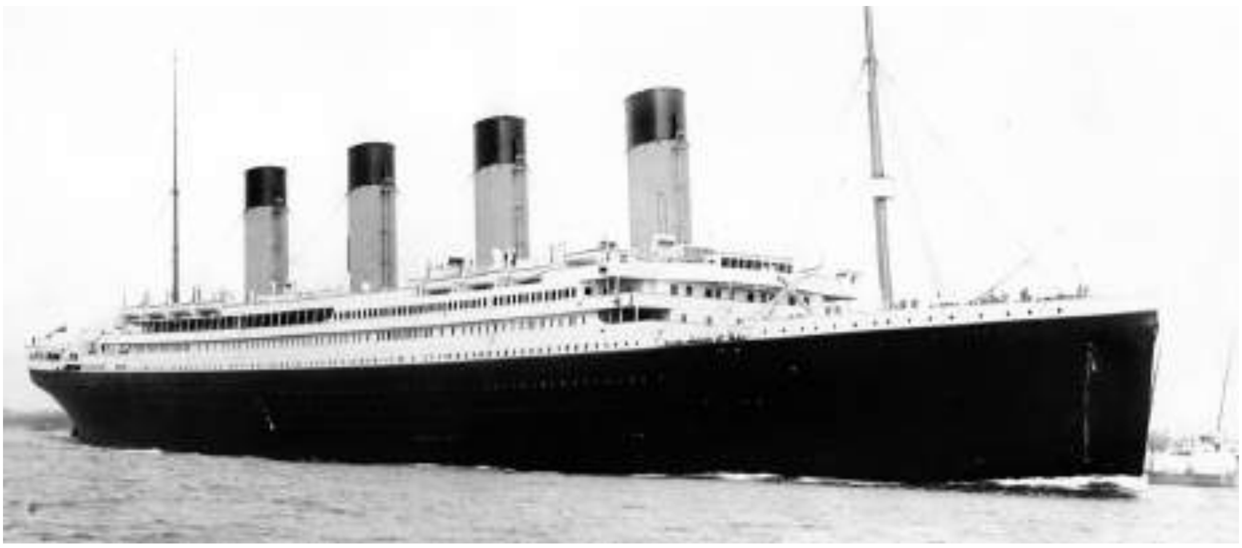

Figure 7 Royal Mail Ship Titanic

A very much more recent event at the time was the loss of Imperial Airways' Vickers Vulcan airliner G-EBLB (Figure 8) from Croydon aerodrome on 13 July 1928 [19, 20, 21]. This had been a post maintenance air test during which the engine failed a few minutes after take-off, resulting in a forced landing and fire. Four airline employees, flying on a "joyride" were killed, one in the impact and three in the post-crash fire – only the pilot and one passenger surviving. The coroner's report into this recommended that the carriage of passengers on test flights should cease [22, 23, 24]; this recommendation was accepted by the state owned Imperial Airways.


Figure 8 Imperial Airways Vickers Vulcan G-EBLB before its accident

Therefore there were adequate recent events in the professional and public consciousness that would have indicated the inadvisability of proceeding in adverse conditions with a large vessel, and in carrying passengers on test flights. (As an aside, just as the Titanic had insufficient lifeboats, the decision had been made with the R.101 to not carry parachutes, presumably at least partly to save weight; they had been carried on the R.34's crossing of the Atlantic.)

## 7. Chronology of the last 3 days

The test flight from the conversion from R.101B to R.101C was "completed" on October 2nd. The Directorate of Airship Development (DAD) management initially wanted to immediately fuel and proceed for India. The captain, Flt.Lt. Irwin, probably working at the limits of his authority, insisted on a 24 hour delay for his crew to prepare and rest.

Early on October 4th, the airship slipped the mast into deteriorating weather – it is likely that the departure was deliberately early to try and get ahead of the weather [25, 26]. The number 5 engine failed, was worked on, and restarted twice, losing nearly 4hrs of running time, but the flight was continued albeit at reduced speed. This will have been conventional practice given that engines of that era were unreliable, and that the aircraft was approximately neutrally buoyant. Regular radio messages were passed with the airship reporting progress, and receiving weather reports; engine problems were reported in code, but there is no indication of particular alarm at running on four out of five engines for part of the flight. Interestingly, the fact of these reports was not included in the inquiry report into the subsequent disaster [27].

Over the English Channel deteriorating weather forced the ship to fly low – the altimeters recording 900ft but experienced airshipmen in the crew believed that it was closer to 700ft. By comparison the optimal altitude would have been about 2,200ft (2.5 times airship length). It is possible that the discrepancy was partly due to flying into an area of lower pressure. Attitude control of any aircraft without reference to a clear horizon is difficult, and it is unlikely that the conditions, dark and under rain bearing cloud, permitted a good visual horizon for the airship crew.

As the airship proceeded across France it passed Beauvais Cathedral, where the engine cars were observed to be at about the same height as the top of the cathedral spire which is 497ft above the ground (perhaps unreliably – height observations of aircraft from the ground were known now, and were known then, to be relatively untrustworthy).

At about 0200 local time on October 5th, the aircraft entered a nose-down pitching motion that became rapidly uncontrollable. This resulted in a ground impact at 0209. The initial impact appears to have been at low speed (~14mph) and survived by all on board. Figure 9 shows an estimate of that flightpath based upon contemporary understanding of the flight mechanic of the airship.

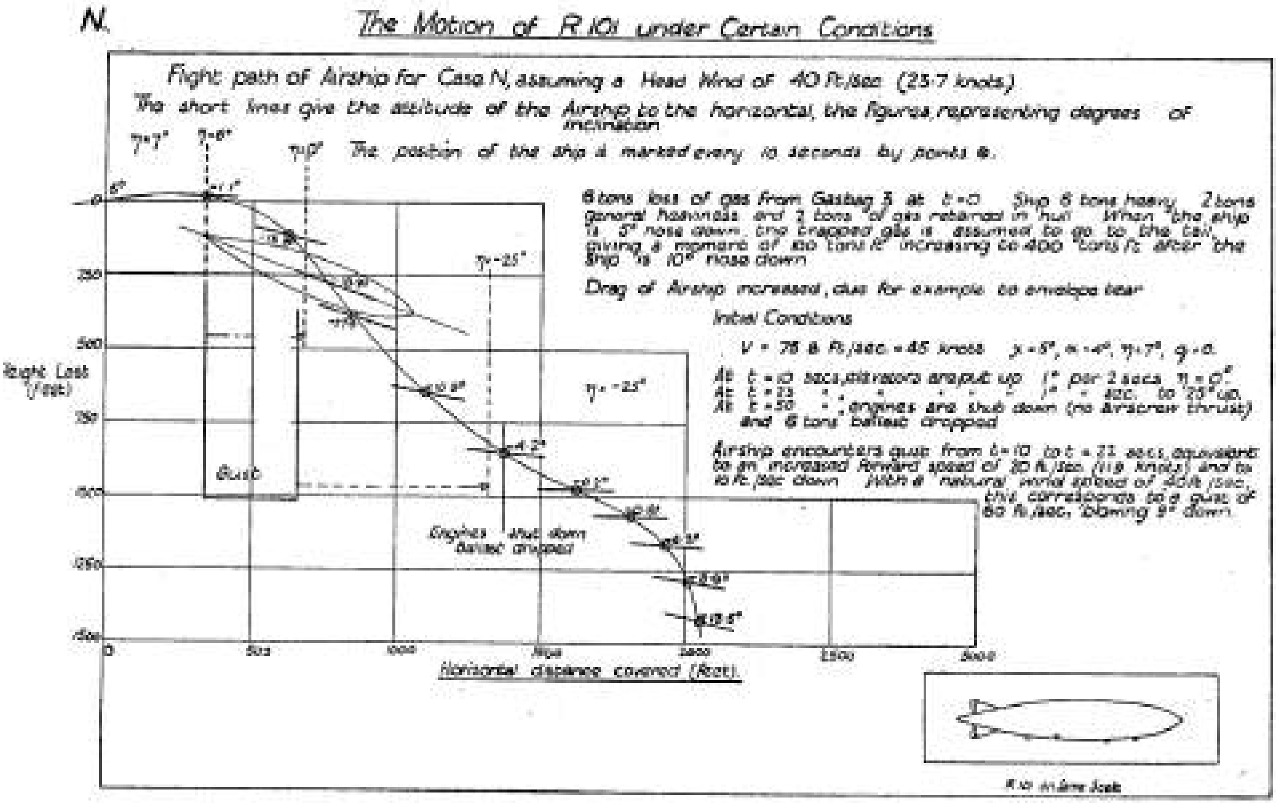


Figure 9 Best estimate of the final flightpath of R.101 to ground collision, prepared by the National Physical Laboratory in 1931

The airship however then caught fire – it is perhaps pointless trying to determine the cause of the fire, given that impact of a 150 ton airship with the ground will create sparks somewhere. But most authorities believe that it was either self-ignition of flares, or an engine car being pushed into a gas bag. Of the 54 persons on board, 46 were killed initially, and a further 2 died in hospital soon after. The six who survived were either in an outlying or secure part of the airship, or soaked by a rupturing water ballast tank above them. Figure 10 shows an aerial image of the wreckage taken a few days later.

Figure 10 Impact location near Beauvais

## 8. Failings compared to contemporary awareness

The Imperial Airways Vulcan crash gave a very strong reason not to carry passengers on test flights. Given that this had been widely reported in the national press, and also both Imperial Airways and the R.101 were state owned, there is every reason to believe that this was understood.

A rigorous reporting system of faults, put in place by competent staff, was subverted by various officials not wishing to be “bearers of bad news” to their powerful superiors.

The history of the RMS Titanic provided another powerful example of the inadvisability of proceeding in a large vessel into adverse conditions. Possibly, not unlike the Titanic, the sheer size of the R.101 was causing turbulence effects in particular to be barely perceptible resulting in a false sense of security.

It is clear from historical records that a rigorous procedure for post modification air testing and inspection of the new R.101C was in place. This was disregarded because of the perceived urgency of departing quickly for India.

It is tempting to consider the perseverance with the flight after an engine failure foolhardy. In reality however, accounts of this and other airships show that this was less serious than would be considered now, or for an aeroplane. Engine failures on multi-engine airships were common, and given the approximately neutral buoyancy of such aircraft, an operational rather than an immediate safety problem in most cases.

## 9. Further failings compared to modern practice

Modern Crew Resource Management theory would be very aware of the importance of adequate crew rest prior to flying an important or demanding mission. Most of the crew of the R.101 had been on duty continuously for 14 days and were highly fatigued.

Modern CRM theory is also very aware of the adverse effects of a “cockpit authority gradient”. The highly experienced but junior ranked captain, Flt. Lt. Irwin, had on board as passengers the head of flying at Cardington, the director of the Cardington airship works, the assistant director for airship development (ADAD), his director (DAD), and the Secretary of State for Air – arguably the second most powerful minister in the government, given his known close personal relationship to the Prime Minister – all of whom had a strong incentive to be in India on time.

Modern flight test practice would include the concepts of knock-it-off (KIO) criteria, and the no-vote. In the highly motivated “succeed at all costs” ethos of that programme, and the highly deferential and hierarchical society which existed in Britain in 1930, neither of those were realistically feasible. It is also a fair question however – how would one terminate a large airship flight where the only four docking masts were in England, Canada, Egypt and India – but the aircraft was in France?

The author has found in his researches no record of emergency drills or exit routes being in place for any of the large airships of this period. This would certainly not be considered acceptable practice now.

Several references studied by the author show that the majority of key officials outside of Cardington, who were actively involved in the decision making process about go/no-go flight and modification decisions, did not have significant airship expertise. This was perhaps understandable, as much of the national expertise in large airship safety was being developed during the design, build and test processes at Cardington. This however meant that remote oversight was weak and ineffective. This is a problem that is rarely written upon, but often discussed within the airworthiness community today, where authorities again may not have sufficient expertise to competently oversee working teams subject to political or financial pressures.

## 10. The USS Akron and the STS Challenger

It is worthy of mention that three years later, the 7,000,000ft$^3$ capacity, 785ft long USS Akron – a larger helium filled airship – was operated off the New Jersey Coast in a similar manner to the R.101 on its fatal flight. That airship had some significant history, and could be regarded as mature and certified. Operated at relatively low altitude into deteriorating weather, it eventually crashed into the sea on the morning of 4 April 1933, killing 73 of its 76 crew. Apart from the nature of the crash, this aircraft was interestingly flying over the sea at low level with no lifejackets on board. Perhaps this is simply a snapshot of another tragedy from an era of inadequate care in such operations – or equally possibly a further example of the failure to learn the lessons of recent and available history. Similarly to the R.101 for Britain, the mishandling of the Akron (also co-incidentally causing the death of a national leader in airship development – in this case Rear Admiral William Moffett) contributed to an eventual end to the USA's involvement with large airships two years later after the further loss of her sister ship the Macon.

Another and much more recent accident is that to the STS Challenger on January 28 1986, a NASA space shuttle which broke up during launch as a result of the failure of a solid rocket booster O-ring seal [18, 28, 29]. The resemblances here to the R.101 are strong, where political pressure and "press-on-itis" conspired to arrange that competent working level safety concerns were not properly expressed upwards to decision making management, who did not themselves fully understand the technical issues.

## 11. In conclusion

The loss of the R.101 was avoidable; whilst best safety practice has of course developed considerably since 1930, there were strong examples of good practice from RMS Titanic and G-EBLB to have shown this team how to prevent such an accident. At the same time, the example of the R.101 has been widely written about with thorough publications between 1931 and 1982 in particular. The lessons for these were widely accessible, yet apparently disregarded by the operators of the Akron in 1933 and of the STS Challenger in 1986.

The author hopes that in writing this paper directed particularly at the flight test community, others will pick up these lessons and help finally disprove the well-known adage penned by Irish writer George Bernard Shaw: "*We learn from history that we learn nothing from history*", preferring instead the words of American statesman Abraham Lincoln: *"Let us therefore study the incidents in this as philosophy to learn wisdom from and none of them as wrongs to be avenged."*. Most current flight test practitioners will find points here that relate directly to both good, and poor, practice visible in the present community, and as such it hopefully will provide value.

**A note on copyright**

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## The author

Dr. Guy Gratton was originally an RAE Farnborough Student Apprentice, and then later a Trials Officer at A&AEE Boscombe Down. He has conducted developmental and certification test flying, including several first flights, and was from 1997-2005 Chief Technical Officer to the British Microlight Aircraft Association for whom remains a test pilot, as he also is for the UK's Light Aircraft Association.

He joined Brunel University in 2005 as a lecturer in aeronautics, where he set up the Flight Safety Laboratory. In 2008 he moved to Cranfield University to head the Facility for Airborne Atmospheric Measurements based there. Since 2014 he has been Head of Airborne Science and Technology for the National Centre for Atmospheric Science, managing development of research aircraft capability for the United Kingdom's atmospheric science community.