QUALIFICATIONS CHASING AVIONICS TECHNOLOGY?

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1. Context

This paper seeks to highlight one area of development – Avionics. It considers the pressures for changes in the educational and vocational qualifications of the workforce employed in the avionics industry. The context of the work is the management of change, of human resource development, of qualification and of competition and efficiency in the avionics industry.

2. Introduction

The date of flight of the first powered aircraft may be regarded as the reference point from which the time-scale of aircraft development is measured. The Wright Flyer is the progenitor of the Boeing 767, the A300 and Concorde. It is also related to the Sopwith Pup, the Flying Fortress and the multitude of military aircraft flying today.

Originally the only electrical systems on aircraft were the engine ignition systems. Over time some electrical power became necessary to provide lighting and instrumentation. The availability of electricity allowed the introduction of other systems designed to enhance the operation of the aircraft, reduce aircrew workload and obtain some perceived operational or commercial advantage. Concomitant with the introduction of electric systems into the airframe came the need for specialists to design, build and maintain these systems. An understanding of electrical theory was required together with an appreciation of the operating environment of the system. Staff were sought with the necessary understanding, some had appropriate qualifications, some required training by the employing companies to a particular certifiable standard. Trained personnel seeking advancement in pay, status or for experience would move between employers. The development of airframes, engines, communications, navigation, control and weapons delivery systems has been continuous. The knowledge base required by those who design, build, maintain and operate these changing aircraft has also been in an unrelenting state of development

3. Moving Frontier of Avionics Technology

Over time the electrical systems became more complex and the knowledge base of an aircraft electrician was deemed to be inappropriate once radio apparatus was added to the aircraft inventory. Another category of aircraft worker was required by the employer, one having knowledge of radio principles and operation together with qualifications appropriate to the individual’s levels of knowledge. Thermionic valve theory was added to electrical theory as radio propagation and reception needed to be understood. The introduction of the magnetron and the development of radar were new techniques and hardware requiring a further expansion of the knowledge base not only of the radio-man but of the forms of certification appropriate to this new area of learning. Wave-guide theory was a new and complex subject and required study, understanding, examination and certification.

The changes have proceeded apace, transistors have replaced valves. Transistor theory has had to be included in the training syllabus and the certification. Operating systems have been developed that are no longer analogue but digital and have been constructed from integrated circuits and not from discrete components. Digital techniques are now included in the syllabus. The radio spectrum has itself been expanded from low frequencies and medium frequencies through high, very high frequencies to the centrimetric, millimetric and beyond. Bandwidths and their utilisation, modulation and the information there-on have altered radically over time.

Just as the systems were made up of discrete components the systems themselves were discrete with inter-connection between them being limited to power supplies and some control and display functions. Today many are microprocessor controlled with dual wire interconnection with other data processor systems which in turn feed into computer generated control and information display systems and in some - functions are shared. Where microprocessors are used there is now a need for information technology and software management comprehension and this has been added to the curriculum.

All these changes have had their impact on the knowledge requirements and the types of certification required of those earning their living in avionics. In terms of equipment there has been an advance from sextants to SatNav, from weapons to weapons systems. The developments continue apace with in-flight entertainment and passenger operated communications being added to the avionics related inventory of equipment within the civil aircraft airframe. Developments in target acquisition, weapons selection and delivery, together with the reliance on computer driven navigation and aircraft control, and weapons management means increasing computer hardware and software complexity and an even broader knowledge base requirement for military orientated personnel. The time of development from research to duty to history is, seemingly, getting shorter, whilst the systems are becoming more diverse and more complex.

4. Knowledge Base and Certification

The basic knowledge requirement for any aspiring maintenance certifying staff within civil aviation operations is to be found in the appropriate Joint Aviation Requirements (JAR-66).

The knowledge levels are given as “Level 1 – familiarization with the principle elements of the subject”, “Level 2 – a greater knowledge of the theoretical and practical aspects of the subject. An ability to apply that knowledge”. Whilst Level 3 is given as ‘A detailed knowledge of the theoretical and practical aspects of the subject. A capacity to combine and apply the separate elements of knowledge in a logical and comprehensive manner.’

Subject Modules	**B2** Avionics
1. Mathematics	X
2. Physics	X
3. Electrical Fundamentals	X
4. Electronic Fundamentals	X
5. Digital Techniques. Electronic Instrument Systems	X
6. Materials and Hardware	X
7. Maintenance Practices	X
8. Basic Aerodynamics	X
9. Human Factors	X
10. Aviation Legislation	X
11. Structures and Systems – Aeroplanes	
12. Structures and Systems – Helicopters	
13. Structures and Systems – Aircraft aerodynamics	X
14. Propulsion	X
15. Gas Turbine Engine	
16.Piston Engine	
17. Propeller	

For the ‘*ab initio*’ student, courses with suitable certification of the required knowledge base are difficult to find. According to Farrow **'The links between academic qualifications and the JAR-66 basic knowledge and experience requirements are tenuous at best'. [2]**

Farrow goes on to say 'that many academic courses have training and assessment criteria that are either too specific or too generalised to be aligned with the criteria published in the JAR. That is not to say that the qualifications obtainable in the UK from City and Guilds, BTEC and other examination boards are not relevant to the avionics and instruments engineer but they may be less so in some theoretical and/or practical subject areas. Farrow indicates in his paper, that the practical aspect of the trainee's work is barely assessed by any of the examination boards, and that this is a deficiency that does not sit well with the JAR-66 requirements. He does, however, offer a suggestion that the British National Vocational Qualification (NVQ) format could easily be adapted to meet this inadequacy and thus provide a qualification that matches the JAR-66 format. He implies that such a qualification could provide trainers and employers, as well as the aspiring engineer, with a qualitative and acceptable basis of training and certification. There are situations where NVQ's are in use. The Royal Air Force incorporates in their promotion procedures a requirement that avionics technicians obtain an NVQ at an appropriate level. Avionics technicians in the Royal Navy also obtain appropriate NVQs but it is not a requirement for promotion. However the Royal Electrical and Mechanical Engineers (REME) Avionics technicians obtain the BTEC National Certificate in Engineering whilst their Artificers require a Higher National Diploma. Thus it would seem that there are forms of certification available to the avionics person. It may be argued that they do not match the requirements of the JAR-66 in either syllabus or experience. Whilst this may be so, there remains the necessity for the avionics person to recognise those areas of theoretical and practical knowledge in which they are deficient and to have the opportunity to obviate this deficiency, obtaining a form of certification. This certification process may or may not match the requirements outlined in JAR-66.

Anyone going to college prior to entering a career that requires an 'in depth' knowledge of electronics will have to spend at least two years covering a syllabus. One that starts with the atom and basic electricity, through fundamental electronic devices, radio theory, control systems and on to computing principles and microprocessors. Coincident with gaining this understanding is that of the physics and maths that underpins the basic theory. Both BCAR's and the JAA state the theoretical knowledge requirements and the levels of understanding required by the would-be licence holder. For those students studying in this area there are various courses and examinations and the levels ranging from City and Guilds, BTEC, National Certificate and National Diploma, Degree and other courses with an electronic core module, but there are fewer courses with an aviation element where the practical application of this theory is demonstrable. It could be argued further that computing skills and appreciation and application of software programming are not currently part of many electronics syllabi; computer languages and their application being regarded almost as a separate discipline, divorced from the hardware operation.

There are three main ways to become an avionics engineer:

a. Training at a college in the United Kingdom for nearly three years.
Entry to this level of study depends on the applicant having GCE 'A' level certificates in Maths or Physics or a BTEC National certificate or suitable experience in an aircraft orientated occupation. At the end of the course the student should have obtained a BTEC Higher National Diploma in Aircraft Maintenance Engineering and a JAR-66 B2 Basic Training Certificate.

b. Training at a college in the United Kingdom for two years for the JAR-66 B2 Basic Certificate. Entry requirements are three GCSE's in English, Maths and Science at grade

C or above and will require two years of study followed by two years experience with an aviation employer before the grant of full B2 status. [3]

c. Training with and working for an aviation employer and studying part time for the licence. The student may take up to four or five years to gain full B2 status.

5. Human Resource Development

With any form of Human Resource Development (HRD) the level of an individual's initial knowledge determines the amount of investment in further education and training that may be required. Licensed engineers in the aviation industry must have **'detailed knowledge of all aspects of the subject'** (their specialisation) and the **'theoretical principles, constructional arrangements, functional and design features, maintenance practices, normal deteriorated and failed functions'. [4]**

With the introduction of each new type of aircraft or system the regulations demand that the licensed engineer has obtained the appropriate type rating added to their licence. This usually necessitates attendance at training providers premises, the payment of a large fee, and to the employer the loss of a member of staff for the period of the course. For some employers this investment in training an individual may have to be made annually as new equipment come into service or replace old ones. Where new techniques or technologies are introduced the expansion of the knowledge base of the individual has to be increased. It could be argued that the individuals ability to absorb, understand and apply new knowledge is dependent on that individuals cognitive agility and their aptitude for learning.

These cognitive factors depend on **'emotional factors, motivation, maturational factors, (…) age, sex, social background, study habits and (…) memory'. [5]**

Adult learners who have a particular interest in learning something new often acquire knowledge reasonably efficiently and trainers are able to capitalise on the learner's enthusiasm. As Knowles [6] put it: **'Adult learners tend to have a perspective of the immediacy of application towards their learning'.** It is arguable that within the avionics discipline (having a broad theoretical knowledge base) new techniques and operating functions are assimilated more easily than when compared with other less theoretically based disciplines. Knowles indicates that the adult's ability to learn remains essentially unchanged throughout life, but difficulties in learning may stem from a lack of confidence, the differing or unfamiliar methodological styles of teaching, lack of internal motivation, and because of ageing affecting sight, hearing or response speeds. Within the avionics industry the requirement for Type Ratings to be obtained by the engineers throughout their employment shows that learning may be habitual and as a consequence comes more easily to these practitioners.

The avionics engineer's knowledge base has to be broad. If this same engineer's licence covers instruments and electrics, then her or his knowledge base has to be broader still. The required knowledge and its application may include such matters as electrical generation, cabling, differing types of equipment, aerials, indicators and displays, data transmission by various means and for use in many differing situations. Add to this a requirement for knowledge on pneumatics, aerostatics, gyroscopic principles, a knowledge of pipes and hoses and their construction and connection, aviation law, human factors and some of the required knowledge base of the JAR-66 X and avionics licensed engineer begins to becomes apparent.

6. De-skilling

Whilst the amount of new knowledge required by the engineer seems to grow as time passes there are subject areas that may cease to be needed. One such theoretical example is thermionic valve theory, the valve having been replaced first by the transistor and then by integrated circuits containing many transistors and their derivatives. When fault finding on some avionics systems the use of 'self diagnostics' functions within the system itself leads to de-skilling. The fault diagnosis or serviceability verification is not dependent on the servicing personnel having an in depth knowledge of the system, thus the knowledge base required of the certifying engineer may be smaller than for one dealing with systems without self diagnostic functions. Ramp maintenance, using the self-diagnostics within systems, becomes less dependent on licensed engineers and may fall to those personnel without the theoretical knowledge base required of the engineer. There is an argument that as systems increase in complexity so there is an increasing necessity for that system to check and validate itself and indicate faults or unserviceable sub-systems. Operatives having the minimum of technical qualifications may then replace these indicated unserviceable parts. Where equipment does need replacement and repair by the manufacturer or in a repair shop the electronics/avionics knowledge base of the repairman may be governed by parameters that are quite unlike those specified by either the JAA or in BCAR's.

The replacement of the licensed engineer with a 'Self Diagnostics Regime' together with less skilled personnel may be a poor strategy should system faults not respond to the box or board changes indicated by the checking system. There are arguments for and against the philosophies of 'Self Diagnostics' Vs 'Engineer's Experience' on various grounds: technical, operational and financial. However these arguments are beyond the remit of this paper.

7. The Shortage of Engineers

In May 1999 in the RAES paper 'The Challenge of the Future' three major factors were identified as likely to contribute towards limiting the expansion of the industry:

a) increased competition from other technically-orientated sectors in the recruitment of personnel:
b) evidence of existing maintenance resources being over-stretched with little capacity for growth:
c) a significant shortage of appropriately skilled labour due to a contraction of the supply of skilled personnel from the armed forces, manufacturing sectors, and the traditional airline apprentice schemes.

Sir Malcolm Field, Chairman of the CAA, speaking at the Royal Aeronautical Society (RAES) Aircraft Maintenance Engineering Task Force Report meeting on 22/02/00 [7], said that the aviation industry needs avionics engineering and maintenance staff to overcome the reported 23% shortage that existed in 1999 and continues to exist in 2000. He went on to indicate that this was in part due to there being little promotion of the industry in schools, inadequate funding during initial training, mediocre pay and conditions. Sir Malcolm included unsociable hours of working, a lack of status especially considering the levels of responsibility, years of study being required and low levels of financial support by employers for study as some of reasons for the shortage of engineers. The suggestion was made that the industry could promote itself in schools as a vibrant and technologically advanced workplace, it could set up modern apprenticeships in conjunction with colleges and it could organise annual intakes of apprentices. For existing engineers the costs of conversion of their BCAR type licences to JAR-66 type licences could be paid by their employers rather than by the individual licence holder. It was suggested that corporate investment in people would bring benefits to individual companies. The point was made that a continuing lack of investment may reduce the capacity of companies to operate as a lack of technical staff, with suitable skills and experience, could result in the withdrawal of essential approvals by the CAA, and that without a maintenance release to service, the aircraft would not be not allowed to fly. He was alluding to the shortages of engineers and technicians at all levels and in all disciplines.

Roland Fairfield, RAES Council Member, at the same meeting, drew attention to the licensed engineer having to work on five, six or seven types of aircraft, and having the appropriate approvals to do so, and pondered on the question of how much information, knowledge and experience could be expected of a single individual. He also was considering all the engineers within the aviation industry. There is a greater demand for avionics engineers than mechanical engineers within the industry. Advances in technology, techniques, and equipment design are likely to be more easily observed within the avionics sector of the aviation world.

John Parkinson, EC Relations Manager, Aviation Group, Department of the Environment, Transport and Regions (DETR) quoting an as yet unpublished DETR survey, stated that there was a shortage of appropriately qualified post 16 entrants for the industry. He reported that the perception of those respondents to this survey was that the Post 16 General Certificate of Secondary Education (GCSE) qualification was of a lower standard than that required by JAR-66 and this inhibited the selection of young people for training to the JAR-66 requirement. (RAES 22/02/00). It would seem that there are not enough would-be engineering applicants to meet the industry's needs and those who do apply are insufficiently qualified.

8. Conclusion

From entry to the industry as an '*ab Initio*' student through to holder of a JAR-66 licence the engineer is in a constant state of learning, acquiring experience, applying knowledge and exercising judgements in a regulated and responsible industry. The cost and effort to obtain and maintain a licence is considerable, some colleges offer '*ab Initio*' training for students but these are few in number. Some employers, together with local colleges have training schemes that offer the chance for new entrants to obtain basic qualifications that may lead to licensing. Some universities offer degree courses that permit graduates, ultimately, to become licensed engineers.

Where sponsorship of some kind has allowed an individual to obtain a licence, the relevant endorsements have then to be obtained. Employers training schemes and sponsorship are important but are often only available when the employer is able to obtain some commercial advantage. For the individual engineer the costs of attending an un-sponsored course may be prohibitive. Whilst the technology of avionics moves ahead it is possible that the engineer is unable to acquire knowledge, understanding and experience because of these financial constraints.

Just as there is continuous development within avionics, there is a continuous need for life-long learning by the avionics engineer. There is also a need for the employer to appreciate this learning skill and to provide a training and learning environment for their common good. There is continuous change in the industry; engineering provision is constantly adapting to meet these changes. Management of these changes requires adaptation of licensing regulations, qualifications appropriate to the changes, acquisition of knowledge and skills, all in a managed and precise way. Industrial developments, commercial pressures, customer demand or legislation may drive these changes.

The supply of avionics engineers to the industry and their subsequent professional development is dependent on people initially getting the necessary basic qualifications together with other factors that need understanding, as well as management and regulation. If the industry as a whole is deficient of engineers of whatever discipline, then the constituent parts of aviation industry (possibly in co-operating with education institutions and government) should take collective responsibility and the initiative of attracting, training and providing for the continuous professional development of its engineers

References

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