Ian Moir, Allan Seabridge
and Malcolm Jukes

Civil Avionics Systems

Second Edition

Aerospace Series
Editors Peter Belobaba, Jonathan Cooper, and Allan Seabridge

WILEY

CIVIL AVIONICS SYSTEMS

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This book is dedicated to Sheena, Sue and Marianne who once again allowed us to indulge our passion for aircraft engineering.

We also wish to acknowledge the passing of a friend, colleague, fellow author, and Series Editor: a major contributor to the Aerospace Series. A vital member of the global aerospace engineering community who passed away on 22 November 2012.

An aerospace systems engineer *'par excellence'*

Roy Langton, 1939 to 2012

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About the Authors

Ian Moir, after 20 years in the Royal Air Force as an engineering officer, went on to Smiths Industries in the UK where he was involved in a number of advanced projects. Since retiring from Smiths (now GE aviation), he is now in demand as a highly respected consultant. Ian has a broad and detailed experience working in aircraft avionics systems in both military and civil aircraft. From the RAF Tornado and Army Apache helicopter to the Boeing 777 electrical load management system (ELMS), Ian's work has kept him at the forefront of new system developments and integrated systems in the areas of more-electric technology and system implementations. With over 50 years of experience, Ian has a special interest in fostering training and education and further professional development in aerospace engineering.

Allan Seabridge was until 2006 the Chief Flight Systems Engineer at BAE Systems at Warton in Lancashire in the UK. In over 45 years in the aerospace industry, his work has included the opportunity to work on a wide range of BAE Systems projects including Canberra, Jaguar, Tornado, EAP, Typhoon, Nimrod, and an opportunity for act as reviewer for Hawk, Typhoon and Joint Strike Fighter, as well being involved in project management, research and development, and business development. In addition, Allan has been involved in the development of a range of flight and avionics systems on a wide range of fast jets, training aircraft, and ground and maritime surveillance projects. From experience in BAE Systems with Systems Engineering education, he is keen to encourage a further understanding of integrated engineering systems. An interest in engineering education continues since retirement with the design and delivery of systems and engineering courses at a number of UK universities at undergraduate and postgraduate level. Allan has been involved at Cranfield University for many years and has recently started a three-year period as External Examiner for the MSc course in Aerospace Vehicle Design.

Malcolm Jukes has over 35 years of experience in the aerospace industry, mostly working for Smiths Aerospace at Cheltenham, UK. Among his many responsibilities as Chief Engineer for Defence Systems Cheltenham, Malcolm managed the design and experimental flight trials of the first UK electronic flight instrument system (EFIS) and the development and application of head-up displays, multifunction head-down displays, and mission computing on the F/A-18, AV8B, Eurofighter Typhoon, Hawk and EH101 aircraft. In this role, and subsequently as Technology Director, he was responsible for product technical strategy and the acquisition of new technology for Smiths UK aerospace products in the areas of displays and controls, electrical power management systems, fuel gauging and management systems, and health

and usage monitoring systems. One of his most significant activities was the application of AMLCD technology to civil and military aerospace applications. Malcolm was also a member of the UK Industrial Avionics Working Group (IAWG), and is now an aerospace consultant and university lecturer operating in the areas of displays, display systems, and mission computing.

Between them the authors have been actively involved in undergraduate, postgraduate and supervisory duties in aerospace at the Universities of Bristol, Bath, City, Cranfield, Lancaster, Loughborough, Imperial, Manchester, and the University of the West of England. The authors are course leaders for the postgraduate Avionics Systems and Aircraft Systems modules for the Continuous Professional Development in Aerospace (CPDA) course delivered by a consortium of the Universities of Bristol, Bath and the West of England to UK aerospace companies including BAE Systems, Airbus UK and Augusta Westland.

Series Preface

The field of aerospace is wide ranging and covers a variety of products, disciplines and domains, not merely in engineering but in many related supporting activities. These combine to enable the aerospace industry to produce exciting and technologically challenging products. A wealth of knowledge is retained by practitioners and professionals in the aerospace fields that is of benefit to other practitioners in the industry, and to those entering the industry from University.

The Aerospace Series aims to be a practical and topical series of books aimed at engineering professionals, operators, users and allied professions such as commercial and legal executives in the aerospace industry. The range of topics is intended to be wide ranging, covering design and development, manufacture, operation and support of aircraft as well as topics such as infrastructure operations, and developments in research and technology. The intention is to provide a source of relevant information that will be of interest and benefit to all those people working in aerospace.

Avionic systems are an essential and key component of modern aircraft that control all vital functions, including navigation, traffic collision avoidance, flight control, data display and communications. It would not be possible to fly today's advanced aircraft designs without such sophisticated systems.

This 2nd edition of *Civil Avionics Systems* provides many additions to the original edition, taking into account many of the innovations that have appeared over the past decade in this rapidly advancing field. The book follows the same successful format of the first edition, and is recommended for those wishing to obtain either a top-level overview of avionic systems or a more in-depth description of the wide range of systems used in today's aircraft.

Peter Belobaba, Jonathan Cooper and Allan Seabridge

Preface to Second Edition

It has been over ten years since the first edition of Civil Avionics Systems was published. The book has been in print since that time and it is used as a course text book for a number of university undergraduate and postgraduate courses. It continues to be popular with students and practitioners, if the sales are anything to go by, and the authors continue to use it as the basis of lectures whilst continuously updating and improving the content.

However, much has happened in the world of commercial aviation and in the technological world of avionics since the first publication, prompting a serious update to the book. Despite worldwide economic recession, people still feel a need to fly for business and leisure purposes. Airlines have introduced new and larger aircraft and also introduced more classes to improve on the basic economy class, with more people choosing premium economy and even business class for their holiday flights. This has seen the introduction of the world's largest airliner, the Airbus A380, and an airliner seriously tackling some of the environmental issues in the form of the Boeing B787.

In the field of avionics there have been many advances in the application of commercial data bus networks and modular avionic systems to reduce the risk of obsolescence. Global navigation systems including interoperability of European, US, Russian and Chinese systems and associated standards will seek to improve the ability of aircraft to navigate throughout the world, maybe leading to more 'relaxed' rules on navigation and landing approaches. The crew have been served well with ergonomically improved flight decks providing improved situational awareness through larger, clearer, head-down displays and the addition of head-up displays, with enhanced flight vision and synthetic vision systems.

Propulsion systems have improved in the provision of thrust, reduced noise, improved availability and economic operation. Modern airliners are beginning to move towards more-electric operation.

All these topics and more are covered in this new edition, at considerable effort to keep the book to a reasonable number of pages.

Preface to First Edition

This book on '*Civil Avionic Systems'* is a companion to our book on '*Aircraft Systems'*. Together the books describe the complete set of systems that form an essential part of the modern military and commercial aircraft. There is much read across – many basic aircraft systems such as fuel, air, flight control and hydraulics are common to both types, and modern military aircraft are incorporating commercially available avionic systems such as liquid crystal cockpit displays and flight management systems.

Avionics is an acronym which broadly applies to AVIation (and space) electrONICS. Civil avionic systems are a key component of the modern airliner and business jet. They provide the essential aspects of navigation, human machine interface and external communications for operation in the busy commercial airways. The civil avionic industry, like the commercial aircraft industry it serves, is driven by regulatory, business, commercial and technology pressures and it is a dynamic environment in which risk must be carefully managed and balanced against performance improvement. The result of many years of improvement by systems engineers is better performance, improved safety and improved passenger facilities.

'Civil Avionic Systems' provides an explanation of avionic systems used in modern aircraft, together with an understanding of the technology and the design process involved. The explanation is aimed at workers in the aerospace environment – researchers, engineers, designers, maintainers and operators. It is, however, aimed at a wider audience than the engineering population, it will be of interest to people working in marketing, procurement, manufacturing, commercial, financial and legal departments. Furthermore it is intended to complement undergraduate and post graduate courses in aerospace systems to provide a path to an exciting career in aerospace engineering. Throughout the book 'industry standard' units have been used, there is therefore a mix of metric and Imperial units which reflects normal parlance in the industry

The book is intended to operate at a number of levels:

- Providing a top level overview of avionic systems with some historical background.
- Providing a more in-depth description of individual systems and integrated systems for practitioners.
- Providing references and suggestions for further reading for those who wish to develop their knowledge further.

We have tried to deal with a complex subject in a straightforward descriptive manner. We have included aspects of technology and development to put the systems into a rapidly changing context. To fully understand the individual systems and integrated architectures of systems to meet specific customer requirements is a long and complicated business. We hope that this book makes a contribution to that understanding.

Ian Moir and Allan Seabridge 2002

Acknowledgements

Many people have helped us with this book, albeit unknowingly in a lot of cases. Some of the material has come from our lecturing to classes of short-course delegates and continuing professional development students. The resulting questions and discussions inevitably help to develop and improve the material. Thanks are due to all those people who patiently listened to us and stayed awake.

Colleagues in industry have also helped us in the preparation. Mike Hirst critiqued a number of chapters, and Brian Rawnsley of GE Aviation reviewed and advised upon the latest regulatory issues. Our Airbus UK course mentors Barry Camwell, Martin Rowlands and Martin Lee provided invaluable advice and really gave a stimulus to generating a lot of new material. We have also been helped by Leon Skorczewski and Dave Holding who have joined in the avionics courses by providing material and lectures.

BAE Systems, Cranfield University and the University of the West of England have invited us to lecture on their continuing professional development courses, which opens the door to discussions with many mature students. We wish to thank the organisers of the courses and also the students.

We have been guided throughout the preparation of the manuscript by Anne Hunt, Tom Carter and Eric Willner at John Wiley's at Chichester, and also to Samantha Jones, Shikha Jain from Aptara Delhi and Wahidah Abdul Wahid from Wiley Singapore for the proof-reading, copy-editing and publishing stages of production. Their guidance and patience is, as always, gratefully received.

Ian Moir, Allan Seabridge and Malcolm Jukes
January 2013

List of Abbreviations

3-D	three-dimensional
4-D	four-dimensional
ABS	automatic braking system
AC	alternating current
AC	Advisory Circular
ACARS	ARINC Communications and Reporting System
ACE	actuator control electronics
ACK	receiver acknowledge
ACFD	Advanced Civil Flight Deck
ACP	audio control panel
ADC	air data computer
ADC	analogue to digital conversion/converter
ADD	airstream direction detector
ADF	automatic direction finding
ADI	attitude director indicator
ADI	aircraft direction indicator
ADIRS	Air Data & Inertial Reference System
ADIRU	Air Data and Inertial Reference Unit (B777)
ADM	air data module
ADP	air-driven pump
ADS-A	automatic dependent surveillance – address
ADS-B	automatic dependent surveillance – broadcast
AEW	airborne early warning
AEW&C	Airborne Early Warning and Control
AFDC	autopilot flight director computer
AFDS	autopilot flight director system
AFDX	Aviation Full Duplex
AH	artificial horizon
AHRS	attitude and heading reference system
AIM	Apple–IBM–Motorola alliance
AIMS	Aircraft Information Management System (B777)
Al	aluminium
ALARP	As Low as Reasonably Practical
ALT	barometric altitude

ALU	arithmetic logic unit
AM	amplitude modulation
AMCC	Applied Micro Circuits Corporation
AMLCD	active matrix liquid crystal display
ANO	Air Navigation Order
ANP	actual navigation performance
AoA	angle of attack
AOC	airline operation communication
AOR-E	Azores Oceanic Region – East
AOR-W	Azores Oceanic Region – West
APEX	Application Executive
API	Application Programming Interface
APU	auxiliary power unit
AR	Authorisation Required
ARINC	Air Radio Inc.
ARM	Advanced RISC machine
ASCB	Avionics Standard Communications Bus (Honeywell)
ASCII	American Standard Code for Information Interchange
ASI	airspeed indicator
ASIC	application-specific integrated circuit
ASPCU	air supply and pressure control unit
ASTOR	Airborne Stand-off Radar
ATA	Air Transport Association
ATC	air traffic control
ATI	air transport indicator
A to D	analogue to digital
ATM	air traffic management
ATN	aeronautical telecommunications network
ATR	Air Transport Radio
ATS	air traffic services
ATSU	Air Traffic Service Unit – Airbus unit to support FANS
AWACS	Airborne Warning and Control System
AWG	American Wire Gauge
B	Blue Channel (hydraulics) Airbus
BAG	bandwidth allocation gap
BAT	battery
BC	bus controller
BCD	binary coded decimal
BGA	ball grid array
BGAN	Broadcast Global Area Network
BIT	built-in-test
BLC	battery line contactors
BPCU	bus power control unit
BPCU	brake power control unit

bps	bits per second
BRNAV	basic area navigation
BSCU	brake system control unit
BTB	bus tie breaker
BTC	bus tie contactor
BTMU	brake temperature monitoring unit
C	Centre
C	Centre Channel (hydraulic) Airbus
C	C Band (3.90 to 6.20 GHz)
C1	Centre 1 (Boeing 777)
C2	Centre 2 (Boeing 777)
CA	Course/Acquisition – GPS Operational Mode
CAA	Civil Airworthiness Authority
CANbus	a widely used industrial data bus developed by Bosch
CAS	calibrated air speed
CAST	Certification Authorities Software Team
Cat I	Automatic Approach Category I
Cat II	Automatic Approach Category II
Cat III	Automatic Approach Category III
Cat I	Category I Autoland
Cat II	Category II Autoland
Cat IIIA	Category IIIA Autoland
Cat IIIB	Category IIIB Autoland
CCA	common cause analysis
CCR	common computing resource
CCS	communications control system
CD	collision detection
Cd/m^2	candela per square metre
CDU	control and display unit
CDR	critical design review
CF	constant frequency
CF	course to a fix
CFIT	controlled flight into terrain
CFR	Code of Federal Regulations
CLB	configurable logic block
CMA	common mode analysis
CMCS	Central Maintenance Computing System (Boeing)
C-MOS	complementary metal-oxide semiconductor
CMS	Central Maintenance System (Airbus)
CNS	Communications, Navigation, Surveillance
CO_2	carbon dioxide
C of G	centre of gravity
COM	command
COMMS	communications mode