Book Reviews

Applied Computational Aerodynamics: a Modern Engineering Approach

R. M. Cummings et al

There have been many textbooks on the topic of computational fluid dynamics (CFD), most with a general coverage of the key elements from flow governing equations, to their discretisation and solution methods with some applications. This is certainly not just another such book. Based on the authors’ teaching and research experience, they have succeeded in composing a volume for students in aeronautical and aerospace engineering by including a number of unique features to enthuse the readers.

Where appropriate, flow visualisation boxes are used to illustrate the points covered in the text, which I believe is rather effective in visualising the invisible ‘air’ around an object. The authors have also incorporated open source computer programs, downloadable from the linked web-site, for the projects presented at the end of most chapters. The students can also find the profiles of some experienced and young researchers in computational aerodynamics, again a feature unique to the book. These unique features make the book not only enjoyable to read but also very useful as a reference book for practical aerospace engineers/researchers.

The coverage of the book is rather comprehensive in the context of computational aerodynamics. The first chapter introduces the readers to the general area of computational aerodynamics. Computer and code related issues are briefly discussed in Chapter 2, including parallel computing and code verification and validation. The following four chapters are on introductory materials for fluid mechanics (Chapter 3), aerodynamics (Chapter 4), classical linear theory (panel methods, Chapter 5) and computational fluid dynamics (Chapter 6). Depending on the background/level of the students, some of these chapters can be selectively skipped.

Chapter 7 is on grid generation techniques with examples related to aerodynamic shapes. Turbulence modelling is presented with emphasis on Reynolds averaged Navier-Stokes solutions and hybrid RANS/LES approaches in the context of computational aerodynamics. A whole chapter (Chapter 9) is devoted to flow visualisation for computational aerodynamics (CA) with some in-depth coverage. The book concludes with a chapter on CA applications from transonic to hypersonic aerodynamic problems, which also covers issues on the integration of computational and experimental aerodynamics, a key topic for validation.

I strongly recommend this textbook for aeronautical or aerospace students at either undergraduate or postgraduate level. Aerospace engineers/researchers will also find it useful as a handbook. This comprehensive volume can be used by those with little background in fluid mechanics, aerodynamics or CFD as
a self-contained learning material. For those who already have some background in these fundamental topics, they will find the applied nature and the unique features interesting in relation to computational aerodynamics, such as the open source programmes, an aerofoil database, a source of data for validation and a web-site link with much more information.

As the authors stated in their objectives, this book is intended to train intelligent users of computational aerodynamics rather than CFD code developers. They have certainly achieved this objective as there are sufficient materials in the text for the students to avoid the blind black-box approach to computational aerodynamics.

Professor Ning Qin, FRAeS, University of Sheffield

This book is immaculately produced by a highly respected publishing house and is written by an author who is adept at solving elementary set-piece problems in stress and strain.

The author provides a pre-chapter Historical Overview, which traces the development of solid mechanics, from Hooke to Timoshenko. ‘Properties of Areas’, Chapter 1, comprises ten fully worked A-Level integral calculus examples which explain how centroids, first and second moments of area are calculated and how parallel/perpendicular axes and transformation equations are applied.

‘Static Equilibrium’, Chapter 2, develops vector equations and promotes free-body diagrams as the preferred way of calculating forces in multi-force situations. However, the Triangulation Principle, so important in design and directly applicable to the Warren Truss (Fig 2.11) is not explained and no vector force diagram is provided. It may be the author regards graphic statics as ‘old hat’ but knowing how to construct a vector force diagram for a multi-bay bridge and observe the build-up of bending moment and configure the design accordingly is not without its uses. The author also fails to mention that Figures 2.9 and 2.10 are mechanisms with one degree of freedom and are not technically structures. These basic points need to be addressed. How to draw shear force and bending moment diagrams is explained rather better.

‘Basic Stress and Strain’, Chapter 3 (pages 61-65), expose the author’s inability to summarise, introduce and explain basic issues in clear, uncluttered, simple terms. Given, the author quotes Robert Hooke’s dictum: ‘as the extension so the force’ (see page 3), he might, at least, have provided a Load v Extension diagram and explained the full meaning of Stiffness and Flexibility (compliance) its converse. The
The author’s handling of Intrinsic Material Properties is no better. Limit of proportionality, proof, yield and ultimate strengths are marked symbolically on notional stress v strain diagrams, but are presented as subordinate to Safety Factor, under which sub-heading they appear. Only the excellent fully worked examples save the day.

‘Linear Elasticity’, Chapter 4, also begins by spraying the reader with mumbo-jumbo scatter shot, before an overdue Load v Extension diagram based on credible data appears. The relationship between the elastic constants and the extended use of Hooke’s Law are mathematical issues which are clearly explained. The chapter is well supported by fully worked examples, as is the case throughout the book.

‘Bending and Shear in Beams’, Chapter 5, develops the engineers theory in a conventional way and introduces the principle of super-position. The author explains how transverse shear produces complementary shear stresses in the longitudinal direction and how bending and shear stresses are distributed over a variety of different cross sectional shapes. The concept of shear flow in thin-walled open and closed tubes is also clearly explained using quasi aerostructures examples.

‘Slope and Deflection of Beams’, Chapter 6, shows how easy it is to compute the slope and deflection at any point on a beam, when the loading is statically determinate and simple. But add a few structural redundancies and other ways of solving the problem are required. The author answers the call by supplying seven fully worked examples, which show how Mohr’s area movement method may be applied. Macaulay’s Step Function approach, the skew-symmetric method and Maxwell’s reciprocal theorem are also discussed.

‘Theories of Torsion’, Chapter 7, develops the engineers theory and addresses two separate issues: (1) Power transmitting shafts in which uniform, tapered, and stepped variants, loaded by single and multiple torque inputs are considered, (2) Open and closed tubes, typical of those encountered in basic aircraft structures, for which the Bredt-Batho theory is used.

‘Buckling of Struts’, Chapter 8, provides a balanced (50-50) account of Euler’s classical theory of elastic stability and a wide variety of empirical approaches offered by Rankin, Gordon, Johnson, Perry-Robertson, Fidler and Engesser. ‘Buckling of Plates and Tubes’, Chapter 9, is another chapter in which the author seems duty bound to summarise every detail of what is to come, before getting down to the nitty-gritty, so much so the reviewer suggests that all new to the subject will find the transition from Struts to Plates far less daunting if they skip the Summary and Section 9.1 and read from Section 9.2 to Section 9.7 directly. The content of this chapter is fairly mathematical and with the exception of stringer stabilised (wing) skins, flagged up as a ‘red-herring’ at the end of the summary, all aspects including tension field beams are covered and bolstered by extracts from ESDU data sheets.

‘Energy Methods’, Chapter 10, explains how the conservation of energy principle (otherwise known as the first law of thermodynamics) is used to solve problems in solid mechanics. As the author explains: the essence is to equate the external work done in deforming a structure or component to the internal energy stored. How this works is clearly illustrated by the author’s analysis of springs. Impact loading is also considered. Various equations which apply to other elemental situations are developed and the application of Castigliano’s force and displacement theories demonstrated, by way of numerous worked examples. Stationary potential energy is also discussed.

‘Plane Stress and Strain’, Chapter 11, arrives late, the topic being more commonly found
in the early chapters of most standard texts: Megson (*Aircraft Structures for Engineering Students* – Chapter 1), Sun (*Mechanics of Aircraft Structures* – Chapter 2), Riley et al (*Mechanics of Materials* – Chapter 2), Peery and Azar (*Aircraft Structures* – Chapter 3). The wedge element, Fig 11.1 for example, is directly relevant to the virtual test piece, the shape of which was described without significant comment 372 pages before. This said, the author’s treatment of Plane Stress and Plain Strain is sound. Section 11.5 on strain gauge rosette analysis using Wheatstone bridge circuit theory is also good.

‘Yield, Strength and Fracture Criteria’, Chapter 12, covers all five classical theories of ductile metal failure: (1) Maximum Principal Stress, (2) Maximum Principal Strain, (3) Maximum Shear Stress, (4) Total Strain Energy, (5) Distortional Energy. Theories for brittle solids and fibrous materials are also discussed. There is, however, no coverage of Fatigue or Fracture Mechanics.

‘Finite Elements’, Chapter 13, introduces relatively advanced concepts, pitched at just the right level for undergraduate study. The reviewer’s earlier call for more attention to be paid to Stiffness arrives with Section 13.1 in which the author describes in detail how to set up a stiffness matrix for: (1) an axially loaded bar, (2) a beam, (3) a shaft, (4) several very basic triangulated frames. The Principle of Virtual Work (PVW) and the principle of Stationary Potential Energy (SPE) are also fully explained.

The author takes a very simplistic view of what constitutes an Engineering Structure and prospective buyers should read the first line of blurb (back cover) before purchasing this book impromptu. Readers should also reflect on the author’s statement (page 1) where he writes ‘solid mechanics is concerned with an understanding of what happens within a body when it is expected to carry loads’, for this grand vision is not fulfilled. Suffice to report that there is not a word about crystal structures, atomic bonds or Dislocations and no explanation as to what internal changes actually occur. Another area in which the reader is short-changed emanates from the author’s penchant for applying arbitrary safety factors without reference to Codes of Practice or any mention of the interactive statistical nature of Applied Load and Load Capability. The author does, however, provide 150 fully worked examples which will undoubtedly attract Swats and Freshers. The reviewer is also able to recommend Chapters 10-13, to those more advanced in their studies.

Peter C. Gasson, CEng, MI MechE, FRAeS

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**Microwave Radar and Radiometric Remote Sensing**

F. T. Ulaby *et al*

Microwave remote sensing and its applications have seen exponential growth in importance over the two decades that I have had the privilege to study it. With almost a thousand pages, this book by F. T. Ulaby and co-authors is guaranteed to satisfy every curiosity you ever had about microwave radar remote sensing. This book covers a whole spectrum of knowledge, from the basic principles of electromagnetic wave propagation, remote sensing antennas, microwave dielectric properties of materials, radar scattering processes, microwave radiometry and radiative transfer processes, to practical applications of microwaves in radiometric systems, atmospheric sounding, scattering models, land and ocean observations, SAR interferometry, scatterometers and radar altimetry.

Whether you want to read up on how ice clouds influence radar signals, how wet and dry soil appears in a radar image or where in the world the hotspots of radar interference lie, you are guaranteed to find the answer. I particularly enjoyed the section on volume scattering models and land observations, which introduces the different scattering types and applies them to a variety of agricultural crop canopies and tree canopies of different growth forms. Due regard is given to look angle effects, dew, wind, dry and wet snow packs and other environmental factors that influence the signal.

Microwave radiometry on spacecraft goes back to the Mariner 2 Venus flyby mission in 1962 and since then has grown to become an operational part of the global Earth observation system.

A good balance is struck between mathematical equations to define the physical principles, and application examples and illustrations. This greatly helps in applying the principles of microwave remote sensing to acquired images and data. Throughout the book, important definitions and equations are highlighted in coloured text boxes. Sketches, diagrams, images, photos and maps add to the understanding of the subject matter.

F. T. Ulaby and colleagues have produced an outstanding compendium of knowledge about microwave radiometry and modern microwave remote sensing.

Professor Heiko Balzter, Director of Centre for Landscape and Climate Research, NERC National Centre for Earth Observation, University of Leicester.

Basic Radar Analysis

M. C. Budge and S. R. German

There are a great number of books which aim to cover the subject of radar systems and analysis, and quite a few of them that have been published in the Artech House
radar series. This one is based on a set of three courses on radar taught at the University of Alabama in Huntsville and the authors are from the Dynetics company in the US.

The book is organised in eighteen chapters and two appendices. Both the fundamentals, such as detection theory, radar waveforms, radar receivers, phased arrays and synthetic aperture radar and advanced topics such as Space-Time Adaptive Processing and (in the final chapter) MIMO radar and cognitive radar, are covered. The two appendices treat the subjects of suboptimal filtering and data windowing functions. The style is appropriate to practicing radar engineers at a postgraduate level, with the emphasis on presenting, understanding and using the mathematical equations to describe the operation of radar systems. These are supported by clear diagrams and graphs. In addition, many of the classic references are listed so that the origins of each topic can be followed up. Each chapter concludes with a set of exercises, with numerical examples and derivations; these will be useful both to the reader, to help develop his or her understanding, and to instructors.

The book also comes with a DVD containing a range of MATLAB scripts and functions. These will be especially valuable to practitioners in analysing and modelling radar systems.

In summary, this is a useful and distinctive addition to the radar literature, both at an academic and practical level.

Professor H.D. Griffiths, FREng, FIET, FIEE, THALES/Royal Academy of Engineering Chair of RF Sensors, University College London.

Jet Propulsion: a simple guide to the aerodynamics and thermodynamic design and performance of jet engines – Third edition

N. Cumpsty and A. Heyes

This book provides an excellent overview of the thermodynamic analysis and performance of turbojet based engines for the aircraft industry. This being the Third edition of this classic textbook covering the detailed analysis of the aero turbojet/turbofan cycle, several changes to the treatment of this analysis have been put into effect to enable a clearer understanding of current trends in engine design and to put these in context of earlier designs. Similar to earlier editions the book includes a good treatment of the basic background material which helps to make this book an effective self-contained text on the topic.

The book includes an excellent set of example questions for each section which are given a
relevant contemporary context. The book is also supported by a wealth of online material including solutions for example questions and digital copies of all the significant figures. This is an excellent resource for anyone wishing to use this as a textbook as part of an undergraduate aerospace engineering programme.

The authors have used their extensive industrial links to develop a textbook that is not only useful to undergraduate students on any programme covering aero gas turbine engines but would find a suitable place on the desk of professionals working in the industry.

K. L. Smith, BEng (Hons), PhD, MRAeS, FHEA

This book provides a good and comprehensive overview of spacecraft attitude determination and control systems (ADACS), including a broader than usual coverage of payload pointing. The book successfully targets an audience of engineers and graduate students. It would have been helpful to provide specific examples of actual space missions with unclassified information. A space systems engineering background is useful but not essential. The theoretical and practical fundamentals of spacecraft dynamics, estimation and control are indeed provided and linked to electro-optical payloads properties.

The book is organised in nine chapters. The introduction Chapter 1 outlines the way the content is organised to describe the ADACS design and development from mission, subsystems and payload requirements. Chapter 2 describes the starting point in ADACS design from mission level systems engineering requirements. Different types of Earth observation missions are considered together with their pointing requirements. The implications on imaging payload design and spacecraft configurations are also described, with a useful configuration design example. It would have been useful to extend this section to also briefly explain the links between off-pointing requirements and image coverage from an Earth observation satellite with a brief discussion of satellite orbit designs and ground tracks which are relevant to ADACS design. Practical considerations such as the use of forward motion compensation (FMC) should also have been briefly discussed as an alternative way of improving image quality.

Chapter 3 describes the electro-optical systems requirements flowdowns from payload mechanical and electrical designs. A brief discussion of the electromagnetic wave nature of light is followed by a description of
the requirements on imaging quality (MTF), brightness, magnification, resolution. Practical considerations such as aberration effects and jitter specifications are also accurately described. Telecommunication link budgets are discussed very shortly, but are beyond the scope of the book, despite their link to payload pointing requirements.

The ADACS hardware is described at the right level of detail in Chapter 4. A comprehensive description of the conventional types of attitude sensors and actuators and radiation detectors is provided together with their mathematical modelling and a description of the space environment.

In Chapter 5 conventional attitude parameterisations of spacecraft kinematics are clearly described together with their associated attitude propagation models. The geometry of attitude determination from two (triad) or more vector observations and its solution using least squares is also described. It might have been useful to indicate that one of the methods used is more generally known as the $q$-method. The appendices 5.1 and 5.2 on topological aspects of rotations and Lie Group formulation sof attitude kinematics are challenging but amongst the most interesting features of the book. It would have been helpful to also discuss the applications of the approach such as motion planning and geometric estimation and control. The appendix 5.3 on changing attitude by changing shape is another interesting feature of the book.

The spacecraft dynamics fundamentals are very clearly illustrated and described in Chapter 6, starting with a very good description of torque free motion. Gimbal dynamics could have been described in more detail. Practical considerations such as flexible body dynamics and fuel slosh are very clearly presented.

Chapter 7 is dedicated to spacecraft control. The disturbance torques affecting spacecraft dynamics are described in sufficient detail, but with a certain lack of numerical examples to better comprehend their relative effects. Gravity gradient stabilisation is described with and without augmentation by a pitch momentum wheel, which is another good contribution of the book. Momentum bias and three-axis stabilisation are described in sufficient detail with their corresponding models of attitude dynamics. Conventional quaternion based feedback attitude control is described. The use of CMGs (Control Moment Gyros) for satellite attitude control is described with a good discussion of their singularities and ways of avoiding them. The various applications of magnetic torquers are presented including the momentum dumping of the wheels and the B-dot controller used to de-tumble spacecraft in a safe mode. Practical considerations of pulse modulation for thruster controls are also presented. It would have been useful to indicate the strategies used in ADACS systems to switch between different control modes.

The control and estimation theory described in Chapter 8 represents another useful feature of this book. Frequency domain linear control design methods and state space approaches are concisely but very clearly presented. This chapter also includes a useful section on linear optimal control using linear quadratic regulation (LQR) and explains the strengths and limitations of the approach. Robust control is also presented, including the fundamentals of sensitivity, robust stability, as well as the optimisation based $H$-infinity problems and their solution in the presence of constrained disturbance. Another interesting feature of the book is the discussion of nonlinear control methods, including exact feedback linearisation, Lypapunov design and sliding mode control. The estimation theory behind Kalman filtering is presented together with a clear description
of the Kalman filter algorithm, which remains the most commonly used attitude determination method. Two illustrative examples are provided, including an attitude determination application. Practical considerations in the control of flexible bodies such as notch filtering are briefly discussed. The generation of optimal profiles for time optimal retargeting is also presented using a conventional Euler-Lagrange approach.

The Integration, test and verification of ADACS systems is briefly described in Chapter 9. It would have been useful to discuss the failure modes and consequences more in detail because of the increased interest in recent years for fail safe system design.

In conclusion, the book is a good and useful resource for engineers and graduate students wishing to develop a broad understanding of spacecraft dynamics and control, as well as payload pointing in the context of Earth observation applications. Without the need to keep the length down, certain practical aspects of ADACS could have been described in more detail, particularly image coverage, motion compensation to improve image quality, the implications of satellite orbit design. It would have been nice to provide examples of overall ADACS architectures for specific space missions illustrating the control modes used throughout the mission and the transitioning between them.

This book fills a gap in the existing literature on spacecraft dynamics and control, where payload pointing is rarely discussed at this level of detail. The book also provides a very welcome description of advanced nonlinear, optimal and robust control and estimation theory and an interesting introduction to Lie Group kinematics, in the context of spacecraft control.

Dr Nadjim Horri  
Senior Lecturer in Aerospace Engineering  
Coventry University

Progress in Aeronautics and Astronautics (Volume 246)

P. Zarchan and H. Musoff  
American Institute of Aeronautics and Astronautics, 1801 Alexander Bell Drive, Suite 500, Reston, VA 20191-4344, US. 2015. Distributed by Transatlantic Publishers Group, 97 Greenham Road London N10 1LN, UK. 876pp. Illustrated £112. (20% discount available to RAeS members on request; email: mark.chaloner@tpgltd.co.uk Tel: 020 8815 5994).

Kalman filtering is important in many modern engineering endeavours including integrated navigation and data fusion. This textbook takes a logical approach to describing this field. The book is not a rigorous academic tome but instead uses practical examples and a cookbook style of presentation including computer code to lead the reader from the basic concepts through to some of the most modern methods. There is an emphasis on the reader trying the examples and through guided experience gaining an understanding of the art of Kalman filtering. The examples are taken from
projectile and vehicle navigation, including the ubiquitous subject of satellite navigation (GPS).

The book is interesting even to a seasoned Kalman filter designer and it covers many interesting topics that are often missed from other textbooks; it presents many alternatives to a conventional Kalman filter and emphasises the importance of simulation. Furthermore, it acknowledges and discusses the realities of engineering life where there are approximations, unknowns and the like in the problem definition.

As with all books, there are gaps in the material covered. The most important limitation is in the discussions of filter divergence and stability: the standard Kalman filter equations are conditionally unstable and no mention is made of the numerous superior alternative formulations including the large class of Square Root algorithms (U-D, SRIF, Potter, etc.).

I have had the pleasure of reviewing all four editions of this book over the past decade and more. Each update has added new content on the cutting edge of Kalman filtering design. This edition is no exception. There are new chapters on State Dependent Riccati Equation (SDRE) technique, Unscented Kalman Filter (UKF) and the Interactive Multiple Method (IMM) model. Some of the Third edition content has been removed but it may be found along with example computer code as an online resource which, having bought the book, you are given access to at the American Institute of Aeronautics and Astronautics (AIAA) website.

In summary, this is a good practical introduction to Kalman filtering and may be useful as a reference to experts.

**Dr Geoff Henderson BSc, MEng, PhD, CEng, MIEE**

**Quieting the Boom: the Shaped Sonic Boom Demonstrator and the Quest for Quiet Supersonic Flight. NASA SP-2013-601. NASA Aeronautics Book Series**

**L. R. Benson**


On 27 August 2003 a small supersonic jet took off from Air Force Plant 42 in Palmdale, USA. With an odd bulge beneath its chin, the aircraft looked more akin to a pelican than to the Northrop F-5E Tiger II on which it was based. Followed by a standard F-5E, the peculiarly-shaped aircraft set off for a series of supersonic flights over an array of pressure sensors and microphones laid out in the California desert. The F-5 Shaped Sonic Boom Demonstrator (SSBD) would go on to prove that, by careful shaping of the airframe, it is possible to reduce the strength of sonic booms.
The experiment represented the culmination of four decades of research aimed at mitigating the strength of sonic booms. This book presents us with a history of that work and the story of the SSBD aircraft. As the author tells us in his preface, it ‘is intended to be a general history of sonic boom research, emphasising the people and organisations that have contributed, and not a technical study of the science and engineering involved’.

After a short and breezy introduction, Chapter 1 provides a brief history of the early years of supersonic flight, early plans for an American Supersonic Transport (SST) aircraft, the rising public opposition to sonic booms, and early tests evaluating the impact of sonic booms. Chapter 2 takes us through the technical advances that the SST program engendered, the experimental and analytical studies, and the test facilities developed, before telling us how growing public hostility to sonic booms, alongside other technical, operational and economic hurdles, resulted in the cancellation of the SST programme.

The continuing, though reduced, research effort in the decade after the end of the SST programme is discussed in Chapter 3, including the introduction of Computational Fluid Dynamics (CFD), until in 1981, external economic factors forced NASA to cancel Supersonic Cruise Research. In Chapter 4 we hear about the revival of supersonic research in the mid-1980s in the form of the High-Speed Civil Transport (HSCT), the impact of the ‘CFD revolution’, and further flight tests and acceptability studies. Unfortunately, one outcome of these studies was the conclusion that the public would not accept supersonic flight over land, and so the HSCT programme was refocussed on supersonic flight only over water and sonic boom research was once again scaled back.

Chapter 5 relates how the concept of the Supersonic Business Jet revived interest in sonic boom research, until in 2001 the Defence Advanced Research Projects Agency (DARPA) picked up the gauntlet with its Quiet Supersonic Platform (QSP). The QSP sponsored industrial conceptual studies as well as academic work, and also spawned the Shaped Sonic Boom Demonstrator, which was awarded to Northrop Grumman. Chapters 6 and 7 take us through the SSBD project and the design and manufacture of the Shaped Sonic Boom Demonstrator vehicle. The initial SSBD flight tests are described in Chapter 8, along with the NASA-sponsored follow-on Shaped Sonic Boom Experiment which built on the lessons learnt during the first set of tests. Finally, Chapter 9 takes us through developments following SSBD and looks at plans for the future.

The SSBD represents a significant milestone in the journey towards the next supersonic civilian aircraft, whether business jet or transport, and for those who are interested this book provides us with a good record of the work leading up that demonstration. It is a very US-centric – even Concorde barely merits a mention – but given the focus on work leading to the SSBD this can be forgiven. Although it does not cover technical aspects in detail, the very comprehensive lists of sources provide plenty of scope for further investigation.

This book is perhaps also of interest to those curious about the research and development process, at least in the manner in which it often occurs in the aerospace industry. It illustrates well, for example, how political, economic or environmental pressures both engender and disrupt the development of new technology; how fundamental research, computational and experimental facilities underpin the development process; and the often surprising amount of effort required to prepare for and execute a
flight demonstration test. It is, at times, a little dry, and fails perhaps to capture the excitement that often accompanies significant advances in understanding, and which must have been felt on the completion of the flight tests. But nevertheless it makes interesting reading.

Craig J. Mead, CEng, MRAeS
Aero Acoustics Ltd