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A Literature Survey

on

The Gyroscope and its Applications

by

Dr-Ing Helmut Sorg

NORTH ATLANTIC TREATY ORGANIZATION

AGARD Report 582

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ADVISORY GROUP FOR AEROSPACE RESEARCH AND DEVELOPMENT

(ORGANISATION DU TRAITE DE L'ATLANTIQUE NORD)

A Literature Survey on THE GYROSCOPE AND ITS APPLICATIONS

December 1970

by

Dr.-Ing Helmut Sorg

Institut A fur Mechanik, Universität Stuttgart

Report listing books in the field of gyroscopes prepared for the Guidance and Control Panel of AGARD

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AGARD Report 582 North Atlantic Treaty Organization, Advisory Group for Aerospace Research and Development THE GYROSCOPE AND ITS APPLICATIONS Dr.-Ing Helmut Sorg Published February 1971 20 pages The report is a consolidated listing of all known unclassified texts on the subject of the gyroscope and its application, which are readily available to scientists and engineers from commercial sources, documentation centers and public as well as corporate libraries. Each entry cites the author, publication year, title, documentation center source and a brief abstract of the work.	53.082.16	AGARD Report 582 North Atlantic Treaty Organization, Advisory Group for Aerospace Research and Development THE GYROSCOPE AND ITS APPLICATIONS Dr.-Ing Helmut Sorg Published February 1971 20 pages The report is a consolidated listing of all known unclassified texts on the subject of the gyroscope and its application, which are readily available to scientists and engineers from commercial sources, documentation centers and public as well as corporate libraries. Each entry cites the author, publication year, title, documentation center source and a brief abstract of the work.	53.082.16
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FOREWORD

In the last decade many books about gyroscopes and their applications have been published. The purpose of this report is to offer engineers and scientists a listing of books which are readily available from commercial sources, as well as from various documentation centers and libraries. Only books which were unclassified and unrestricted were considered for this bibliographical listing. This list is a comprehensive tabulation of works by engineers and scientists in the various NATO nations. It also includes some Russian texts on the subject, many of which have been translated into English.

It is believed that this list will contribute to broaden the knowledge and prevent a duplication of research in the field of gyroscopes.

C.T.Leondes
Professor

ABBREVIATIONS

Appl. Mech. Rev.	Applied Mechanics Reviews The American Society of Mechanical Engineers United Engineering Center, New York, N.Y., 10017
CFSTI	Clearing House for Federal Scientific and Technical Information US Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22151
Eng. Ind.	The Engineering Index Engineering Index, Inc. 345 East 47th Street, New York, N.Y., 10017
IAA	International Aerospace Abstracts Technical Information Service, American Institute of Aeronautics and Astronautics, Phillipsburg, N.J.
STAR	Scientific and Technical Aerospace Reports National Aeronautics and Space Administration Superintendent of Documents, United States Government Printing Office, Washington D.C. 20402
ZfM	Zentralblatt für Mathematik und ihre Grenzgebiete Springer Verlag, Berlin-Heidelberg-New York.

AGARD – Conference Proceedings No.43. **Inertial Navigation – Systems and Components.** 1968, 579 p. Available from CFSTI.

Proceedings of AGARD-Symposia held in Oxford (UK) and Braunschweig (Germany). Thirty papers cover the broad area of inertial navigation, presenting research and new developments in the fields of components, systems and applications.

ANDERSON, E.W. **The Principles of Navigation.** New York, American Elsevier Publishing Co., 1966, 653 p.

This text is an overall review of navigation and is an attempt to contribute to the exchange of ideas between the navigator, scientist, and engineer by delineating the discipline as a whole so that each problem can be viewed against a wider background, and by suggesting a common language appropriate to the study of navigation. Land, sea, air, and space navigation are seen as parallel developments which may learn much from each other. Such aspects of instrumentation as control, heading, and speed are discussed, and the course, dead reckoning, and the route are considered. Basic aids including position finding, general and visual aids, and astronavigation are analyzed. Radio and radio bearings, radio distance measurement, and radar and sonar are studied.

IAA 1966

ANDREEV, V.D. **Theory of Inertial Navigation – Autonomous Systems.** Moscow, Izdatel'stvo Nauka, 1966., 580 p. In Russian.

This book contains a rigorous and systematic treatment of the theoretical foundations of the performance of inertial navigation systems, without a priori simplifications and restrictions. The methods of analysis employed are based on the ideas of Ishlinskii. Particular attention is given to the equations of the unperturbed operation of an inertial system and to the equations defining the error of an inertial navigation system. An analysis of these equations leads to operational stability estimates and expressions relating the error of the elements and the accuracy of the determination of the navigational parameters of a system. Problems associated with the autonomous operational adjustment of an inertial system are examined.

IAA 1967

ANDREEV, V.D. **Theory of Inertial Navigation – Aided Systems.** English translation of the Russian edition (1967, 424 p.) Available from CFSTI No.TT-69-55027.

The general aspects of the application of external guidance information, and the theory of inertial systems where an altimeter provides additional information on the distance of the moving object from the earth's surface are considered. Tuned gyropendulum systems and various gyroscopic instruments are discussed with emphasis on the dynamic analogy between the Schuler-tuned gyropendulum systems and the two accelerometer inertial guidance systems. Astronomical correction procedures, whereby telescopes are used to fix directions to certain stars, are presented. The dynamics of autonomous and aided inertial systems with random errors are analyzed as functions of the statistical characteristics of the navigation instruments errors.

STAR 1970

ARNOLD, R.N., MAUNDER, L. **Gyrodynamics and its Engineering Applications.** New York, Academic Press Inc., 1961, 484 p.

Interest in gyrodynamics is growing at an accelerated pace as shown by the overwhelming flood of technical literature concerned with rocketry, missiles, guidance and control systems. Much of this material is so specialized that it is difficult to relate it, on the one hand, to the basic dynamics from which it is derived and, on the other hand, to the overall purpose of the system of which it may describe but a single component. To fill these voids is the function of a textbook. Arnold and Maunder have performed this task with clarity, completeness and rigor.

Appl. Mech. Rev. 1962

AUTONETICS, Anaheim, Calif. **Application of Gyrocompassing to Space Missions.** Technical Report. N 66-19641 in STAR 1966, 481 p.

Gyrocompassing in general, including both the situations under which it is used and the instrumentation utilized, is considered. Uses are operation at a fixed site on the earth or other planet, and in a moving vehicle on the surface or in free orbital flight. The techniques are classified broadly into two groups: measurement gyrocompassing for determining direct rotation and direction of local vertical, and indirect gyrocompassing utilizing stable inertial platforms. The applications and instrumentations discussed in detail are: sensors, including gyroscopes, accelerometers, horizon sensors, and optical telescopes; indirect gyrocompassing on fixed sight on earth, using gyroscopes only to stabilize the platform; direct terrestrial gyrocompassing for prelaunch alignment of accelerometers and gyroscopes for space probes; gyrocompassing at fixed location on other planets; indirect gyrocompassing involving techniques for the orbital gyrocompassing alignment of a

gimballed locally level platform; and mechanization techniques for measurement gyrocompassing in orbit. Included also are tables and discussions of errors.

STAR 1966

BABAYEVA, N.F., YEROFEYEV, V.M. **Components and Elements of Gyroscopic Instruments.** English translation of page 1-306 of the Russian edition, 575 p. Available from CFSTI, No.AD-650616.

Problems in the design and planning of standard components and elements for gyromotors, suspensions, gimbals, power transmission devices, erecting and caging devices, gyroscopic servosystems, and pickoffs are considered. The book is intended for engineers in the instrumentation industry and as a study aid for students in Soviet instrument-design institutes.

STAR 1967

BODDE, T. **Gyroscope, its Laws and Mysteries.** Tientsin-Peiping (China), Peiyang Press. 1933, 23 p.

Brief non-mathematical explanation of laws of gyroscope comes from Peiyang University, and is intended to provide understanding of principles of gyroscopic action which will enable students to follow practical applications with understanding.

Eng. Ind. 1933

BOGDANOVICH, N.M., IL'IN, P.A. **Gyroscopic Instruments and Systems. Basic Theory.** Leningrad. 1961, 360 p. In Russian.

The work contains the descriptions and equations for the most important gyroscopic instruments – directional gyro, gyrocompasses, gyro-horizons, SDF-gyros, twin-gyro stabilizer, gyros for the determination of the geographical latitude and navigation systems.

ZfM 98/2

BRASLAWSKII, O.A., LOGUNOV, S.S., PEL'POR, D.S. **Aircraft Instruments.** Moscow, Izdatel'stvo Mashinostroenie, 1964, 740 p. In Russian.

This book discusses the theory and design of aircraft instruments, autopilots, and gyroscopes used on modern aircraft. Part I gives a classification of aircraft instruments and examines their operational environment as well as the methods used to calculate the static and dynamic characteristics and to assess the systematic error of aircraft instruments. A review of ac and dc telemetering systems is also given. Part II examines mechanical and electromechanical manometers; electric pressure-measuring techniques; mechanical, electrical, and thermoelectrical thermometers; various types of fuel meters; centrifugal, magnetic, and electric (ac and dc) tachometers; barometric and radar altimeters; manometric air speed indicators, true air-speed indicators, machmeters, and cruising-speed indicators; manometric variometers and other methods of measuring vertical velocity; airspeed-altitude computers; compensating and integrating accelerometers; and the magnetic flux-gate, distant-reading, and astro compasses. Part III deals with the theory of gyroscopes and discusses the gimbal-suspension gyro, differentiating and integrating gyros, including turn indicators, angular velocity indicators, rate gyros, and three-degree-of-freedom (free) differentiating and integrating systems; vertical, compass-controlled, and directional gyros, direct and indirect autopilots, and autopilots with transverse and longitudinal stabilization. The book is designed essentially as a textbook for students but should also be useful to engineers and technicians working in the field.

IAA 1965

BROZGUL, L.J., SMIRNOV, Ye.L. **Vibratory Gyroscopes.** Mashinostrojenije, Moscow, 1970, 214 p.

The authors discuss mathematically and in detail rotary-drive and vibratory-drive, vibratory-output gyroscopes.

BROXMEYER, C. **Inertial Navigation Systems.** New York, McGraw-Hill Book Co., 1964, 254 p.

The volume by Broxmeyer is concerned with navigation rather than the general problem of guidance in that he has not considered the problem of motion along three-degree-of-freedom paths; rather he has concentrated on two-degree-of-freedom motion along paths that remain on surfaces over which the earth's field is essentially constant. Applications are to submarines, ships and aircraft. The book begins with an exposition of inertial frames of reference and physical elements employed in inertial navigation, namely accelerometers, stable tables and gyroscopes. With the aid of matrix algebra, equations to be mechanized by an inertial navigation system are developed. The effect of the shape of the earth on the gravitational field is explained.

The characteristics of integrating, rate, cryogenic and electric vacuum gyros, single– and three-degree-of-freedom stable tables, and pendulous accelerometers are covered with the aid of suitable coordinate systems.

The results are applied to several complete inertial-navigation-system designs. The remainder of the volume is devoted to linear error analysis, the effect of damping on navigation error and the design of damping equalizers, and the uses of general purpose digital computers for studying nonlinear system performance.

In the opinion of the reviewer this volume eminently satisfies the need of the guidance community for an up-to-date exposition of the state of the art.

App. Mech. Rev. 1965

BULGAKOV, B. **Applied Theory of Gyroscopes.** English translation by J.Schorr/Kon. Available from CFSTI No.TT 60-21166.

1. The gyroscopic pendulum
2. Foucaults gyroscopes
3. Applications of the astatic gyroscope
4. Gyrocompasses
5. Direct gyroscopic stabilizer
6. The general theory based on exact equations.

BULOVSKII, P.I., IDEL'SON, E.M. **Testing of Aircraft Instruments.** English translation of the Russian edition (1966, 352 p.) Available from CFSTI, No.AD-702973.

This book discusses the foundations and test methods of aircraft instruments, with particular reference to navigation instruments (pilot-static tube, accelerometers, astronomical compass), aircraft engines, gyroscopic instruments, and individual subsystems and components. The design and schematic diagrams of the various items of test equipment are examined, together with the methods used to test and to adjust them. The characteristic features of standard test procedures are reviewed. The book should be of interest to engineers employed in designing and manufacturing aircraft instruments.

IAA 1966

BURGER, W., CORBET, A.G. **Marine Gyro-Compasses and Automatic Pilots.** Pergamon Press – The Macmillan Company, New York, 1964.

Vol. I: Gyrocompasses, 202 p.
Vol. II: Automatic Pilots, 209 p.

CAMPBELL, R.W. **Tops and Gyroscopes.** Crowell Company, New York, 1959, 161 p.

An interesting non-mathematical treatment of the gyroscope and its applications.

CARPENTIER, J. **Navigation par Inertie.** Dunod, Paris, 1962, 291 p. In French.

Part I: Inertial navigation on board of ballistic missiles.
Part II: Inertial navigation on board of aircraft.
Part III: Gyroscopes and accelerometers.

CENTRE NATIONAL D'ETUDES SPATIALES. **The Mechanical Gyroscopes.** (Les Gyroscopes mécaniques) Part I and II. Imprimerie Nationale, Paris, 1964, 192 and 153 p. In French.

12 (Part I) and 11 (Part II) articles presented at the "Semaine d'études sur les gyroscopes mécaniques", organized by the French Centre National d'Etudes Spatiales. The authors are American, British, French and German scientists.

CHALMERS, T.W. **The Gyroscopic Compass.** Constable Co. Ltd., London, 1920, 163 p.

A non-mathematical treatment of the gyro compass with descriptions of the Sperry, Brown and Anschütz compass.

COCHIN, I. **Analysis and Design of the Gyroscope for Inertial Guidance.** John Wiley and Sons, New York, 1963, 150 p.

Review of elementary dynamics – Fundamentals of the gyroscope – Elementary gyrodynamics – Suspension schemes for the rotary gyroscope – Fundamentals of gyroscopic drift – Fundamentals of gyroscopic drift testing – Test equipment and facilities.

COULTHARD, W. **Aircraft Instrument Design.** Pitman, London, 1952.

CRABTREE, H. **Spinning Tops and Gyroscopic Motion.** Chelsea Publishing Company, New York, 1967, 186 p. Reprint of the second edition of 1923.

An attempt to present an elementary, and at the same time a scientific view of the subject.

DANILIN, V.P. **Gyroscopic Instruments.** Moscow 1965, 528 p. In Russian.

DAVIDSON, M. **Gyroscope and its Application.** Hutchinsons Scientific and Technical Publications, London and New York, 1946, 256 p.

General theory – Marine applications – Aeronautical applications.

DEIMEL, R.F. **Mechanics of the Gyroscope.** Macmillan Co., New York, 1929, 192 p. Dover publication, New York, 1950.

Comprehensive discussion of dynamics of rotation, intended for engineers; physical and mathematical principles are briefly reviewed in three introductory chapters, after which seven chapters are devoted to rotational phenomena and behavior of typical gyroscopic apparatus, such as compasses and stabilizers; physical, rather than structural features are emphasized.

Eng. Ind. 1929

DOBRONRAVOV, O.E., KIRILENKO, Iu.L. **Principles of Automatic Control, Automatic Equipment and Control Systems of Aircraft, Vol.1 and 2.** English translation of the Russian edition (1965, 453 p.) Available from CFSTI No.AD-683017, Vol.1 and AD-682813, Vol.2.

Vol.1: The theoretical principles of automatic control for linear and nonlinear systems are discussed and their functional and dynamic elements described. The fundamentals of the theory of gyroscopes, autopilots, and flight vehicle power plant control systems are reviewed. Brief data on guidance systems, radio remote control, and preset guidance is given. Volume I contains sections on: Elements of automatic control and regulating systems of flight vehicles; Fundamentals of theory of automatic control systems (first part).

Vol.2: The volume contains sections on: Fundamentals of the theory of automatic control systems (second part); Automatic flight control devices and propulsion systems regulators; Systems for automatic control of an aircraft along a given trajectory.

STAR 1969

DRAPER, C.S., WRIGLEY, W., GROHE, L.R. **The Floating Integrating Gyro and its Application to Geometrical Stabilisation Problems on Moving Bases.** Institute of the Aeronautical Sciences, New York, 1955, 99 p.

A comprehensive presentation of the MIT-Single-Degree-of-Freedom-Gyro.

DRAPER, C.S., WRIGLEY, W., HOVORKA, J. **Inertial Guidance.** Pergamon Press, New York, 1960, 130 p.

This volume is an exposition by leaders in the field. It treats basic principles of guidance. It is not a text on the mathematics of the subject. It treats the history of the field, role in navigation, guidance system configurations, force tracking, Schuler tuning, gyros and accelerometers. The volume closes with a discussion of applications of inertial components, i.e. gyros, accelerometers, gimbals and computers, to geophysical and astronomical problems. In the opinion of the reviewer this superbly written monograph will give both the layman and expert a broad picture of the principles and devices that have played such an important role in the development of missiles and satellites.

App. Mech. Rev. 1962

DUDA, Th. **Aircraft Instruments** (Flugzeuggeräte, I and II). VEB-Verlag Technik, Berlin, 1959 and 1961, Vol.I 306 p., Vol.II 218 p. In German.

Two books for the engineer working in the field of aircraft equipment, but also for students. In Vol.I we find the basic design of artificial horizons and rate gyros, their equations and errors. Vol.II contains a comprehensive presentation of directional gyros, gyromagnetic compasses and instruments for inertial navigation.

EFIMOV, M.V. **Ballistic Missile Aiming Systems.** English translation of the Russian edition (1970, 131 p.) Available from CFSTI, No.AD-704219.

The book is intended for soldiers, sergeants, and students in military schools, as well as for the general reader interested in missile technology. On the basis of Soviet and foreign sources the author gives an analysis of the aiming of ballistic missiles with the use of external as well as onboard information. Also presented is a discussion of gyroscopic units, tracking systems, and other information on the aiming of ballistic missiles. There is a bibliography of 14 titles.

STAR 1970

FERNANDEZ, M., MACOMBER, G.R. **Inertial Guidance Engineering.** Prentice-Hall Inc., Englewood Cliffs, N.J., 1962, 530 p.

This book is intended to be a reference source for the subject of inertial guidance. The volume treats basic guidance principles, inertial navigation, gyroscopes and gyro-stabilized platforms, accelerometers, inertial systems, inertial navigating system configurations, steering, errors in inertial and inertial navigation systems, aids for reducing errors and the problems of navigation and guidance on space missions. Engineering as well as mathematical properties of physical components are presented in detail. In the opinion of the reviewer this book is superbly well suited to the needs of the average space control engineer and gives him the tools he needs to go from fundamental principles to actual hardware applications.

App. Mech. Rev. 1963

FERRY, E.S. **Applied Gyrodynamics.** John Wiley and Sons, New York, 1932, 277 p.

Purpose of work is to bring gyrodynamics out from behind integral signs and to present it to acquaintance of engineers and students having mathematical equipment of ordinary graduate of engineering or physics; it develops laws underlying gyroscopic devices used in industry; numerous problems illustrate practical use of equations derived from laws.

Eng. Ind. 1932

FRIDLENDER, G.O. **Inertial Navigation Systems.** English translation of the Russian edition (1963, 236 p.) Available from: Joint Publications Research Service, Building Tempo E, East Adams Drive, Washington D.C. 20443.

This report examines the principles which are the basis for inertial systems, possible errors in systems of this kind, and briefly elucidates the operation of inertial systems in a closed circuit which includes the inertial system – autopilot – winged aircraft. The problem of special features in the application of inertial systems to future controlled interplanetary flight is also investigated.

STAR 1964

FRIDLENDER, G.O., KOZLOV, M.S. **Aircraft Gyroscopes** (Selected Parts). English translation of p.175-197, 243-377 of the Russian edition (1961). Available from CFSTI No.AD-413521.

Aviation directional gyroscope – High-speed gyroscopes – Integrating gyroscopes – Gyroscopic power systems – Gyroscopic systems unperturbed by inertia.

STAR 1964

FROLOV, V.S. **Inertial Navigational Systems.** English translation of the Russian edition (1963, p.1-126). Available from CFSTI No.AD-607853.

This paper discusses operation conditions, interaction of separate units, and causes of error in inertial guidance and navigational systems. Considerable attention is given to analysis of the operation of inertial systems under conditions of spaceflight and to their use in the single navigational complex of an aircraft.

STAR 1965

GORENSHTEYN, I.A., SCHUL'MAN, I.A., SAFARYAN, A.S. **Inertial Navigation.** English translation of the Russian edition (1963, p.1-244). Available from CFSTI No.AD-432079.

This book covers the following: (1) theoretical basis of inertial navigation (with an error analysis); (2) methods of designing inertial navigation systems; (3) methods of readying inertial navigation systems for operation; (4) methods of correcting these systems; (5) elements of inertial navigation systems – accelerometers, gyros, computing devices, and other components of the systems.

STAR 1964

GRAMMEL, R. **The Gyroscope; its Theory and Applications, Vol.I and II.** Springer Verlag, Berlin, 1950, 281 p. and 268 p. In German.

These two volumes appear to be a revision of a similar work by the same author published before World War II. As a result of author's teaching experience in German colleges and the revision process, these books present a thorough treatment of gyroscopic theory and a great number of good applications. The line-drawing illustrations are numerous and very clear. An appendix to the volume on theory gives a treatment of gyroscopic motion by theta functions.

The shortcomings of the work lie in omissions. If the books are to be used in the classroom or for self-education, there is a lack of illustrative numerical examples and problems. If they are to be used as references for practicing engineers they need more material on gyroscopes as parts of servomechanisms and on modern applications of gyroscopes in controlling and stabilizing vehicles of the aircraft type. For example, only one paragraph is given specifically to the application of gyroscopic theory to helicopters.

App. Mech. Rev. 1951

GARY, A. **A Treatise on Gyrostatics and Rotational Motion, Theory and Applications.** Dover Publications, Inc., New York, 1959, 530 p.

This new Dover edition is an unabridged and unaltered publication of the work first published in 1918.

GREEN, M.C. **Proceedings of the AFMDC Inertial Guidance Test Symposium, Volume I, Holloman Air Force Base, 1962.** Air Force Missile Development Center, Holloman AFB, New Mexico.

Precision indexing of an accelerometer to facilitate the measurement of higher-order nonlinearities.
Simplification of inertial component test equipment.
Central Inertial Guidance Test Facility laboratory standardization efforts.
Accelerometer error coefficient derived from track tests.
Testing of stellar inertial guidance systems.
A long hard look at guidance system testing programs.
Band concept versus statistical method in inertial guidance testing.
The space-time measuring system of the Holloman track.
Evolution of the VATE system.
Guidance system evaluation using the guidance evaluation missile.
Inertial guidance equipment testing on the MIT Precision Centrifuge with comparison sled testing.

STAR 1963

GREENHILL, G. **Gyroscopic Theory.** Chelsea Publishing Company, New York, 1966, 275 p.

This is a reprint of the first edition with the title "Report on Gyroscopic Theory", London 1914.

INSTITUTION OF MECHANICAL ENGINEERS. **Gyros.** The Institution of Mechanical Engineers, Proceedings 1964-65, Volume 179, Part 3E, 200 p.

A symposium arranged by the Automatic Control Group.

Contents:
An introduction to the gyroscope: a historic instrument.
Recent development in gyrodynamics.
Aerodynamic gas spin axis bearings for gyros.
A survey of low-torque gyroscope gimbal suspensions.
Consideration of precision gyro designs using symmetrical rotors, including a discussion of floatation fluids.
Testing of inertial quality gyroscopes.
Rotor ball bearings for precision gyroscopes.
Measurement and generation of truly circular form.
Miniature rate gyroscopes.
Rotorace gyros.
Development of a cordite-driven gyroscope.
Development of an accurate tuning-fork gyroscope.
A gyroscope for satellite damping.
The Arma-Brown two-axis floated gyro.
The Sperry Mark 19 gyro-compass.
Gyroscopic techniques as applied to shipborne stabilizers and inertial navigation.

ISHLINSKII, A.Yu. **Mechanics of Gyroscopic Systems.** English translation of the Russian edition (1965, 316 p.) Oldbourne Press, 1-5 Portpool Lane, London, E.C.1.

A wide range of problems in mechanics connected with the practical application of gyroscopes are discussed. The solutions of geometric problems of the kinematics of gimbal systems; and of geometric problems connected with the accuracy of orientation of gyro-controlled objects are considered. Also considered are phenomena connected with the elasticity of gyro-system elements; methods for establishing equations of motion of gyroscopic systems; nonlinear behaviour of forces acting on gyroscopic systems; and various other gyroscopic problems. In addition, the equations of motion for determining the position of an object moving arbitrarily on the earth, and the theory of complex gyroscopic stabilization systems are given.

STAR 1966

JOHNSON, V.E. **The Gyroscope.** E. & F.N. Spon Ltd., London, 1915, 52 p.

An experimental study from the spinning top to the mono-rail.

KASHEVAROV, Yu.B. **Gyroscopic Orientation.** English translation of the Russian edition, (1964, p.1-77) Available from CFSTI No.AD-663622.

Contents: Peculiarities of topographic preparation of contemporary artillery and rockets; Short history of the development of gyro-instruments; Basic information from mechanics, necessary for studying the elementary theory of gyroscope; Gyrocourse indicator and its use for topographic surveying (basic rules of motion of a gyroscope; precession of gyrocourse indicator; losses of gyroscope stability; basic peculiarities of the design of a gyrocourse indicator, emanating from an analysis of accuracy of its work; basic peculiarities of the use of gyrocourse indicator; use of the gyrocourse indicator for topographic surveying of rockets and artillery); The gyrocompass and its use for topographical surveying (principles of layout and work of a gyroscopic compass; peculiarities of design and use of pendular gyrocompass designed for a topographic works; recommendation on reducing the time of orientation); Short description of the layout of Mine Surveyor Gyrocompass MG.

STAR 1968

KEARFOTT COMPANY INC. **Technical Information for the Engineer.** Kearfott Division, General Precision Inc., Little Falls, N.J., USA.

No.3: Gyros, Platforms, Accelerometers, 75 p.
No.4: Testing and Test Equipment, 44 p.

KLEIN, F., SOMMERFELD, A. **Theory of the Gyroscope.** Johnson Reprint Corporation, New York – B.G.Teubner, Stuttgart, 1965, 966 p. In German.

This is a reprint of the fundamental work about the theory of the gyroscope by F.Klein and A.Sommerfeld, first published in 1897.

KOSLOV, A.S. **Theory of the Gyroscopic Instruments for Air-Navigation.** Moskow, 1956, 252 p. In Russian.

KOVALEV, M.P., MORSHAKOV, S.P., TEREKHOVA, K.S. **Dynamic and Static Balancing of Gyroscopic Devices.** English translation of the Russian edition (1965, 304 p.) Available from CFSTI No.AD-677162.

The book presents the theory of balancing rotating parts of machines and instruments demonstrating the dependence of precision of dynamic balancing upon the quality of the support. Also, it analyses basic causes of vibrations and methods of their elimination. Explanations are given of the principles of action of balancing machines and their elements, and practical recommendations on the technique of constructing and balancing them are given.

STAR 1969

KOVALEV, M.P., MORSHAKOV, S.P., TEREKHOVA, K.S. **Dynamic Balancing of Rotors of Gyroscopic Systems.** English translation of the Russian edition (1962, p.1-258.) Available from CFSTI No.AD-628504.

Principles are expounded of the theory and techniques of dynamic balancing of rotors of miniature gyromotors. There is description of latest balancing equipment, there is offered methodology for tuning balancing machines, and there is also given basic information on structure and techniques of assembling model supports of gyroscopic instruments and devices. It considers reasons for vibrations arising in gyro-instruments. Book is

intended for designers and technicians of instrument-making industry, engineering and technical workers occupied in design and operation of balancing instrumentation, and also may be used by students of instrument-making faculties of higher technical and middle specialized institutions.

STAR 1966

KRANENBORG, H.J. **A Survey of Gyroscopes and Accelerometers with Particular Attention to Modern Developments.** ELDO-Report. Available from CFSTI.

This report is a result of a literature study on gyroscopes and accelerometers especially regarding latest developments. Conventional and unconventional types of gyroscopes are dealt with which comprise pick off and torquer devices, and the drift causes and errors appearing in the described types are explained. Weight, performance data etc. are tabulated. Accelerometers, both direct type and force – balance instruments are described.

STAR 1968

KRYLOV, A.N., KRUTKOV, J.A. **General Theory of Gyroscopes and Some of their Engineering Applications.** Academia Nauk USSR, 1932, 394 p. In Russian.

Principles of rigid kinematics and dynamics; simple case of movement of solid of revolution; Foucault gyroscope and its modifications; gyroscope on movable foundations; use of gyroscope for stabilization; vector analysis of gyroscope theory; description of gyro compass, stabilizers and similar apparatus.

Eng. Ind. 1933

KUDREVICH, B.I. **Theory of Gyroscopic Instruments, Vol.I.** English translation of the Russian edition (1963, 328 p.) Available from CFSTI No.AD-611040.

A discussion is presented of some topics in general gyroscope theory, of the theory of vertical gyroscopes, and of gyrostabilization elements. Major sections of the work cover such areas as the basic equations used to study the gyroscope, the theory of undamped and damped vertical-gyroscope oscillations, the fundamentals of free-oscillation theory for compound gyroscopic pendulums, and directional gyroscopes. This paper is an unedited rough draft translation of the first volume of two on the subject.

STAR 1965

KUDREVICH, B.I. **Theory of Gyroscopic Instruments, Vol.II.** Leningrad, Gos. Soyuzn. Izd. Sudostroitel'noy Prom., 1965, 296 p. In Russian.

LEES, S. **Air, Space and Instruments, Draper Anniversary Volume.** McGraw-Hill Book Company, New York, 1963, 502 p.

This volume covers a variety of topics with the single thread of Draper's wide-ranging activities to connect them.

LEVINE, St.L. **Gyro Fundamentals.** John F.Rider Publisher Inc., New York, 1964, 117 p.

This book will teach the basic operation of gyroscopes, without mathematics, through the use of programed instruction. A series of brief, logically developed steps are presented, and when the student completes the last step, he will have a clear understanding of how a gyroscope operates. (Author)

It is no book for engineers or scientists, but it can be a good help to give the workers in gyro production an understanding of the gyro characteristics.

LUNTS, Ya.L. **Errors in Gyro Devices.** English translation of the Russian edition (1969, 272 p.) Available from CFSTI No.AD-693229.

The book is dedicated to the analysis of errors in gyroscopic instruments arising due to rocking of the support base and for other reasons resulting from oscillations of the sensing elements. Nonlinear effects are analyzed and described by equations of second approximation. In many cases, precise equations of movement of the gyroscopic instrument can be investigated. Errors such as shifts and zero drift are determined for various gyroscopic devices for regular and irregular rocking. In the latter case, external excitations are assumed to be random functions of time. The book is designed for engineering-technical and scientific workers, but also may be used as a text for senior students and post-graduate students specializing in the area of applied gyroscopy.

STAR 1970

MACHOVER, C. **Basics of Gyroscopes, Vol.I and II.** J.F.Rider Publisher Inc., New York, 1960, 98 and 109 p.

For non-specialists, students, technicians, engineers, salesmen and managers who come in contact with gyroscopes in their studies or work, a more descriptive and less mathematical presentation.

MACMILLAN, W.D. **Dynamics of Rigid Bodies.** Dover Publications Inc., New York, 1960, 478 p.

This new Dover edition is an unabridged and unaltered republication of the first edition published by the Mcgraw-Hill Book Company in 1936.

MAGNUS, K. **The Gyroscope.** Industrie-Druck GmbH, Göttingen, 1965, 120 p. In German.

A guide through the field of the gyroscope and its applications with a description of many experiments.

MAGNUS, K. **Gyroscopes, Theory and Applications.** (In German). Springer, Berlin, 1971. (In print, approx. 500 p.)

This book is intended for students, engineers and scientists. The first 8 chapters are devoted to the theory of the gyroscope, the following 8 chapters to its applications. Growing out of the author's outstanding lectures and research on this subject, a clear and well-written book can be expected.

MARKEY, W., HOVORKA, J. **The Mechanics of Inertial Position and Heading Indication.** John Wiley and Sons, New York, 1961, 94 p.

This little book informs the reader very well about principles of inertial navigation. Mathematical developments start at the point reached by graduate students in classical so-called "rational mechanics", and use Laplace transform and matrix techniques.

Some knowledge of analog computers also is required. Explanations are clear and well written; figures are well drawn. However, reviewer would have preferred the use of spherical trigonometry for presentation of angles in three-dimensional space.

Except for a single page at the end of the book, practically no performance is quoted nor are errors discussed. (Reviewer was expecting for instance the effect of double integration on errors coming from acceleration measurements.)

App. Mech. Rev. 1962

McCLURE, C.O. **Theory of Inertial Guidance.** Prentice-Hall Inc., Englewood Cliffs, N.J., 1960, 340 p.

The object of this book is to provide a self-contained introduction of the theory of inertial guidance. The book may be divided into three main sections. The first, an introduction, deals with elementary facts concerning the figure and motion of the Earth and with basic concepts of navigation. The second section, Chapters 2-6, is a development of rigid-body kinematics and kinetics, with special emphasis on gyroscopic motion. The third part, Chapters 7-10, treats guidance systems as such.

App. Mech. Rev. 1961

MERKIN, D.R. **Gyroscopic Systems.** Moscow, Gos. Izdat. Teckh. -Teor. Lit., 1956, 299 p. In Russian.

This monograph goes to the basis of the theory of gyroscopic systems as indicated by W.Thomson and P.Tait in their "Treatise on natural philosophy" (Cambridge, 1879). This conception treats, from a general viewpoint, the role of gyroscopic forces occurring in the equations of motion for mechanical systems with gyroscopes. One of the most important facts in studying such questions lies in the possibility of replacing the exact equations of gyroscopic systems by simpler relations in order to facilitate the solution of a problem. Nevertheless, such a simplification can be made only under special conditions and one has always to estimate the degree of resulting approximation. Book pays special attention to considerations of this kind.

App. Mech. Rev. 1957

MOLLOY, E., KNOTT, E.W. **Aeroplane Instruments, Pt.I.** Chemical Publishing Co., New York, 1940, 132 p.

Volume deals with operation and maintenance of Sperry gyropilot, Sperry aircraft instruments and Smith's aircraft instruments.

Eng. Ind. 1940

MOURRE, L. **Gyrocompass.** Paris 1953, 115 p. In French.

NIKITIN, E.A., a.o. **Designing Differentiating and Integrating Gyroscopes and Accelerometers.** English translation of the Russian edition (1969, 270 p.) Available from CFSTI No.AD-700605.

The book covers the fundamentals of analysis and designing of differentiating and integrating gyroscopes and accelerometers, and an analysis of their errors under different operating conditions is given. Simple calculation formulas for determination of the basic parameters of these instruments and also their instrumental and methodical errors are given. Depending upon the assignment of the instrument, requirements for static, dynamic and accuracy characteristics are shown. Much attention is given to the description of the physical essence and causes of appearance of the examined errors.

STAR 1970

NIKOLAI, E.L. **Theory of the Gyroscopes.** Moscow 1948, 171 p. In Russian.

NIKOLAI, E.L. **The Gyroscope and some of its Technical Applications.** Moscow 1947, 152 p. In Russian.

NIKOLAI, Y.L. **The Gyroscope in Gimbal Suspension.** English translation of the Russian edition (1964, 136 p.) Available from CFSTI No.AD-620837.

Contents: Differential equations of motion of a gyroscope in a gimbal mount: Stability of the axis of a rapidly spinning gyroscope; Pseudoregular precession of a gyroscope acted on by a constant moment; The case of constant friction at the gimbal axes. The representative point method; Elementary cases of gyroscope motion in the presence of friction at the gimbal axes; Small oscillations of a balanced gyroscope in the presence of friction at the gimbal axes; Pseudoregular precession of a gyroscope in the presence of friction at the gimbal axes; Motion of a gyroscope in the presence of friction forces proportional to the normal components of the dynamic reactions; Present state of the theory of the astatic gyroscope in a gimbal mount.

STAR 1966

O'DONNELL, C.F. **Inertial Navigation Analysis and Design.** McGraw-Hill Book Co., New York, 1963, 442 p.

Text on inertial navigation, covering system and component analysis, and basic hardware design. The text can be used by persons with a background in general engineering, physics, or applied mathematics. Some familiarity with circuit and servo-mechanism theory, Laplace transforms, and vector analysis is assumed. A survey of the principles of inertial navigation is first presented, which establishes the general characteristics and requirements of inertial navigation systems. Following the survey are descriptions and analysis of: (1) inertial and optical components; (2) inertial platforms, including design and stabilization techniques; (3) supporting subsystems; (4) mechanization and error analysis; (5) design of a high-precision inertial autonavigator for worldwide operation; (6) modified systems, including stellar reference systems, position reference, and velocity reference; and (7) ballistic guidance. The first inertial navigator used in a submarine crossing of the North Pole is described in detail to illustrate integrated system design. Cruise vehicle applications have been used for the initial examples and demonstrations of inertial navigation concepts. A large bibliography is included.

IAA 1964

O'HARA, W. **Mariner's Gyro-Navigation Manual.** Cornell Maritime Press, Cambridge, Maryland, 1951, 157 p.

This manual has been compiled for the purpose of guiding those mariners who are charged with the responsibility of operating and maintaining the gyroscopic compass equipment on shipboard.

OKUNEV, B.N. **Free Motion of a Gyroscope.** Moscow 1951, 379 p. In Russian.

OL'MAN, E.V., SOLOVJEV, Ja.I., TOKAREV, V.P. **Autopilots.** Moscow 1946, 471 p. In Russian.

PARVIN, R.H. **Inertial Navigation.** D. van Nostrand Company, Inc., New York, 1962, 352 p.

Chapters: Characteristics of inertial systems – Laplace Transformation – Transfer Functions – Closed Loop systems – Vectors, matrices and coordinate transformation – The gyro – The accelerometer – The Inertial Measuring Unit – The earth in inertial space – Basic system mechanization – Prelaunch trim and alignment – Classes of point systems – The computer – Space ballistics: Inertial frames in motion – Guidance equations.

PAVLOV, V.A. **Theory of the Gyroscope and Gyroscopic Instruments.** English translation of the Russian edition (1964, 495 p.) Available at CFSTI No.AD-649420.

The volume is designed as a textbook for students in higher technical institutes specializing in gyroscopic instrumentation. It sets forth applied gyroscope theory, the fundamentals of the theory of gyroscopic instruments used in stabilization and control systems for moving vehicles, and the working principles, design peculiarities and methodical and certain instrumental errors of single-rotor gyroscopic instruments. Considerable attention is devoted to explaining the physical essence of the gyroscopic phenomena. For a better understanding of the theoretical propositions, the book cites a large number of examples that will aid the reader in familiarizing himself with the subject on his own. Scientists, engineers and technicians concerned with gyroscopic devices will also find this book useful.

STAR 1967

PAVLOV, V.A. **The Gyroscopic Effect: Its Manifestations and Uses.** English translation of the Russian edition (1970, 178 p.) Available from CFSTI No.AD-701967.

The book is intended to familiarize the reader with the essentials of the gyroscopic effect observed in the spinning top; it discusses the manifestations of this effect in the natural world around us and in machines and weapons that we use, and deals with its uses in various branches of engineering.

STAR 1970

PEL'POR, D.S. **Gyroscopic Instruments and Autopilots.** Moscow 1964, 389 p. In Russian.

PEL'POR, D.S. **Theory of Gyroscopic Stabilizers.** Moscow, Izdatel'stvo Mashinostroenie, 1965, 348 p. In Russian.

This monograph examines the design principles of gyrostabilizers. An analysis is given of the errors arising in an astatic gyroscope in conditions of overloading, rolling, vibration, and when the rotor axis approaches the axis of the outer gimbal. A theory is developed for single-axis gyrostabilizers equivalent to an astatic gyro in which the rotor axis is stabilized in a direction normal to the plane of the outer gimbal. Some problems involved in the design of gyrostabilizers for use in automatic control systems are examined. The error of a single-axis gyrostabilizer is assessed for various operational environments. A theory is developed for two-axis and three-axis spatial gyrostabilizers, and their errors due to angular oscillations of an aircraft are assessed. The book should be of interest to both specialists and students.

IAA 1966

PERRY, J. **Spinning Tops and Gyroscopic Motion.** Dover Publications, New York, 1957, 102 p.

This report of an experimental lecture is a republication of the work originally published under the title Spinning Tops in 1919.

PETROV, V.P., SOCHIVKO, A.A. **Rocket Control.** English translation of the Russian edition (1963, p.1-204). Available from CFSTI No.AD-659661.

The book outlines the physical principles of rocket weapon control. Basic information from jet propulsion theory is given, and the most common rocket guidance systems described in the non-Soviet press are considered.

STAR 1968

PITMAN, G.R. **Inertial Guidance.** John Wiley and Sons, New York, 1962, 481 p.

Book is divided into three sections. The first and somewhat introductory section consisting of five chapters is concerned with inertial sensing instruments, stabilized platforms and computers. The second section, of four chapters, treats design and mechanizing problem for cruise vehicles including marine vessels. The third and last section, in five chapters, is devoted to guidance systems for rocket-propelled vehicles and space navigation. A unified and common analytical treatment is given in the first chapter for cruise vehicles and rocket systems, together with a very illuminating introduction. Each chapter is contributed by a specialist, and presented in compact and comprehensive form.

Reviewer believes the book is one of the most brilliant and inspiring texts treating wide-spread topics in the field.

App. Mech. Rev. 1962

POLIAKOV, N.I. **Technology and Design of Gyroscopic Instruments.** Moscow, Izdatel'stvo Mashinostroenie, 1964, 175 p. In Russian.

New trends in gyroscope development – Technological aspects of instrument design – Effect of technological factors on the precision in gyromotor assembling – Dynamic balancing of rotors used in instrument engineering – Moments generated by form errors of ball-bearing rolling surface – Determination of the maximum values of the gravitational drift and the drift due to irregular rigidity in integrating floated-type gyroscopes – Operation of an integrating floated-type gyroscope in the capacity of an angular-motion nonfollowup pickup. – Effect of power-supply parameters on the accuracy of angular-velocity pickups – Increasing the reliability and precision of gyro-instrumentations potentiometric pickups – Calculation procedure for contact brushes of potentiometric gyro-instruments – Method of increasing the precision and economy of part machining by machine adjustment.

IAA 1965

RADIX, J.Cl. **Inertial Navigation.** Paris, Presses Universitaires de France, 1967, 128 p. In French.

Discussion of inertial navigation, a process which seeks to determine the position of a vehicle in a continuous manner, automatically and as independently of the exterior of the vehicle as possible. The process consists of a systematic exploitation of the laws of rational mechanics, which were conceived to explain the motions of solid bodies. Basic principles are considered, followed by a discussion of gyroscopes, accelerometers, and platform stabilization. Attention is given to inertial control panels, Schuler panels, error evolution, and inertia-assisted control panels. Start-up methods are outlined, applications are described, and examples of inertial systems are cited. Some basic fundamentals of rational mechanics are summarized.

IAA 1967

RAWLINGS, A.L. **Theory of Gyroscopic Compass and its Deviations.** Macmillan Co., New York, 1944, 182 p.

Theory of this compass is presented and description of Sperry, Anschuetz, Arma and other models in use today are included.

Eng. Ind. 1944

RICHARDSON, K.I.T. **The Gyroscope Applied.** Hutchinson's Scientific and Technical Publications, 1954, 384 p.

Fundamentals – Marine applications – Aeronautical applications – Military applications – Other applications of the gyroscope.

RIVKIN, S.S. **The Theory of Gyroscopic Devices, Vol.1, Part 1 and 2.** English translation of the Russian edition (1962). Available from CFSTI No.AD-682103, Vol 1 and AD-682104, Vol.2.

The fundamentals of the applied theory of gyroscopes and gyroscopic devices (GD) based on the use of an astatic gyroscope with three degrees of freedom without correction and with a pendulum correction system. The methods used in applied gyroscopy and methods of automatic control theory are also used to determine the errors of the GD.

STAR 1969

RIVKIN, S.S. **Theory of Gyroscopic Devices, Vol.2.** English translation of the Russian edition (1964, 548 p.) Available from CFSTI No.AD-629424.

This book is the second part of a work on the theory of gyroscopic devices. In it the theory of active-type gyroscopic stabilizers, differentiating and integrating gyroscopes, gyroscopic navigational systems, and also certain questions of gyroscopic stabilization are considered. Basic attention is allotted to determination of dynamic errors in conditions of random controls and disturbances. The book is intended for engineering technical and scientific workers, studying questions of applied gyroscopy, and can serve as a training aid for students and post graduates, studying the theory of gyroscopic instruments.

STAR 1966

ROITENBERG, Ia.N. **Gyroscopes.** Moscow, Izdatel'stvo Nauka, 1966, 399 p. In Russian.

This monograph is an exposition of the theory of gyroscopic instruments and devices installed in moving objects such as ships and aircraft. Particular attention is devoted to ascertaining the conditions of operating capability of the gyroscopic systems under consideration, determining their accuracy under real operating conditions, and finding ways of synthesizing the most rational circuits of gyroscopic devices and selecting

their dynamic characteristics. The first chapter is devoted to vertical gyroscopes. It is pointed out that by the use of a multigyroscope system rather than a single gyroscope the input of corrections during maneuvering of the vessel is no longer necessary, and by proper selection of the parameters a high degree of accuracy of the instrument can be obtained during rolling as well as during maneuvering. Motions and errors of gyrocompasses, as well as methods of correcting their errors, are the subject of the second chapter. The third and final chapter of the book is devoted to the theory of single-axis powered gyrostabilizers, direct gyrostabilizers, and powered gyro horizons. Only electromechanical gyroscopes are discussed. A brief bibliography and subject index are included.

IAA 1966

ROPARS, J. **The Gyroscopic Compass.** Editions Maritimes et d'Outre-Mer, Paris, 1961, 144p. In French.

Theory of the gyrocompass and description of the Sperry, Brown, Anschuetz and Arma compasses, gyropilot and ship-stabilizers.

ROSS, J.F.S. **The Gyroscopic Stabilization of Land Vehicles.** Edward Arnold & Co., London, 1933, 161 p.

This work gives the results of an investigation undertaken with the objects of determining whether monorail traction is scientifically sound and definitely practicable; of showing why the efforts of inventors have hitherto only met with partial success; and of placing the whole subject on a more scientific footing, and giving it a more complete and orderly treatment than it had yet received.

RYABOV, B.A. **Navigation and Gyroscopic Devices.** English translation of the Russian edition (1963, 189 p.) Available from CFSTI No.AD-413081.

Twelve articles examine the problems of measuring accelerations, calculating navigation accelerometers and their structural diagrams, calculating measuring systems with force compensation, as well as the theory of navigation systems and various gyroscopic instruments and devices. The collection is intended for aeronautical instrument engineers and technicians as well as for teachers and students of advanced courses of instrument building specialities at technical institutes of higher learning.

SAIDOV, P.I. **Theory of Gyroscopes, Part I.** Moscow, Vyssaja Skola, 1965, 470 p. In Russian.

This work would be better characterized with the title "Theory of gyroscopic instruments". The several chapters deal with the general characteristics of the gyroscope, gyro-pendulum, gyro-vertical, gyro-compass, TDF-gyros, SDF-gyros, gyro-accelerometer and integrating gyros, gyrostabilizers and navigational gyros.

ZfM 132/1

SAIDOV, P.I., SLIV, E.I., TSCHERTKOV, P.I. **Problems of Applied Gyrodynamics.** Leningrad 1961, 427 p. In Russian.

SAPOROSHENKO, S. **Aircraft Piloting.** Moscow 1958, 200 p. In Russian.

SAVANT, C.J., HOWARD, R.C., SOLLOWAY, C.B., SAVANT, C.A. **Principles of Inertial Navigation.** McGraw-Hill Book Co., New York, 1961, 246 p.

This volume was originally prepared as a series of lectures to be delivered to graduate engineers working in this new and expanding field. The first part presents the general principles of navigation, the components, coordinate systems and errors which occur in inertial navigation systems; and examples of practical autonavigators. The second part considers the autonavigator components and computers, platform controller, ground alignment, performance and preflight testing. The chapters of the third part describe the various coordinate systems which can be used, the system error analysis, and a presentation of ballistic guidance. The appendixes include a discussion of gravity, equations of motion, equations of a gyroscope, and orbital trajectories.

SAVET, P.H. **Gyroscopes, Theory and Design.** McGraw-Hill Book Co., New York, 1961, 396 p.

Fundamentals of vector and operational calculus – Theory of the gyroscope – Functional characteristics and restraints – The gyrocompass – The gyrovertical – Inertial navigation – Fundamentals of gyro design – Gyroscopic elements – Electrical design of gyros – Gyro evaluation.

One of the best books in this field, for students and engineers.

SCARBOROUGH, J.B. **The Gyroscope, Theory and Applications.** Interscience Publishers, New York, 1958, 254 p.

Vector analysis – Some fundamental principles of mechanics – Theory of the gyroscope – Motion of the gyroscope under the action of gravity. The top – Gyroscopic action in vehicles and rotating bodies – The gyroscope as a direction indicator and steering device – The gyroscope as a stabilizer – Astronomical applications.

SCHILOVSKY, P.P. **Gyroscope, its Practical Construction and Application.** Chemical Publishing Co., New York, 1938, 224 p.

Reissue of book which appeared originally in 1924, treating of physics and experimental mechanics of gyroscope, and explaining its application to stabilization of monorailways, ships, airplanes, marine guns, etc.

Eng. Ind. 1938

SIFF, E.J., EMMERICH, Cl. **An Engineering Approach to Gyroscopic Instruments.** R.Speller, New York, 1960.

Basic gyroscopics – Basic gyro configurations – Special gyro designs – Some instrument gyroscope applications.

SLATER, J.M. **Inertial Guidance Sensors.** Reinhold Publishing Corp., New York, 1964, 221 p.

A discussion of the gyros, accelerometers, and optical trackers used in inertial guidance systems is presented. Topics included are: (1) principles of operation and classification of inertial guidance system sensors; (2) gyros utilizing gimbaled rigid rotors including the dynamics and stabilization of single- and double-axis gyros, sources of error, autocompensation methods, mechanical components, and electrical components; (3) gyros utilizing ball-and-socket supported rigid rotors including dynamics and stabilization, sources of error, and design features; (4) the Foucault pendulum and displacement and rate vibratory gyros; (5) gyros utilizing the angular momentum of a spinning liquid body and those employing Coriolis force measurements; (6) nuclear angular-momentum instruments and gyros utilizing transitional momentum of electrons; (7) mechanical types of accelerometers including those using spring distortion; viscous-shear, inertial force, and time measurements; (8) electrical types of accelerometers including electro-statically and electromagnetically restored accelerometers, principles of eddy-current induction torque generation, and permanent magnets as precision instrument components; (9) gravitational field measurements with accelerometers on unstable bases; and (10) optical trackers including searching and tracking operations, angle measurement, photosensitive devices, and terrestrial and extraterrestrial use of optical trackers.

IAA 1964

SLATER, J.M. **Types of Gyroscopes.** Autonetics Division of North American Rockwell Corporation, Anaheim, California 92803, 1967, 55 p.

This document is intended to serve as a *catalogue raisonné* of modern gyroscopes and to provide the reader with understanding of the principles of gyroscopic operation sufficient to compare the several types. Emphasis is placed on conventional and unconventional gyros for navigational use. Much of the material is also applicable to gyros for flight control.

SLOMYANSKII, G.A., PRYADILOV, Yu.N. **Floating Gyroscopes and Their Application.** Moscow, Oborongiz, 1958, 244 p. In Russian.

The book consists of six chapters: A brief account of the properties and of some applications of gyroscopes – The construction and the main parameters of floating gyroscopes – The theory of the floating integrating gyroscope – The theory of the floating differentiating gyroscope – The testing of floating gyroscopes – The inertia system of navigation.

App. Mech. Rev. 1962

SLOMYANSKIY, G.A., a.o. **Gyroscopes: Production and Research.** English translation of the Russian edition (1969, 185 p.) Available from CFSTI No.JPRS-49860.

Contents: Methods of controlling instrument contamination – Problems of manufacturing technology for precision gyroscopic devices – Some means of improving the accuracy of integrating floating gyroscopes – Effect of structural-technological factors on the quality of gyromotors for precision gyro devices – Investigation of thermal displacements of the center of gravity of gyromotors for precision instruments – Method of reducing the ready time of gyro devices – Measuring the axial vibration of rapidly rotating radial thrust

ball – Experimental determination of the axial moment of inertia of a gyromotor rotor – Universal equipment for testing gyromotors – Study of natural oscillation frequencies of equally rigid sliding current leads without a contact lug – Gyroscope drift from asymmetry of friction in cantilever current conductors with vibration – Possibilities of the contactless method of determining the scaling coefficient of a gyrointegrator.

STAR 1970

SPARKS, J.C. **Gyroscopes.** E.P.Dutton & Co., New York, 1964, 91 p.

A non-mathematical treatment of the gyroscope and its applications.

SPERRY GYROSCOPE CO. **Aircraft Gyroscopic Flight Instruments.** Sperry Gyroscope Co., Brentford, England, 1965, 144 p.

A handbook containing information on gyroscopic flight instruments is presented. Described are automatic pilot and flight controls, gyro-magnetic compasses, gyro horizons, integrated instrument systems, remote gyros, zero reader flight directors, and turn-and-slip indicators. Information on a twin gyro platform, a fully manoeuverable attitude and heading reference system is also presented. The initial chapter includes a study of the principles of the gyroscope.

STAR 1966

TOPELBERT, D.G. **Electrical Instruments for Navigation.** Moscow-Leningrad, 1950, 428 p. In Russian.

USENER, H. **The Gyroscope as Direction Indicator.** Militärische Verlagsanstalt, München, 1917, 154 p. In German.

A work for the practical engineer about the gyrocompass.

VERMISHEV, Yu.Kh. **Fundamentals of Missile Guidance.** English translation of the Russian edition (1969, 342 p.) Available from CFSTI No.AD-693004.

This book is intended for students of military academies and institutes of higher education, as well as for engineering and technical personnel concerned with the immediate problems of the operation and testing of control systems, or with related problems. The various sections of the book, which are a comprehensive description of the physical processes, may be recommended for readers with intermediate technical education. The principles of building guidance systems, as well as the mathematical bases for calculating these systems, are examined on the basis of materials published in the domestic and foreign literature. There is a discussion of modern engineering methods of calculating complex systems of automatic regulation, and the basic methods and physical nature of the linearization of nonlinear systems are outlined. The physical principles of guiding rockets of various aerodynamic configurations, as well as the basic mathematical relationships describing the motion of rockets, are presented.

STAR 1970

VILAJEWSKAJA, T.I. **Aircraft Instruments and Autopilots.** Moscow, 1954, 212 p. In Russian.

WRIGLEY, W., HOLLISTER, W.M., DENHARD, W.G. **Gyroscopic Theory, Design and Instrumentation.** MIT Press, 1970.

Part I: *Theory*
Introduction – Motion, frames of reference, and the theorem of Coriolis – The laws of mechanics – The gyro model – Two-degree-of-freedom gyroscopes – Single-degree-of-freedom gyroscopes – Aircraft attitude indication – Gyrodirectional instruments – The space integrator – The gyrocompass – The vertical: vertical indicating systems and Schuler tuning – Inertial navigation.

Part II: *Design and Instrumentation*
General considerations for gyroscope design – Design of gyroscopes – Testing of gyroscopes – Appendix: Coordinate Transformation.

WRIGLEY, W., WOODBURY, R.B., HOVORKA, J. **Inertial Guidance.** New York, 1957, 86 p. In Russian.

YAGODKIN, V.V., a.o. **Gyroscopic Devices of Ballistic Missiles.** English translation of the Russian edition (1969, 227 p.) Available from CFSTI No.AD-694902.

This book is intended for people interested in problems of rocket and missile guidance. The principal types of gyro-devices for guiding modern ballistic rockets are discussed. Data is presented on structural plans of guidance systems, their specific parts, and their functions. Much attention has been paid to physical principles of operating gyro-devices, factors affecting their accuracy, and hydrostabilizers as the principal master-measuring devices of modern rockets. This book is based on open Soviet and Western materials.

STAR 1970

YAKUSHENKO, A.A. **Basis of Inertial Navigation.** English translation of the Russian edition (1963, 146 p.) Available from CFSTI No.AD-656562.

The work expounds the basis of the theory of inertial systems designed for naval navigation, the principle of action of their component elements and questions of long-term development of inertial navigation for the naval fleet. As the basis of the book there are the somewhat expanded and consideration is given to the kinematics of systems of inertial navigation, oriented in certain coordinate systems, which are of interest for the naval fleet, composed of block diagrams of inertial reference-points in these coordinate systems; also considered are certain specific errors of naval inertial systems, and principles are presented of automatic pilotage using inertial systems.

STAR 1967

ZHOLDAK, S.A. **Production Technology of Miniature Gyromotors.** English translation of the Russian edition (1964, 357 p.) Available from CFSTI No.AD-429103.

This volume considers problems of the production technology of components and units and also the assembly and testing of one of the basic elements of any gyroscopic instrument – the gyromotor. The principal attention is devoted to the technology of the miniature electric gyromotor. Devices used to insure high manufacturing precision are described. The material of the book is arranged in the sequence in which the components are usually finished and the units assembled in the production by gyromotors.

ZIEGLER, H. **Gyrodynamics.** Springer-Verlag, Berlin, 1963, 303 p. International Union of Theoretical and Applied Mechanics – Symposium, Celerina, Switzerland, 1962.

This volume contains the papers in French, German and English, presented at the First International Symposium on gyrodynamics, the book consists of 23 technical articles.

In the opinion of the reviewer the techniques presented in this volume to attain the extreme accuracy required for space applications should be of use to designers of precision instruments and controllers in many other areas of engineering as well.

App. Mech. Rev. 1965

AGARD Report 582 North Atlantic Treaty Organization, Advisory Group for Aerospace Research and Development THE GYROSCOPE AND ITS APPLICATIONS Dr.-Ing Helmut Sorg Published February 1971 20 pages The report is a consolidated listing of all known unclassified texts on the subject of the gyroscope and its application, which are readily available to scientists and engineers from commercial sources, documentation centers and public as well as corporate libraries. Each entry cites the author, publication year, title, documentation center source and a brief abstract of the work.	53.082.16	AGARD Report 582 North Atlantic Treaty Organization, Advisory Group for Aerospace Research and Development THE GYROSCOPE AND ITS APPLICATIONS Dr.-Ing Helmut Sorg Published February 1971 20 pages The report is a consolidated listing of all known unclassified texts on the subject of the gyroscope and its application, which are readily available to scientists and engineers from commercial sources, documentation centers and public as well as corporate libraries. Each entry cites the author, publication year, title, documentation center source and a brief abstract of the work.	53.082.16
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