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RTO EDUCATIONAL NOTES **EN-SET-064**

Advances in Navigation Sensors and Integration Technology

(Les avancées en matière de capteurs de navigation et de technologies d'intégration)

The material in this publication was assembled to support a Lecture Series under the sponsorship of the Sensors and Electronics Technology Panel (SET) presented on 20-21 October 2003 in London, UK; 23-24 October 2003 in Ankara, Turkey; and 27-28 October 2003 in Paris, France.

Published February 2004

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RTO is the single focus in NATO for Defence Research and Technology activities. Its mission is to conduct and promote co-operative research and information exchange. The objective is to support the development and effective use of national defence research and technology and to meet the military needs of the Alliance, to maintain a technological lead, and to provide advice to NATO and national decision makers. The RTO performs its mission with the support of an extensive network of national experts. It also ensures effective co-ordination with other NATO bodies involved in R&T activities.

RTO reports both to the Military Committee of NATO and to the Conference of National Armament Directors. It comprises a Research and Technology Board (RTB) as the highest level of national representation and the Research and Technology Agency (RTA), a dedicated staff with its headquarters in Neuilly, near Paris, France. In order to facilitate contacts with the military users and other NATO activities, a small part of the RTA staff is located in NATO Headquarters in Brussels. The Brussels staff also co-ordinates RTO's co-operation with nations in Middle and Eastern Europe, to which RTO attaches particular importance especially as working together in the field of research is one of the more promising areas of co-operation.

The total spectrum of R&T activities is covered by the following 7 bodies:

- AVT Applied Vehicle Technology Panel
- HFM Human Factors and Medicine Panel
- IST Information Systems Technology Panel
- NMSG NATO Modelling and Simulation Group
- SAS Studies, Analysis and Simulation Panel
- SCI Systems Concepts and Integration Panel
- SET Sensors and Electronics Technology Panel

These bodies are made up of national representatives as well as generally recognised 'world class' scientists. They also provide a communication link to military users and other NATO bodies. RTO's scientific and technological work is carried out by Technical Teams, created for specific activities and with a specific duration. Such Technical Teams can organise workshops, symposia, field trials, lecture series and training courses. An important function of these Technical Teams is to ensure the continuity of the expert networks.

RTO builds upon earlier co-operation in defence research and technology as set-up under the Advisory Group for Aerospace Research and Development (AGARD) and the Defence Research Group (DRG). AGARD and the DRG share common roots in that they were both established at the initiative of Dr Theodore von Kármán, a leading aerospace scientist, who early on recognised the importance of scientific support for the Allied Armed Forces. RTO is capitalising on these common roots in order to provide the Alliance and the NATO nations with a strong scientific and technological basis that will guarantee a solid base for the future.

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Advances in Navigation Sensors and Integration Technology

(RTO-EN-SET-064)

Executive Summary

The objective of this two-day Lecture Series is to present the current state-of-the-art in inertial navigation sensors and system integration technology through the improved use of advanced, low-cost navigation sensor technologies. Lecturers will present material that provides an understanding of the issues faced by today's system designers. Through this Lecture Series, the technical community will be updated on sensors and current integration techniques as practiced by leading experts in the field. The first day of the Lecture Series is primarily a tutorial to bring the audience up-to-date with current practices. The second day focuses on sensors and applications.

The first day begins with an overview paper that focuses on accuracy and other technology trends for inertial sensors, Global Positioning Systems (GPS), and integrated Inertial Navigation System (INS/GPS) systems that will lead to better than 1-m accuracy navigation systems of the future. The paper provides the rationale for the remaining papers. The second paper starts with a brief overview of inertial sensing and the technology trends underway. Discussions are presented on gyro and accelerometer technology development, with specific emphasis on designs and performance of MEMS sensors. The third paper provides an overview of the major computational elements associated with strapdown inertial systems. The fourth paper provides an overview of assorted analysis techniques associated with strapdown inertial systems and computational elements. The fifth paper focuses on INS/GPS integration architectures including "loosely coupled", "tightly coupled", and "deeply integrated" configurations. The advantages and disadvantages of each level of integration are discussed. In the sixth and final paper of the first day, the three major INS/GPS systems architectures discussed in the previous paper will have their performance compared for various mission scenarios.

The second day of the Lecture Series focus on sensors and applications. The first paper discusses MEMS. The specific advantage of MEMS in ruggedness and size is demonstrated with reference to specific applications, such as guided munitions. The second paper provides details of a silicon vibrating structure gyro. Information is presented on the basic design of the silicon ring based structure and details of the gyro characteristics and performance are also provided. The third paper gives an overview of the French MEMS expertise from R&D to products within the European context. The fourth paper gives a systems application based on a silicon gyro based inertial measurement unit developed and tested for a number of munitions and missile programmes which all require operation under high dynamic range and high roll rate conditions. The fifth and final paper on the second day explains the main aspects of fiber optic gyros and of MEMS accelerometers. Examples for different inertial system architectures based upon these sensors are given and their special advantages are discussed.

Les avancées en matière de capteurs de navigation et de technologies d'intégration

(RTO-EN-SET-064)

Synthèse

Les deux journées de ce cycle de conférences ont pour objectif de présenter l'état actuel des connaissances dans le domaine des capteurs de navigation inertiels et des technologies de l'intégration des systèmes, en accordant une attention particulière à la mise en œuvre de technologies de capteurs de navigation avancées et de coût modique. Les conférenciers donneront un aperçu des défis qui sont à relever par les concepteurs de systèmes d'aujourd'hui. Ce cycle de conférences permettra d'informer les spécialistes techniques des pays membres de l'OTAN des derniers développements en ce qui concerne les capteurs et les techniques d'intégration, tels que réalisés par les meilleurs experts du domaine. La première journée prend la forme d'un cours destiné à informer les participants des dernières pratiques. La deuxième journée est axée sur les capteurs et les applications.

La première journée débute par une présentation de synthèse sur la précision, ainsi que sur d'autres tendances technologiques actuelles pour les capteurs inertiels, les systèmes de positionnement global (GPS) et les systèmes de navigation inertiels intégrés (INS/GPS), qui permettront d'obtenir une précision supérieure à 1m. Cette communication donne l'orientation pour les présentations qui suivent. La deuxième communication commence par un bref aperçu de la télédétection inertielle ainsi que des tendances technologiques actuelles. Des discussions sont présentées sur le développement des technologies des gyroscopes et des accéléromètres, l'accent étant mis en particulier sur les réalisations et les performances des capteurs MEMS. La troisième communication présente un tour d'horizon des principaux éléments informatiques associés aux centrales inertielles liées. La quatrième communication donne un aperçu de diverses techniques d'analyse associées aux centrales inertielles liées et aux éléments informatiques. La cinquième communication concerne les architectures d'intégration INS/GPS y compris les configurations « faiblement couplées », « fortement couplées » et « totalement intégrées ».Les avantages et les désavantages de chaque niveau d'intégration sont discutés. La sixième et dernière communication de la première journée fait la comparaison des trois principales architectures systèmes examinées lors de la présentation précédente, pour différents scénarios opérationnels.

La deuxième journée du Cycle de conférences porte sur les capteurs et les applications. La première communication examine les MEMS. Les avantages apportés par les MEMS du point de vue de leur robustesse et de leur faible encombrement La deuxième communication décrit un gyroscope à structure vibrante en silicone. Des informations sont présentées sur la conception de base de la structure à base d'anneau en silicone, ainsi que sur les caractéristiques et les performances du gyroscope. La troisième communication présente un aperçu des connaissances françaises en matière de MEMS, allant de la R&D jusqu'aux produits finis, dans le contexte de l'Europe. La quatrième communication décrit une application systèmes basée sur une centrale inertielle à gyroscope silicone développée et testée dans le cadre d'un certain nombre de programmes de munitions et de missiles, exploités dans des conditions de grande dynamique et de grande vitesse angulaire de roulis. La cinquième et dernière communication expose les principaux aspects des gyroscopes à fibres optiques et des accéléromètres MEMS. Des exemples sont donnés de différents architectures de systèmes inertiels basés sur ces capteurs et leurs avantages particuliers sont discutés.

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Sensors and Electronics Technology Panel

CHAIRMAN

Dr. D. FAUBERT
Director General
DRDC
Val Cartier, Quebec G3J 1X5
CANADA

DEPUTY CHAIRMAN

Professor M. TACKE
FGAN-FOM
Gutleuthausstr. 1
76275 Ettlingen
GERMANY

List of Authors/Lecturers

Lecture Series Director: Dr. George T. SCHMIDT
The Charles Stark Draper Laboratory, Inc.

SPEAKERS

Dr. Neil M. BARBOUR
The Charles Stark Draper Laboratory, Inc.

Dr J. Richard FOUNTAIN
BAE SYSTEMS

Dr. Gottfried Eberhard HANDRICH
LITEF GmbH

Mr Gaëtan MENOZZI
MEMSCAP S.A.

Mr. Paul G. SAVAGE
Strapdown Associates, Inc.

CO-AUTHORS

Mr. Richard E. PHILLIPS
The Charles Stark Draper Laboratory, Inc.

Mr. Eric PLESKA
DGA-STTC

PANEL EXECUTIVE

Lt. Colonel G. FIAMINGO (ITAF)
e-mail: fiamingog@rta.nato.int

From Europe:

RTA-OTAN
Attn: SET Executive
BP 25
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Integrated systems
MEMS (Micro-Electro-Mechanical System)
Microelectronics
Mission profiles
Navigational aids
Performance evaluation
Precision guided munitions
Strapped down systems

14. Abstract

This Lecture Series presented the current state-of-the-art in navigation sensors and integration technology through the improved use of advanced low-cost navigation sensor technologies. The following topics were covered:

- Future of interial sensors/integrated systems
- Advances in gyro technology
- Strapdown system computational elements
- Strapdown system performance analysis
- System integration principles
- Innovative MEMS navigation applications
- Advanced Sensor applications
- Highly integrated systems

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GRECE (Correspondant)
Defence Industry & Research
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