NORTH ATLANTIC TREATY ORGANISATION

RESEARCH AND TECHNOLOGY ORGANISATION

AC/323(SET-081)TP/47

www.rta.nato.int

RTO EDUCATIONAL NOTES **EN-SET-081**

Radar Polarimetry and Interferometry

(La polarimétrie et l'interférométrie radar)

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 14-15 October 2004 in Brussels, Belgium; 18-19 October 2004 in Washington, DC, USA; and 21-22 October 2004 in Ottawa, Canada.

Published February 2005

NORTH ATLANTIC TREATY ORGANISATION

RESEARCH AND TECHNOLOGY ORGANISATION

AC/323(SET-081)TP/47

www.rta.nato.int

RTO EDUCATIONAL NOTES **EN-SET-081**

Radar Polarimetry and Interferometry

(La polarimétrie et l'interférométrie radar)

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 14-15 October 2004 in Brussels, Belgium; 18-19 October 2004 in Washington, DC, USA; and 21-22 October 2004 in Ottawa, Canada.

The Research and Technology Organisation (RTO) of NATO

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.

Published February 2005

ISBN 92-837-1130-0

Radar Polarimetry and Interferometry

(RTO-EN-SET-081)

Executive Summary

Radar Polarimetry and Radar Interferometry deliver and use the complete information which can be gained with electromagnetic wave remote sensing about targets of any kind. Therefore, the use of high resolution full polarimetric SAR is indispensable for surveillance, reconnaissance, and remote sensing, and the related fields SAR Polarimetry and SAR-Interferometry are advancing rapidly.

Scientists and engineers already engaged in the fields of radar surveillance, reconnaissance and scattering measurements, for instance, generally gain their specialist knowledge in Polarimetry by working through scientific papers and specialised literature available on the subject. Presently, the treatment of basic Polarimetry concepts, in the currently available literature, lacks a coherent framework of theory, and, moreover, several basic definitions and conventions are not yet unified sufficiently under the light of physical principles. This Lecture Series is an attempt to redress this problem. The aim of this Lecture Series is to provide a substantial and balanced introduction to the basic theory, scattering concepts, systems and applications typical to polarimetric and interferometric radar reconnaissance and surveillance, to introduce the cutting-edge technologies, and new ideas and methodologies as well. Application examples are presented, and, additionally, each chapter contents an excessive reference list which covers the most important publications in these fields of the last decade.

Each target is a specific polarization transformer and, therefore, these technologies are increasing the target identification and classification capability decisively. With multi polarization the target fine-structure, target orientation, symmetries and material constituents can be re-covered with considerable improvement above that of standard ‘amplitude-only’ radar. With radar interferometry the target’s spatial structure can be explored and differential interferometry, presently, is the most sensitive all weather technique for change detection. In ‘Polarimetric Interferometric SAR’ it is possible to recover co-registered textural and spatial information simultaneously, including the extraction of ground based stealth targets, the development of Digital Elevation Maps etc. as well. Among surveillance and reconnaissance techniques, the polarimetric & interferometric SAR attracts currently the most appreciable and outranking attention because of its capabilities for 3-D high resolution imaging with abundant additional information. Then, by either designing ‘Multiple Dual-Polarization Antenna POL-IN-SAR’ systems or by applying advanced ‘POL-IN-SAR image compression techniques’ this will result in ‘Polarimetric Tomography’, which is an important progress in Foliage Penetration and Ground Penetration Radar as well.

In this Lecture Series the successive advancements are sketched beginning with the fundamentals, and highlighting the salient points of these diverse remote sensing techniques. The following topics are addressed: Basics, advanced concepts and applications of both radar Polarimetry and SAR interferometry. For Interferometry cross track and along track interferometry, single and dual pass interferometry, interferometry errors and accuracies, and differential interferometry as well as permanent scattering interferometry. Basics of Polarimetry are presented also like electromagnetic vector wave and polarization descriptors, vector wave scattering operators and the polarimetric scattering matrices. The Polarimetric Radar optimization for coherence is discussed as well as processing and image analysis, and the most important decomposition theorems. A general formulation for vector wave interferometry is presented and the strong polarization dependence of the coherence is addressed as well as an analytical solution for optimum polarization states that maximizes the interferometric capability of a SAR. A new coherent

decomposition theorem for interferometric applications based on the singular value spectrum of a 3 x 3 complex matrix which allows the decomposition of polarimetric interferometric problems into a set of coherent scattering mechanisms is presented as well as a decomposition theorem for interferometric applications based on the Singular value spectrum of a 3 x 3 complex matrix which allows the decomposition of polarimetric interferometric problems into a set of coherent scattering mechanisms. Beside different airborne systems the following spaceborne systems are addressed: SIR-C/X-SAR, SRTM, ERS-1/2, both RadarSAT 1 and 2, ENVISAT/ASAR, TerraSAR, SAR-Lupe and, as example for a future possible System, CARTWHEEL.

La polarimétrie et l'interférométrie radar

(RTO-EN-SET-081)

Synthèse

La polarimétrie et l'interférométrie radar fournissent et exploitent l'ensemble des informations pouvant être acquises sur toutes sortes de cibles par la télédétection par ondes électromagnétiques. Par conséquent, le SAR polarimétrique intégral à haute résolution est indispensable à la surveillance, à la reconnaissance et à la télédétection. Aussi, les domaines associés de la polarimétrie SAR et l'interférométrie SAR sont en rapide évolution.

En général, les scientifiques et les ingénieurs travaillant déjà dans les domaines de la surveillance radar, la reconnaissance et le contrôle de la diffusion par exemple, acquièrent leurs compétences techniques en polarimétrie et en interférométrie en étudiant les communications techniques et la littérature spécialisée disponibles sur le sujet. A l'heure actuelle, la discussion des concepts de polarimétrie de base, telle que présentée dans la littérature, manque de cadre théorique, et, en outre, bon nombre de définitions et de pratiques convenues restent à standardiser du point de vue de leurs principes physiques. Ce cycle de conférences tente de résoudre ce problème. Il a pour objectif de fournir une introduction détaillée et cohérente aux théories de base, aux concepts de diffusion, aux systèmes de base ainsi qu'aux applications spécifiques à la reconnaissance et à la surveillance radar polarimétriques et interférométriques. Il présente également les technologies de pointe, les nouveaux concepts et les nouvelles méthodologies. Des exemples d'applications sont donnés, et chaque chapitre contient une liste de référence très complète couvrant les publications les plus importantes qui ont paru dans ces domaines au cours de la dernière décennie.

Chaque cible représente un transformateur de polarisation spécifique et, par conséquent, ces technologies ont pour effet d'augmenter considérablement les capacités d'identification et de classification des systèmes radar. La multipolarisation permet de récupérer la structure fine des cibles, l'orientation des cibles, les symétries et les éléments constitutifs matériels avec des résultats largement supérieurs à ceux obtenus par les radars classiques « à amplitude ». L'interférométrie radar permet d'examiner la structure spatiale de la cible, tandis que l'interférométrie différentielle est la technique de dissimilarité tous temps la plus sensible qui existe à l'heure actuelle. Les systèmes SAR interférométriques et polarimétriques permettent de récupérer simultanément des données spatiales et texturales co-enregistrées, y compris l'extraction de cibles furtives au sol, d'élaborer des cartes de sites numériques, etc... Parmi les techniques de surveillance et de reconnaissance actuellement disponibles, le SAR polarimétrique et interférométrique suscite le plus d'intérêt en raison de sa capacité de fournir de l'imagerie 3-D à haute résolution, accompagnée d'une abondance d'informations supplémentaires. Par la suite, la « tomographie polarimétrique » sera obtenue, soit par la réalisation de « systèmes multiples POL-IN-SAR à antenne à polarisation double », soit par des techniques avancées « POL-IN-SAR » de compression d'image. La tomographie polarimétrique représentera également une avancée importante pour les radars de pénétration du feuillage et les géoradars.

Ce cycle de conférences résume les progrès successifs réalisés, en partant des débuts, et en soulignant les caractéristiques principales de ces techniques de télédétection. Les sujets suivants y sont abordés : les éléments de base, les concepts avancés et les applications de la polarimétrie radar et de l'interférométrie SAR. Dans le domaine de l'interférométrie : l'interférométrie transversale et longitudinale, à une seule passe et à deux passes, les erreurs et la précision, l'interférométrie différentielle, ainsi que

l'interférométrie à diffusion permanente. Les principes de l'interférométrie sont présentés, comme par exemple, les descripteurs d'ondes vecteur électromagnétiques et de polarisation, les opérateurs de diffusions des ondes vecteur et les matrices de diffusion polarimétriques. L'optimisation de la cohérence des radars polarimétriques est examiné, ainsi que le traitement et l'analyse de l'image, et les théorèmes de décomposition les plus importants. Une formulation générale pour l'interférométrie des ondes vecteur est présentée. La forte dépendence de polarisation de la cohérence est examinée, ainsi qu'une solution analytique des états optimums de polarisation qui maximise les capacités interférométriques d'un SAR. Un nouveau théorème de décomposition cohérente est présenté, basé sur le spectre de valeurs unique d'une matrice complexe 3 x 3, qui permet de décomposer les problèmes interférométriques polarimétriqes en une série de mécanismes de diffusion cohérente. En plus de différents systèmes aéroportés, les systèmes spatiaux suivants sont examinés : SIR-C/X-SAR, SRTM, ERS-1/2, les RadarSAT 1 et 2, ENVISAT/ASAR, TerraSAR, SAR-Lupe et, comme exemple de futur système possible, le CARTWHEEL.

Table of Contents

Sensors and Electronics Technology Panel

CHAIRMAN

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

DEPUTY CHAIRMAN

Dr. Yolanda JONES KING
Technical Advisor, Spacecraft Technology Division
AFRL/VSS
Kirtland AFB, NM 87117-5776
USA

LIST OF AUTHORS/LECTURERS

Lecture Series Director: Dr. Ing. E.H. Wolfgang KEYDEL
DLR Oberpfaffenhofen
Mittelfeld 4
82229 Hechendorf
GERMANY

LECTURERS

Prof. Eric POTTIER
Université de Rennes 1 – UFR S.P.M.
Campus de Beaulieu – Bât. 11D, Bureau 116
263, avenue Général Leclerc
CS 74205, 35042 Rennes Cedex
FRANCE

Prof. Dr. Wolfgang-Martin BOERNER
UIC-ECE Communications
Sensing & Navigation Laboratory
900 W. Taylor St. SEL (607) W-4210
M/C 154
Chicago, IL 60607-7018
USA

Dr. Martin HELLMANN
German Aerospace Center (DLR), Strategy and Networking
Linder Höhe
51140 Köln
GERMANY

CO-AUTHORS

Shane R. CLOUDE
School of Electrical and Electronic Engineering
University of Adelaide
South Australia 5005
AUSTRALIA

Jong-Sen LEE
Naval Research Laboratory
Remote Sensing Division
Washington, DC 20375-5351
USA

Laurent FERRO-FAMIL
Université de Rennes 1 – UFR S.P.M.
Campus de Beaulieu – Bât. 11D, Bureau 116
263, avenue Général Leclerc
CS 74205, 35042 Rennes Cedex
FRANCE

PANEL EXECUTIVE

Lt.Col. G. FIAMINGO (ITAF)
E-mail: fiamingog@rta.nato.int

From Europe:

RTA-OTAN
Attn: SET Executive
BP 25, F-92201 Neuilly-sur-Seine Cedex
FRANCE

From the USA or Canada:

RTA-NATO
Attn: SET Executive
PSC 116
APO AE 09777

REPORT DOCUMENTATION PAGE

1. Recipient's Reference	2. Originator's References	3. Further Reference	4. Security Classification of Document
	RTO-EN-SET-081 AC/323(SET-081)TP/47	ISBN 92-837-1130-0	UNCLASSIFIED/ UNLIMITED

5. Originator

Research and Technology Organisation
North Atlantic Treaty Organisation
BP 25, F-92201 Neuilly-sur-Seine Cedex, France

6. Title

Radar Polarimetry and Interferometry

7. Presented at/Sponsored by

The Sensors and Electronics Technology Panel (SET) to support a Lecture Series presented on 14-15 October 2004 in Brussels, Belgium; 18-19 October 2004 in Washington, DC, USA; and 21-22 October 2004 in Ottawa, Canada.

8. Author(s)/Editor(s)	9. Date
Multiple	February 2005
10. Author's/Editor's Address	**11. Pages**
Multiple	326

12. Distribution Statement

There are no restrictions on the distribution of this document. Information about the availability of this and other RTO unclassified publications is given on the back cover.

13. Keywords/Descriptors

Accuracy	E-SAR	RadarSAT
Adaptive systems	Image processing	Reviews
Algorithms	Interferometric SAR	Signal processing
CARTWHEEL	Polarimetric Interferometry	SIR-C/X-SAR
Clutter	Polarimetric Radar Interferometry	SRTM
Data acquisition	Polarimetric SAR	Synthetic aperture radar
ENVISAT/ASAR	Polarimetry	Target acquisition
ERS-1/2	Radar signals	Target signatures

14. Abstract

Scientists and engineers already engaged in the fields of radar surveillance, reconnaissance and scattering measurements, for instance, generally gain their specialist knowledge in both polarimetry and interferometry by working through scientific papers and specialised literature available on the subject. Usually, this is a time consuming exercise, as it is difficult to collate respective material tailored to newcomers. This Lecture Series is an attempt to redress this problem.

The aim of this Lecture Series was to provide a substantial and balanced introduction to the basic theory, scattering concepts, systems and applications typical to polarimetric and interferometric radar reconnaissance and surveillance and to introduce the cutting-edge technologies, new ideas and methodologies.

Topics covered were: basics, advanced concepts and applications of both radar polarimetry and SAR interferometry and the combination of both techniques as well with respect to cross track and along track, single and dual pass configurations; the interconnection between interferometry measurement errors and SAR system accuracy with respect to both platform flight path geometry and attitude, and principal radar system accuracies; polarimetric SAR processing and image analysis and the most important decomposition theorems; polarimetric interferometry and differential interferometry and the respective SAR image analysis, processing principles and calibration problems; and applications especially with respect to Digital Elevation Models and target classification; realized and future airborne and spaceborne systems as Examples (E-SAR, SIR-C/X-SAR, SRTM, ERS-1/2, RadarSAT, ENVISAT/ASAR, CARTWHEEL) together with a concluding outlook in the future development airborne and space borne polarimetric SAR with interferometry capability.

NORTH ATLANTIC TREATY ORGANISATION

RESEARCH AND TECHNOLOGY ORGANISATION

BP 25
F-92201 NEUILLY-SUR-SEINE CEDEX • FRANCE
Télécopie 0(1)55.61.22.99 • E-mail mailbox@rta.nato.int

DIFFUSION DES PUBLICATIONS

RTO NON CLASSIFIEES

Les publications de l'AGARD et de la RTO peuvent parfois être obtenues auprès des centres nationaux de distribution indiqués ci-dessous. Si vous souhaitez recevoir toutes les publications de la RTO, ou simplement celles qui concernent certains Panels, vous pouvez demander d'être inclus soit à titre personnel, soit au nom de votre organisation, sur la liste d'envoi.

Les publications de la RTO et de l'AGARD sont également en vente auprès des agences de vente indiquées ci-dessous.

Les demandes de documents RTO ou AGARD doivent comporter la dénomination « RTO » ou « AGARD » selon le cas, suivi du numéro de série. Des informations analogues, telles que le titre est la date de publication sont souhaitables.

Si vous souhaitez recevoir une notification électronique de la disponibilité des rapports de la RTO au fur et à mesure de leur publication, vous pouvez consulter notre site Web (www.rta.nato.int) et vous abonner à ce service.

CENTRES DE DIFFUSION NATIONAUX

ALLEMAGNE
Streitkräfteamt / Abteilung III
Fachinformationszentrum der
Bundeswehr (FIZBw)
Friedrich-Ebert-Allee 34, D-53113 Bonn

BELGIQUE
Etat-Major de la Défense
Département d'Etat-Major Stratégie
ACOS-STRAT – Coord. RTO
Quartier Reine Elisabeth
Rue d'Evère, B-1140 Bruxelles

CANADA
DSIGRD2
Bibliothécaire des ressources du savoir
R et D pour la défense Canada
Ministère de la Défense nationale
305, rue Rideau, 9e étage
Ottawa, Ontario K1A 0K2

DANEMARK
Danish Defence Research Establishment
Ryvangs Allé 1, P.O. Box 2715
DK-2100 Copenhagen Ø

ESPAGNE
SDG TECEN / DGAM
C/ Arturo Soria 289
Madrid 28033

ETATS-UNIS
NASA Center for AeroSpace
Information (CASI)
Parkway Center, 7121 Standard Drive
Hanover, MD 21076-1320

FRANCE
O.N.E.R.A. (ISP)
29, Avenue de la Division Leclerc
BP 72, 92322 Châtillon Cedex

GRECE (Correspondant)
Defence Industry & Research
General Directorate, Research Directorate
Fakinos Base Camp, S.T.G. 1020
Holargos, Athens

HONGRIE
Department for Scientific Analysis
Institute of Military Technology
Ministry of Defence
H-1525 Budapest P O Box 26

ISLANDE
Director of Aviation
c/o Flugrad
Reykjavik

ITALIE
Centro di Documentazione
Tecnico-Scientifica della Difesa
Via XX Settembre 123
00187 Roma

LUXEMBOURG
Voir Belgique

NORVEGE
Norwegian Defence Research Establishment
Attn: Biblioteket
P.O. Box 25, NO-2007 Kjeller

PAYS-BAS
Royal Netherlands Military
Academy Library
P.O. Box 90.002
4800 PA Breda

POLOGNE
Armament Policy Department
218 Niepodleglosci Av.
00-911 Warsaw

PORTUGAL
Estado Maior da Força Aérea
SDFA – Centro de Documentação
Alfragide
P-2720 Amadora

REPUBLIQUE TCHEQUE
LOM PRAHA s.p.
VTÚL a PVO o.z.
DIS ČR – NATO RTO
Tiskařská 8
100 38 Praha 10

ROYAUME-UNI
Dstl Knowledge Services
Information Centre, Building 247
Dstl Porton Down
Salisbury
Wiltshire SP4 0JQ

TURQUIE
Milli Savunma Bakanlığı (MSB)
ARGE ve Teknoloji Dairesi Başkanlığı
06650 Bakanliklar – Ankara

AGENCES DE VENTE

NASA Center for AeroSpace Information (CASI)
Parkway Center, 7121 Standard Drive
Hanover, MD 21076-1320
ETATS-UNIS

The British Library Document Supply Centre
Boston Spa, Wetherby
West Yorkshire LS23 7BQ
ROYAUME-UNI

Canada Institute for Scientific and Technical Information (CISTI)
National Research Council
Acquisitions, Montreal Road, Building M-55
Ottawa K1A 0S2, CANADA

Les demandes de documents RTO ou AGARD doivent comporter la dénomination « RTO » ou « AGARD » selon le cas, suivie du numéro de série (par exemple AGARD-AG-315). Des informations analogues, telles que le titre et la date de publication sont souhaitables. Des références bibliographiques complètes ainsi que des résumés des publications RTO et AGARD figurent dans les journaux suivants :

Scientific and Technical Aerospace Reports (STAR)
STAR peut être consulté en ligne au localisateur de
ressources uniformes (URL) suivant:
http://www.sti.nasa.gov/Pubs/star/Star.html
STAR est édité par CASI dans le cadre du programme
NASA d'information scientifique et technique (STI)
STI Program Office, MS 157A
NASA Langley Research Center
Hampton, Virginia 23681-0001
ETATS-UNIS

Government Reports Announcements & Index (GRA&I)
publié par le National Technical Information Service
Springfield
Virginia 2216
ETATS-UNIS
(accessible également en mode interactif dans la base de
données bibliographiques en ligne du NTIS, et sur CD-ROM)

NORTH ATLANTIC TREATY ORGANISATION

RESEARCH AND TECHNOLOGY ORGANISATION

BP 25
F-92201 NEUILLY-SUR-SEINE CEDEX • FRANCE
Télécopie 0(1)55.61.22.99 • E-mail mailbox@rta.nato.int

DISTRIBUTION OF UNCLASSIFIED RTO PUBLICATIONS

AGARD & RTO publications are sometimes available from the National Distribution Centres listed below. If you wish to receive all RTO reports, or just those relating to one or more specific RTO Panels, they may be willing to include you (or your Organisation) in their distribution.

RTO and AGARD reports may also be purchased from the Sales Agencies listed below.

Requests for RTO or AGARD documents should include the word 'RTO' or 'AGARD', as appropriate, followed by the serial number. Collateral information such as title and publication date is desirable.

If you wish to receive electronic notification of RTO reports as they are published, please visit our website (www.rta.nato.int) from where you can register for this service.

NATIONAL DISTRIBUTION CENTRES

BELGIUM
Etat-Major de la Défense
Département d'Etat-Major Stratégie
ACOS-STRAT – Coord. RTO
Quartier Reine Elisabeth
Rue d'Evère
B-1140 Bruxelles

CANADA
DRDKIM2
Knowledge Resources Librarian
Defence R&D Canada
Department of National Defence
305 Rideau Street
9th Floor
Ottawa, Ontario K1A 0K2

CZECH REPUBLIC
LOM PRAHA s.p.
VTÚL a PVO o.z.
DIS ČR – NATO RTO
Tiskařská 8
100 38 Praha 10

DENMARK
Danish Defence Research Establishment
Ryvangs Allé 1
P.O. Box 2715
DK-2100 Copenhagen Ø

FRANCE
O.N.E.R.A. (ISP)
29, Avenue de la Division Leclerc
BP 72
92322 Châtillon Cedex

GERMANY
Streitkräfteamt / Abteilung III
Fachinformationszentrum der Bundeswehr (FIZBw)
Friedrich-Ebert-Allee 34
D-53113 Bonn

GREECE (Point of Contact)
Defence Industry & Research General Directorate, Research Directorate
Fakinos Base Camp, S.T.G. 1020
Holargos, Athens

HUNGARY
Department for Scientific Analysis
Institute of Military Technology
Ministry of Defence
H-1525 Budapest P O Box 26

ICELAND
Director of Aviation
c/o Flugrad, Reykjavik

ITALY
Centro di Documentazione Tecnico-Scientifica della Difesa
Via XX Settembre 123
00187 Roma

LUXEMBOURG
See Belgium

NETHERLANDS
Royal Netherlands Military Academy Library
P.O. Box 90.002
4800 PA Breda

NORWAY
Norwegian Defence Research Establishment
Attn: Biblioteket
P.O. Box 25, NO-2007 Kjeller

POLAND
Armament Policy Department
218 Niepodleglosci Av.
00-911 Warsaw

PORTUGAL
Estado Maior da Força Aérea
SDFA – Centro de Documentação
Alfragide, P-2720 Amadora

SPAIN
SDG TECEN / DGAM
C/ Arturo Soria 289
Madrid 28033

TURKEY
Milli Savunma Bakanlığı (MSB)
ARGE ve Teknoloji Dairesi Başkanlığı
06650 Bakanliklar – Ankara

UNITED KINGDOM
Dstl Knowledge Services
Information Centre, Building 247
Dstl Porton Down
Salisbury, Wiltshire SP4 0JQ

UNITED STATES
NASA Center for AeroSpace Information (CASI)
Parkway Center, 7121 Standard Drive
Hanover, MD 21076-1320

SALES AGENCIES

NASA Center for AeroSpace Information (CASI)
Parkway Center
7121 Standard Drive
Hanover, MD 21076-1320
UNITED STATES

The British Library Document Supply Centre
Boston Spa, Wetherby
West Yorkshire LS23 7BQ
UNITED KINGDOM

Canada Institute for Scientific and Technical Information (CISTI)
National Research Council
Acquisitions
Montreal Road, Building M-55
Ottawa K1A 0S2, CANADA

Requests for RTO or AGARD documents should include the word 'RTO' or 'AGARD', as appropriate, followed by the serial number (for example AGARD-AG-315). Collateral information such as title and publication date is desirable. Full bibliographical references and abstracts of RTO and AGARD publications are given in the following journals:

Scientific and Technical Aerospace Reports (STAR)
STAR is available on-line at the following uniform resource locator:
http://www.sti.nasa.gov/Pubs/star/Star.html
STAR is published by CASI for the NASA Scientific and Technical Information (STI) Program
STI Program Office, MS 157A
NASA Langley Research Center
Hampton, Virginia 23681-0001
UNITED STATES

Government Reports Announcements & Index (GRA&I)
published by the National Technical Information Service
Springfield
Virginia 2216
UNITED STATES
(also available online in the NTIS Bibliographic Database or on CD-ROM)

ISBN 92-837-1130-0