



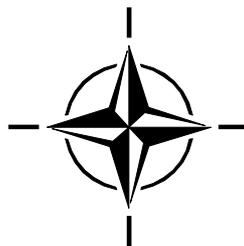
RTO TECHNICAL REPORT

TR-SAS-076

# **NATO Independent Cost Estimating and the Role of Life Cycle Cost Analysis in Managing the Defence Enterprise**

(Estimation indépendante des coûts de l'OTAN  
et rôle de l'analyse des coûts globaux de  
possession au sein de l'OTAN)

This Report presents the findings of Task Group SAS-076.



Published August 2012





RTO TECHNICAL REPORT

TR-SAS-076

# **NATO Independent Cost Estimating and the Role of Life Cycle Cost Analysis in Managing the Defence Enterprise**

(Estimation indépendante des coûts de l'OTAN  
et rôle de l'analyse des coûts globaux de  
possession au sein de l'OTAN)

This Report presents the findings of Task Group SAS-076.

---

# 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 System Analysis and Studies 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.

The content of this publication has been reproduced directly from material supplied by RTO or the authors.

Published August 2012

Copyright © RTO/NATO 2012  
All Rights Reserved

ISBN 978-92-837-0162-0

Single copies of this publication or of a part of it may be made for individual use only. The approval of the RTA Information Management Systems Branch is required for more than one copy to be made or an extract included in another publication. Requests to do so should be sent to the address on the back cover.

# Table of Contents

	<b>Page</b>
<b>List of Figures</b>	<b>viii</b>
<b>List of Tables</b>	<b>xi</b>
<b>List of Acronyms</b>	<b>xiv</b>
<b>Acknowledgements</b>	<b>xviii</b>
<b>SAS-076 Membership List</b>	<b>xix</b>
<b>Executive Summary and Synthèse</b>	<b>ES-1</b>
<b>1.0 Introduction</b>	<b>2</b>
1.1 Background	2
1.2 Provenance and Approval	2
1.3 Objectives	3
1.4 Scope	4
<b>2.0 Approach</b>	<b>6</b>
2.1 Independent Cost Estimates	6
2.2 Role of Life-Cycle Cost Analysis in Managing the Defense Enterprise	7
<b>3.0 Summary of Results</b>	<b>7</b>
3.1 ICE on NATO Alliance Ground Surveillance System (AGS)	7
3.2 ICE on Royal Netherlands Navy LPDs	8
3.2.1 Acquisition ICE	8
3.2.2 Operational & Support ICE	11
3.3 Role of Life-Cycle Cost Analysis in Managing the Defense Enterprise	12
<b>4.0 Lessons Identified</b>	<b>14</b>
4.1 Main ICE Lessons and Related SAS-076 Experience	14
4.1.1 Establishing Needs with Customers	14
4.1.2 Establishing a Program Baseline	14
4.1.3 Developing Baseline Cost Estimates	15
4.1.4 Conducting Risk and Uncertainty Analysis	15
4.1.5 Verifying and Validating Estimates	15
4.1.6 Presenting and Defending Estimates	16
4.2 Other ICE Lessons	16
4.3 Life Cycle Cost Analysis in Managing the Defense Enterprise	17
<b>5.0 Conclusions</b>	<b>18</b>
<b>6.0 References</b>	<b>20</b>

## **Annex A – Estimating the Acquisition Cost of the Alliance Ground Surveillance (AGS) System** **A-1**

1.0	Introduction	A-2
1.1	Historical Background	A-2
1.2	AGS Core Overview	A-2
1.3	Study Objective	A-4
1.4	Scope	A-4
1.5	Outline	A-4
2.0	The AGS Program Baseline	A-6
2.1	General Assumptions	A-6
2.2	The Cost Breakdown Structure (CBS)	A-6
2.2.1	The Air Vehicle Segment	A-7
2.2.2	The Payload Segment	A-8
2.2.3	The Ground/Support Segment	A-8
2.2.4	Miscellaneous Support Elements 1.4 – 1.12	A-8
3.0	Financial Considerations	A-9
3.1	Inflation	A-9
3.2	Raw Aircraft Procurement	A-9
3.3	Weighted Aircraft Procurement	A-9
3.4	Foreign Exchange Rate	A-10
4.0	The AGS Cost Estimate	A-12
4.1	The Air Vehicle	A-12
4.1.1	The Airframe Wing	A-13
4.1.2	The Airframe Fuselage	A-15
4.1.3	The Airframe Empennage	A-16
4.1.4	The Airframe Subsystems	A-17
4.2	Global Hawk Propulsion	A-18
4.3	Communications	A-18
4.3.1	Datalinks	A-19
4.3.2	Ku Band Satellite Radio	A-19
4.3.3	Satellite Communications (SATCOM) Voice	A-20
4.3.4	International Maritime SATCOM	A-21
4.3.5	UHF/VHF Communications	A-22
4.4	Navigation/Guidance	A-23
4.4.1	Global Positioning Systems (GPS)	A-24
4.4.2	OmniStar Differential Global Positioning System (DGPS)	A-24
4.4.3	IFF Transponder/Traffic Alert & Collision (TCAS-II)	A-24
4.4.4	Worldwide Operations Hardware Suite	A-26
4.5	Miscellaneous Air Vehicle Components	A-26
4.5.1	The Central Computer	A-26
4.5.2	Auxiliary Equipment	A-27
4.5.3	Integration, Assembly, Test & Checkout (IATC)	A-28
4.6	The Payloads	A-28
4.6.1	Multi-Platform Radar Technology Insertion Program (MP-RTIP)	A-28
4.7	The Ground/Support Segment	A-30
4.7.1	AGS Ground Segment Parametric Cost Estimation	A-31

4.7.2	Ground Segment Hardware	A-31
4.7.3	Sample Calculation: VHF/UHF Antenna	A-32
5.0	Risk and Uncertainty Analysis for NATO AGS	A-36
5.1	Background	A-36
5.2	Point Estimate and Position on S-Curve	A-36
5.3	Risk Elements	A-36
5.4	Selection of CV	A-39
5.5	Scenarios	A-40
5.6	S-Curve	A-41
5.7	S-Curve Excursion	A-42
6.0	Conclusions	A-43
7.0	References	A-44
	Appendix A-1: A General Overview of the Advanced Cost Estimating Systems (ACES)	A-46
	Appendix A-2: ACES Input and Output Parameter Definitions	A-48
 <b>Annex B1 – Estimating the Acquisition Cost of the Royal Netherlands Navy Landing Platform Dock Ships: An Ex Post Analysis</b>		<b>B1-1</b>
1.0	Introduction	B1-2
1.1	Background	B1-2
1.2	Objective	B1-3
1.3	Scope	B1-3
1.4	Outline	B1-3
2.0	Data	B1-3
2.1	Technical Data	B1-6
2.2	Cost Data	B1-8
3.0	Parametric Cost Estimation	B1-10
3.1	The M5 Model Tree System	B1-11
3.1.1	Discussion	B1-12
3.2	Application to SAS-076 Ship Data Set	B1-12
3.2.1	Comparison to Linear Regression Models	B1-18
4.0	Cost Estimation by Analogy	B1-19
4.1	Hierarchical Cluster Analysis	B1-19
4.2	Application to SAS-076 Ship Data Set	B1-19
4.3	Discussion	B1-26
5.0	Results	B1-27
5.1	M5 Model Tree Results	B1-27
5.2	Linear Regression Results	B1-29
5.3	Hierarchical Cluster Analysis Results	B1-29
5.4	Discussion	B1-32
5.5	Ex Post Revelation	B1-32
6.0	Lessons Identified	B1-34
6.1	General Management of the Estimating Process	B1-34
6.2	Definition of the Aims and Cost Boundary	B1-36
6.3	Data and Assumptions	B1-36
6.4	Methods, Models and Tools	B1-37
6.5	Risk and Uncertainty Analysis	B1-38
6.6	Analysis and Presentation of Results	B1-38

7.0	Conclusion	B1-39
8.0	References	B1-41
	Appendix B1-1: Data Set	B1-43
	Appendix B1-2: Principal Component Data Set	B1-53
	Appendix B1-3: M5 Model Tree Algorithm	B1-54
 <b>Annex B2 – Estimating the Operation and Support Costs of the Royal Netherlands Navy Landing Platform Dock Ships: An Ex Ante Analysis</b>		<b>B2-1</b>
1.0	Introduction	B2-2
1.1	Background	B2-2
1.2	Objective	B2-2
1.3	Scope	B2-2
1.4	Outline	B2-2
2.0	Methodology	B2-3
2.1	Analogy Method	B2-3
2.2	Parametric Method	B2-3
2.3	Engineering “Bottom-up” Method	B2-3
3.0	Tools	B2-4
4.0	Data and Assumptions	B2-4
4.1	Analogy and Parametric	B2-5
4.2	Engineering Bottom-up	B2-5
4.2.1	Organizational and Operational Data	B2-5
4.2.2	Technical Data	B2-12
4.2.3	Indirect Support	B2-20
5.0	Cost Normalization	B2-20
6.0	Results and Analysis	B2-20
7.0	Comparing CAIG and GCBS Models	B2-25
7.1	Analysing the Models	B2-25
7.2	Results	B2-26
7.3	Discussion	B2-26
8.0	Lessons Learned	B2-29
8.1	General Management of the Estimating Process	B2-29
8.1.1	Initial Plan	B2-29
8.1.2	Actual Implementation of the Initial Plan	B2-30
8.1.3	Lessons Identified	B2-30
8.2	Definition of the Aims and Cost Boundary	B2-30
8.2.1	The Team’s Approach	B2-30
8.2.2	Lessons Identified	B2-31
8.3	Data and Assumptions	B2-31
8.3.1	The Team’s Approach	B2-31
8.3.2	Lessons Identified	B2-32
8.4	Methods, Models and Tools	B2-32
8.4.1	The Team’s Approach	B2-32
8.4.2	Lessons Identified	B2-33
8.5	Risk and Uncertainty Analysis	B2-33
8.5.1	The Team’s Approach	B2-33
8.5.2	Lessons Identified	B2-33

8.6	Analysis of Results	B2-33
8.6.1	The Team’s Approach	B2-33
8.6.2	Lessons Identified	B2-34
8.7	Presentation of the Results	B2-34
8.7.1	The Team’s Approach	B2-34
8.7.2	Lessons Identified	B2-34
9.0	Conclusions	B2-34
10.0	References	B2-36
	Appendix B2-1: CATLOC LCC Model Description	B2-37
	Appendix B2-2: Ex Ante Testing – CAIG	B2-46
	Appendix B2-3: Cost Breakdown Structure for the GCBS-CAIG Model	B2-51
	Appendix B2-4: Cost Breakdown Structure for the CAIG Model	B2-52
	Appendix B2-5: Tree Report Table for GCBS-CAIG Model	B2-54
 <b>Annex C – The Role of Life Cycle Cost Analysis in Managing the Defense Enterprise</b>		<b>C-1</b>
1.0	Introduction	C-2
1.1	Background	C-2
1.2	Study Objectives	C-2
1.3	Scope	C-3
2.0	Management of the Defense Enterprise	C-4
3.0	Capability Portfolio Analysis	C-5
3.1	Background	C-5
3.2	International CPA Conference	C-6
4.0	U.S. Pilot Effort in Portfolio Analysis	C-7
4.1	Background	C-7
4.2	Mine Warfare	C-7
	4.2.1 Mission and Threat	C-7
	4.2.2 Portfolio	C-8
4.3	Methodology	C-10
	4.3.1 Assessing Capability – System Architecture	C-10
	4.3.2 Assessing Capability – Execution Details	C-11
	4.3.3 Estimating Risks	C-12
	4.3.4 Estimating Costs	C-13
4.4	Findings	C-13
4.5	SAS-076 Evaluation	C-16
4.6	SAS-076 Recommendations	C-17
5.0	National Templates	C-18
5.1	Overview	C-18
5.2	Commonalities and Differences	C-18
5.3	Strategic Framework	C-18
5.4	Needs and Solutions	C-23
5.5	Lexicon and Taxonomy	C-30
5.6	Role of Life-Cycle Cost Analysis in Defence Planning	C-32
6.0	Best Practices and Recommendations	C-36
7.0	References	C-39

# List of Figures

<b>Figure</b>		<b>Page</b>
<b>REPORT</b>		
Figure 1	The life cycle cost iceberg	4
Figure 2	The strategic defense management loop	5
Figure 3	Methodology for the development of independent cost estimates	6
Figure 4	Estimating the cost for software development (example)	8
Figure 5	Estimated acquisition cost of NATO AGS	9
Figure 6	M5 model tree applied to the NATO RTO SAS-076 ship data set	10
Figure 7	Dendrogram illustrating the arrangement of the clusters produced by the hierarchical clustering of ships	10
Figure 8	Probability density function and cumulative distribution function of the M5 model tree and hierarchical clustering estimates of HMS Rotterdam LPD cost	11
Figure 9	Probability density function and cumulative distribution function of the M5 model tree and hierarchical clustering estimates of HMS Johan de Witt LPD cost	11
Figure 10	Risk-reward bubble diagram (example)	13
Figure 11	Macro analysis of role of life-cycle cost analysis in defence planning	14
<b>ANNEX A</b>		
Figure 1	Principle of operation of the AGS core wide-area ground surveillance system	A-2
Figure 2	Elements of the NATO AGS system	A-3
Figure 3	Methodology for the NATO AGS independent cost estimate	A-6
Figure 4	U.S. dollar/euro historical and forecasted exchange rate	A-11
Figure 5	Northrop Grumman Global Hawk air vehicle features	A-13
Figure 6	Estimated air vehicle wing unit costs in U.S. FY 10 \$M	A-15
Figure 7	Estimated air vehicle fuselage unit costs in U.S. FY 10 \$M	A-16
Figure 8	Estimated air vehicle empennage unit costs in U.S. FY 10 \$M	A-17
Figure 9	Estimated Ku band satellite radio unit costs in U.S. FY 10 \$M	A-20
Figure 10	Estimated air vehicle SATCOM voice unit costs in U.S. FY 10 \$M	A-21
Figure 11	Estimated Maritime SATCOM unit costs in U.S. FY 10 \$M	A-22
Figure 12	Estimated air vehicle UHF/VHF communication unit costs in U.S. FY 10 \$M	A-23
Figure 13	Estimated air vehicle GPS two-unit costs in U.S. FY 10 \$M	A-25
Figure 14	Estimated air vehicle computer two-unit costs in U.S. FY 10 \$M	A-27
Figure 15	Estimated air vehicle Integration, Assembly, Test & Checkout costs in U.S. FY 10 \$M	A-29
Figure 16	Harris RF-9070 parameters	A-33
Figure 17	Harris RF-9070 input to ACES	A-34

Figure 18	Harris RF-9070 output from ACES	A-35
Figure 19	Euro area inflation rate (actual change on consumer price index)	A-37
Figure 20	Growth count in estimated lines of code	A-38
Figure 21	International participation	A-39
Figure 22	Task Group scenarios	A-40
Figure 23	Estimated acquisition cost of NATO AGS	A-41
Figure 24	Estimated acquisition cost of NATO AGS	A-42

## ANNEX B1

Figure 1	HMS Rotterdam L800 Landing Platform Dock Ship	B1-2
Figure 2	Histogram of normalized costs (millions NCC)	B1-10
Figure 3	Example M5 model tree	B1-11
Figure 4	M5 model tree applied to the NATO RTO SAS 076 ship data set	B1-14
Figure 5	M5 model tree: correlation plot of actual vs. predicted ship costs (millions NCC)	B1-17
Figure 6	Hierarchical clustering with simple distance function: correlation plot of actual vs. predicted ship costs (millions NCC)	B1-20
Figure 7	Dendrogram illustrating the arrangement of the clusters produced by the hierarchical clustering of ships (simple distance function)	B1-21
Figure 8	Dendrogram illustrating the arrangement of the clusters produced by the hierarchical clustering of ships (weighted distance function)	B1-25
Figure 9	Weighted hierarchical clustering: correlation plot of actual vs. predicted ship costs (millions of NCC)	B1-26
Figure 10	Probability density function and cumulative distribution function of the M5 model tree estimate of HMS Rotterdam LPD cost	B1-27
Figure 11	Probability density function and cumulative distribution function of the M5 model tree estimate of HMS Johan de Witt LPD cost	B1-28
Figure 12	Probability density function and cumulative distribution function of the hierarchical clustering estimate of HMS Rotterdam LPD cost	B1-30
Figure 13	Probability density function and cumulative distribution function of the hierarchical clustering estimate of HMS Johan de Witt LPD cost	B1-31
Figure 14	Probability density function and cumulative distribution function of the M5 model tree and hierarchical clustering estimates of HMS Rotterdam LPD cost	B1-33
Figure 15	Probability density function and cumulative distribution function of the M5 model tree and hierarchical clustering estimates of HMS Johan de Witt LPD cost	B1-33

## ANNEX B2

Figure 1	General maintenance levels	B2-10
Figure 2	Sample System Breakdown Structure	B2-13
Figure 3	Input failure rates	B2-14
Figure 4	Preventive maintenance periods	B2-19
Figure 5	LCC showing O&S cost versus acquisition costs	B2-21

Figure 6	O&S cost distribution	B2-22
Figure 7	Distribution of operational costs	B2-22
Figure 8	Distribution of maintenance costs	B2-23
Figure 9	Preventive maintenance costs over time	B2-23
Figure 10	Distribution of cost over resource types	B2-24
Figure 11	Sensitivity analysis over all parameters	B2-24
Figure 12	Structure of CAIG and GCBS models	B2-25
Figure 13	Example of the comparison method	B2-27
Figure 14	GCBS vs. CAIG	B2-28
Figure 15	The LCC tree as listed in the CATLOC model	B2-37
Figure 16	VAMOS O&S cost estimate results for HMS Rotterdam and Johan de Witt	B2-50
Figure 17	Cost Breakdown Structure for the GCBS-CAIG model	B2-51
Figure 18	Cost breakdown structure for the CAIG model	B2-52
Figure 19	Second-level cost estimating structure	B2-53

## ANNEX C

Figure 1	The strategic defense management loop	C-4
Figure 2	The threat of sea mines	C-8
Figure 3	The master warfighting scenario	C-10
Figure 4	Sample scoring template	C-12
Figure 5	Life cycle of defense systems	C-13
Figure 6	Detection, localization, classification, and identification of sea mines	C-14
Figure 7	Analysis of detection, localization, classification, and identification of sea mines	C-15
Figure 8	Analysis of groups of interrelated systems: MH-53E and MH-60S helicopters	C-16
Figure 9	Summary of analysis of nations' responses with respect to strategic planning	C-19
Figure 10	Norway's overall picture of the defence planning	C-22
Figure 11	Summary of analysis of nations' responses with respect to defence needs and solutions	C-24
Figure 12	U.S. capabilities-based framework	C-25
Figure 13	U.S. defense acquisition system milestones	C-26
Figure 14	SAS-076's interpretation of Canada's force development process	C-27
Figure 15	SAS-076's interpretation of Netherlands' defence material process	C-28
Figure 16	SAS-076's interpretation of Norway's capability planning process	C-28
Figure 17	SAS-076's interpretation of Sweden's defence planning process	C-29
Figure 18	SAS-076's interpretation of Germany's customer product management process	C-30
Figure 19	Macro analysis of role of life-cycle cost analysis in defence planning	C-33
Figure 20	Micro analysis of role of life-cycle cost analysis in defence planning	C-34
Figure 21	Current practice of NATO nations with respect to the role of life-cycle cost analysis in defence planning	C-36

## List of Tables

<b>Table</b>		<b>Page</b>
 <b>ANNEX A</b>		
Table 1	The cost breakdown structure for NATO AGS	A-7
Table 2	U.S. constant year dollars (base year highlighted)	A-10
Table 3	U.S. Global Hawk RQ-4 production line	A-14
Table 4	U.S. Global Hawk RQ-4 wing costs	A-14
Table 5	U.S. Global Hawk RQ-4 wing regression statistics	A-14
Table 6	U.S. Global Hawk RQ-4 fuselage costs	A-15
Table 7	U.S. Global Hawk RQ-4 fuselage regression statistics	A-16
Table 8	U.S. Global Hawk RQ-4 empennage costs	A-17
Table 9	U.S. Global Hawk RQ-4 empennage regression statistics	A-17
Table 10	U.S. Global Hawk RQ-4 subsystems costs	A-18
Table 11	U.S. Global Hawk RQ-4 powerplant costs	A-18
Table 12	U.S. Global Hawk RQ-4 datalinks costs	A-19
Table 13	U.S. Global Hawk RQ-4 Ku band satellite radio costs	A-19
Table 14	U.S. Global Hawk RQ-4 SATCOM voice costs	A-20
Table 15	U.S. Global Hawk RQ-4 SATCOM voice regression statistics	A-21
Table 16	U.S. Global Hawk RQ-4 Maritime SATCOM costs	A-21
Table 17	U.S. Global Hawk RQ-4 UHF/VHF communications costs	A-22
Table 18	U.S. Global Hawk RQ-4 UHF/VHF communications regression statistics	A-23
Table 19	U.S. Global Hawk RQ-4 GPS two-unit costs	A-24
Table 20	U.S. Global Hawk RQ-4 GPS two-unit regression statistics	A-24
Table 21	U.S. Global Hawk RQ-4 DGPS costs	A-25
Table 22	U.S. Global Hawk RQ-4 TCAS-II costs	A-25
Table 23	U.S. Global Hawk RQ-4 operations hardware suite costs	A-26
Table 24	U.S. Global Hawk RQ-4 central computer costs	A-26
Table 25	U.S. Global Hawk RQ-4 central computer regression statistics	A-27
Table 26	U.S. Global Hawk RQ-4 auxiliary equipment costs	A-27
Table 27	U.S. Global Hawk RQ-4 Integration, Assembly, Test & Checkout costs	A-28
Table 28	U.S. Global Hawk RQ-4 Integration, Assembly, Test & Checkout regression statistics	A-28
Table 29	The cost breakdown structure for NATO AGS ground Segment	A-32
Table 30	Input definitions for ACES parameters as they apply to the Harris RF-9070 UHF/VHF antenna	A-49
Table 31	Output definitions for ACES parameters as they apply to the Harris RF-9070 UHF/VHF antenna	A-50

Table 32	Output definitions (Cont'd) for ACES parameters as they apply to the Harris RF-9070 UHF/VHF antenna	A-51
----------	---	------

**ANNEX B1**

Table 1	Description of analogous ships	B1-5
Table 2	Categories of ship data	B1-6
Table 3	Complete list of ship data for the Rotterdam and Johan de Witt LPDs	B1-6
Table 4	M5 model tree linear regression models	B1-15
Table 5	Statistics of attributes used in the M5 model tree linear regression models	B1-16
Table 6	M5 model tree classification of SAS-076 ships	B1-16
Table 7	Mean absolute percent errors of known instances and standard deviations per individual M5 model tree linear models	B1-16
Table 8	Principal component analysis results	B1-23
Table 9	Optimal macro-attribute weights for cost estimation by hierarchical clustering	B1-24
Table 10	Percentiles of the fitted log-normal density functions for the M5 model tree estimated HMS Rotterdam LPD and HMS Johan de Witt LPD costs (millions NCC)	B1-29
Table 11	Weighted distance of the Rotterdam LPD to ships in the Rotterdam data set	B1-30
Table 12	Percentiles of the fitted log-normal density functions for the hierarchical clustering estimated HMS Rotterdam LPD and HMS Johan de Witt LPD costs (millions NCC)	B1-31
Table 13	Comparison of the M5 model tree and hierarchical clustering methods and their estimates	B1-32
Table 14	Comparison of actual to estimated costs (millions NCC)	B1-34
Table 15	Technical data for the United Kingdom, Swedish, Norwegian, and French ships	B1-43
Table 16	Technical data for the United States and Canadian ships	B1-48
Table 17	Principal component analysis (80% coverage): resulting attributes	B1-53

**ANNEX B2**

Table 1	Rotterdam class ship manning profile	B2-7
Table 2	Total O&S costs	B2-21
Table 3	The CATLOC model A1-1 Level reporting table (Levels 0–2)	B2-38
Table 4	The CATLOC model A1-1 Level reporting table (Level 3)	B2-39
Table 5	The CATLOC model A1-1 Level reporting table (Levels 4-5)	B2-40
Table 6	The CATLOC model A1-2 Tree reporting table	B2-41
Table 7	The CATLOC model A1-2 Tree reporting table (Cont'd)	B2-42
Table 8	The CATLOC model A1-2 Tree reporting table (Cont'd)	B2-43
Table 9	The CATLOC model A1-2 Tree reporting table (Cont'd)	B2-44
Table 10	The CATLOC model A1-2 Tree reporting table (Cont'd)	B2-45

---

Table 11	Ship parameters	B2-49
Table 12	Tree Report Table for GCBS-CAIG Model (Cont'd on next page)	B2-54
Table 13	Tree Report Table for GCBS-CAIG Model (Cont'd)	B2-55

### **ANNEX C**

Table 1	Scoring of strategic requirements	C-11
---------	-----------------------------------	------

## List of Acronyms

AAS	Amphibious Assault Ship
ACES	Advanced Cost Estimating Systems
AESA	Active Electronically Scanned Array
AGBP	Average Global Bunker Price
AGS	Alliance Ground Surveillance
AOR	Auxiliary Oiler Replenishment
APN	Air Procurement Navy
AST	Acquisition Support Team
ASTOR	Airborne Stand-Off Reconnaissance
BIX	Bunker Index
BWB	Federal Office of Defence Technology and Procurement (German)
BWI	Bunkerworld Index
BY	Budget Year
C2ISR	Command, Control, Intelligence, Surveillance and Reconnaissance
CAD	Canadian Dollar
CAIG	Cost Analysis Improvement Group
CAPE	Cost Assessment and Program Evaluation
CARD	Cost Analysis Requirement Description
CATLOC	Systecon Costing Software
CBS	Cost Breakdown Structure
CER	Cost Estimating Relationship
CIB	CDL Interfacebox
Civ	Civilian
CIWS	Close-In Weapon System
CLM	Contractor Level Maintenance
CLS	Contractor Logistics Support
CM	Corrective Maintenance
CMMI	Capability Maturity Model Integration
CORA	Centre for Operational Research and Analysis
cp	controllable pitch
CSOP	Command Standard Operating Procedure
CV	Coefficient of Variation
CY	Constant Year
DADD	Data and Assumptions Document Definition
DAMA	Demand Assigned Multiple Access
DDQ	Design, Development and Qualification
DGPS	Differential Global Positioning System
DLM	Depot Level Maintenance
DoD	Department of Defense (U.S.)
DRDC	Defence Research and Development Canada
ECM	Electronic Countermeasures Systems
EFV	Expeditionary Fighting Vehicle
ELINT	Electronic Intelligence
EO/IR	Electro-Optical/Infra-Red
eSBM	enhanced Scenario-Based Method
ESLOC	Equivalent Source Lines Of Code

ESM	Electronic Support Measures
EUR	Euro
fp	fixed pitch
FREMM	FRigate Multi-Mission (French)
FRP	Full Rate Production
FV	Future Value
FY	Fiscal Year
G&A	General & Administrative
GBP	(Great Britain) Pound Sterling
GCBS	Generic Cost Breakdown Structure
GMTI	Ground Moving Target Indicator
GPS	Global Positioning System
GS	Ground System
HMS	Her Majesty's Ship
HNMS	Her Netherlands Majesty's Ship
hrs	hours
I&T	Integration & Test
IATC	Integration, Assembly, Test and Checkout
ICE	Independent Cost Estimate
IFF	Identification Friend or Foe
ILM	Intermediate Level Maintenance
ISR	Intelligence, Surveillance and Reconnaissance
JSTARS	Joint Surveillance Target Attack Radar System
kts	knots
LAV	Light Armoured Vehicle
LCAC	Landing Craft, Air-Cushioned
LCC	Life Cycle Costs
LCM	Landing Craft, Mechanized
LCPL	Landing Craft, Personnel, Large
LCS	Learning Curve Slope
LCU	Landing Craft, Utility
LCVP	Landing Craft, Vehicle, Personnel
LOS	Line-Of-Sight
LPD	Landing Platform Dock
LPH	Landing Platform Helicopter
LRE	Launch and Recovery Element
LRIP	Low Rate Initial Production
LRU	Line Replaceable Unit
LSD	Landing Ship Dock
LSE	Logistic Support Elements
LVT	Landing Vehicle, Tracked
m	meters
M	Million
MCE	Mission Control Element
MDAL	Master Data and Assumption List
MGCS	Mobile General Communications Stations
MGGS	Mobile General Ground Stations

Mil	Military
mm	millimeters
MOB	Main Operating Base
MORS	Military Operational Requirement
MOS	Main Operating Station
MP-RTIP	Multi-Platform Radar Technology Insertion Program
MS	Milestone
MT	Metric Ton
MTBF	Mean Time Between Failures
MW	Mega Watts
NAC	North Atlantic Council
NAGSMA	NATO Alliance Ground Surveillance Management Agency
NAGSMO	NATO Alliance Ground Surveillance Management Organisation
NATO	North Atlantic Treaty Organisation
NAVSEA	U.S. Naval Sea Systems Command
NBCD	Nuclear, Biological, and Chemical Defence
NCCA	U.S. Naval Center for Cost Analysis
NGISSI	Northrop Grumman Integrated Systems Sector International
NME	Navy Maintenance Establishment
nmi	nautical mile
NOK	Norwegian Krone
O&S	Operational & Support
OCCAR	Organisation for Joint Armament Cooperation (French)
OECD	Organisation for Economic Co-operation and Development
OLM	Organizational Level Maintenance
OTS	Off-The-Shelf
PAPS	Phased Armaments Programming System
PBM	Panel Business Meeting
PCA	Principal Component Analysis
PfP	Partnership for Peace
PHST	Packing, Handling, Storage, and Transporting
PM	Preventive Maintenance
PM	Program Management
PMoU	Program Memorandum of Understanding
POL	Petroleum, Oil, Lubricant
PPP	Purchasing Power Parity
PSE	Peculiar Support Equipment
PV	Present Value
RADAR	Radio Detection And Ranging
RAMS	Reliability, Maintainability and Supportability
RAP	Raw Aircraft Procurement
RF	Radio Frequency
RFA	Radio Frequency Assembly
RNLN	Royal Netherlands Navy
RTB	Research & Technology Board
RTO	Research & Technology Organisation
RWR	Radar Warning Receiver
SAM	Surface-to-Air Missile
SAR	Synthetic Aperture Radar

---

SAS	Systems Analysis and Studies
SAS-054	NATO RTO SAS-054
SAS-076	NATO RTO SAS-076
SATCOM	Satellite Communications
SDD	System Development and Demonstration
SE	Systems Engineering
SEK	Swedish Krona
SoI	System of Interest
SONAR	Sound Navigation And Ranging
SSM	Surface-to-Surface Missile
STAM	Strategy-to-Task Model
TACAN	Tactical Air Navigation
TCAS	Traffic Collision Avoidance System
TGGS	Transportable General Ground Stations
TOA	Total Obligation Authority
TSPR	Total System Performance Responsibility
TY	Then Year
U.S.	United States
UAV	Unmanned Aerial Vehicle
UCE	Command and Control Elements
UHF/VHF	Ultra High Frequency / Very High Frequency
USD	United States Dollar
USSOCOM	United States Special Operations Command
VAMOSOC	Visibility and Management of Operating and Support Costs
WAP	Weighted Aircraft Procurement
WBDL-LOS	Wideband Datalink Line-Of-Sight
WMA	Wideband Modem Assembly
Y/N	Yes/No

---

## Acknowledgements

The SAS-076 Task Group acknowledges the efforts of the following individuals: (Canada) Dr. Ben Taylor – Defence Research and Development Canada; (France) Mr. Gregory Golf and Mr. Patrick Journée – Direction générale de l’armement; (Greece) Mr. Angelos Tsorovas and Cpt. Nikolaos Angelos – Hellenic General Army Staff; (Italy) Brigadier General Massimo Pica – Italian Army (retired); (Netherlands) Mr. Stephan de Spiegeleire – Hague Centre for Strategic Studies; (Norway) Mr. Steinar Gulichsen, Ms. Solveig Marie Krey, and Dr. Dagfinn-Furnes Vatne – FFI Norwegian Defence Research Establishment; (Turkey) Mrs. Nilay Uygunlar – TUBITAK SAGE; (United States) Lt.Col. Fred Gregory – United States Air Force (retired), Mr. Jake Mender and Mr. John Murray – Naval Center for Cost Analysis.

## SAS-076 Membership List

### CANADA

Dr. Paul E. Desmier  
DRDC CORA, NDHQ 6 CBS  
101 Colonel By Drive  
Ottawa, Ontario K1A 0K2  
Email: [paul.desmier@forces.gc.ca](mailto:paul.desmier@forces.gc.ca)

Dr. Bohdan L. Kaluzny  
DMGOR Acquisition Support Team  
DRDC CORA  
105 Hotel de Ville  
Gatineau, Québec  
Email: [Bohdan.Kaluzny@Forces.gc.ca](mailto:Bohdan.Kaluzny@Forces.gc.ca)

Mr. R.H.A. David Shaw  
DRDC CORA  
101 Colonel By Drive  
Ottawa, Ontario K1A 0K2  
Email: [shaw.d@forces.gc.ca](mailto:shaw.d@forces.gc.ca)

### FRANCE

Mr. Renzo Chiomento  
Ministère de la Défense – DGA  
7-9 rue des Mathurins  
92221 Bagneux Cedex  
Email: [renzo.chiomento@dga.defense.gouv.fr](mailto:renzo.chiomento@dga.defense.gouv.fr)

Mr. Philippe Lacheret  
MINDEF/DGA/DET/SMCO/SDSC/DEAC  
7-9 rue des Mathurins  
00470 Bagneux Armées  
Email: [philippe.lacheret@dga.defense.gouv.fr](mailto:philippe.lacheret@dga.defense.gouv.fr)

### GERMANY

Mr. Walter Boos  
Bundesamt für Wehrtechnik & Beschaffung  
(BWB)  
Ferdinand-Sauerbruch Strasse 1  
D-56073 Koblenz  
Email: [walterboos@bwb.org](mailto:walterboos@bwb.org)

Mr. Joachim Schotten  
Federal Office of Military Technology &  
Procurement – BWB  
Ferdinand Sauerbruch Strasse 1  
D-56073 Koblenz  
Email: [joachimschotten@bwb.org](mailto:joachimschotten@bwb.org)

### GREECE

Major Dimitrios Derpanis  
Email: [dasp-kkz@army.gr](mailto:dasp-kkz@army.gr)

Brigadier General Panagiotis Paganis  
Hellenic Army General Staff. HAGS (GES)  
Head of Life Cycle Cost Section (TM. KKZ)  
Defence Planning @ Programming Division  
(DASP)  
Mesogion 227 Av, Stratopedo Papagou  
Post Code TK 15451  
Holargos, Athens STG 1024  
Email: [dasp-kkz@army.gr](mailto:dasp-kkz@army.gr)

### NETHERLANDS

Mr. Marcel Smit  
TNO Brassersplein 2  
P O Box 5050  
2600 GB Delft  
Email: [marcel.smit@tno.nl](mailto:marcel.smit@tno.nl)

### SWEDEN

Dr. Sorin Barbici  
Swedish Defence Materiel Administration  
FMV KE KogUtv H349  
Banérgatan 62  
SE-115-88 Stockholm  
Email: [sorin.barbici@fmv.se](mailto:sorin.barbici@fmv.se)

Ms. Anna-Lena Berg  
Swedish Defence Material Administration  
Banérgatan 62  
SE-115-88 Stockholm  
Email: [Anna-Lena.Berg@mil.se](mailto:Anna-Lena.Berg@mil.se)

Mr. Göran Berg  
Swedish Defence Material Administration  
Banérgatan 62  
SE-115-88 Stockholm  
Email: [goran.berg@fmv.se](mailto:goran.berg@fmv.se)

Mr. Ulf Jonsson  
FOI Swedish Defence Research Agency  
SE-164-90 Stockholm  
Email: [ulf.a.jonsson@foi.se](mailto:ulf.a.jonsson@foi.se)

---

**TURKEY**

Mr. Murat Arda Cakmak  
Tubitak-Sage P. K. Box 16  
06261 Mamak, Ankara  
Email: [acakmak@sage.tubitak.gov.tr](mailto:acakmak@sage.tubitak.gov.tr)

**UNITED STATES**

Mr. David Baggley  
OSD, PA&E – CAIG  
Room BE779  
1800 Defense Pentagon  
Washington, DC 20301-1800  
Email: [David.Baggley@osd.mil](mailto:David.Baggley@osd.mil)

Dr. Brian Flynn (Chair)  
US DoD Naval Center for Cost Analysis  
OASN (FM&C), NCCA  
Room 4C449  
1000 Navy Pentagon  
Washington, DC 20350-1000  
Email: [Brian.Flynn.ctr@navy.mil](mailto:Brian.Flynn.ctr@navy.mil)

**OCCAR**

Mr. Franck Ramaroson  
OCCAR EA  
Godesberger Allee 140  
D-53175 Bonn  
Email: [franck.ramaroson@occar.int](mailto:franck.ramaroson@occar.int)

<b>REPORT DOCUMENTATION PAGE</b>			
<b>1. Recipient's Reference</b>	<b>2. Originator's References</b>	<b>3. Further Reference</b>	<b>4. Security Classification of Document</b>
	RTO-TR-SAS-076 AC/323(SAS-076)TP/430	ISBN 978-92-837-0162-0	UNCLASSIFIED/ UNLIMITED
<b>5. Originator</b>	Research and Technology Organisation North Atlantic Treaty Organisation BP 25, F-92201 Neuilly-sur-Seine Cedex, France		
<b>6. Title</b>	NATO Independent Cost Estimating and the Role of Life Cycle Cost Analysis in Managing the Defence Enterprise		
<b>7. Presented at/Sponsored by</b>	This Report presents the findings of Task Group SAS-076.		
<b>8. Author(s)/Editor(s)</b>	Multiple		<b>9. Date</b> August 2012
<b>10. Author's/Editor's Address</b>	Multiple		<b>11. Pages</b> 254
<b>12. Distribution Statement</b>	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.		
<b>13. Keywords/Descriptors</b>	Acquisition Cost Estimates Models	Portfolios Ships Simulation Statistics	
<b>14. Abstract</b>	<p>Building upon the efforts of SAS-028, SAS-054 and SAS-069, the goal of SAS-076 was to prove the concepts of these earlier RTO SAS works on Life Cycle Cost Analysis by rigorously applying the guidelines to generate sound, reliable, Independent Cost Estimates (ICE) of major weapon system acquisition programs of current, international interest: HMS Rotterdam and HMS Johan de Witt Landing Platform Docks (LPD) of the Netherlands; and NATO's Alliance Ground Surveillance System (AGS).</p> <p>Innovative, pioneering statistical techniques were employed in these efforts that pushed the state of the art in cost analysis to new frontiers: 1) Decision trees, regression models, and hierarchical clustering, based on scores of technical and performance characteristics, to estimate ship acquisition cost; and 2) Benchmark coefficients of variation coupled with a point estimate to generate a cumulative probability distribution of cost, or S-curve, for NATO AGS.</p> <p>SAS-076 also ventured into the mélange of defence planning, acquisition, and capability portfolio analysis. SAS-076 surveyed procedures and processes of several NATO and PfP Nations for establishing national security guidance and objectives; for identifying military needs; and for developing and procuring solutions. SAS-076 identified commonalities and differences amongst nations, and it recommended a set of best practices in the cost-analysis domain.</p>		





BP 25

F-92201 NEUILLY-SUR-SEINE CEDEX • FRANCE  
Télécopie 0(1)55.61.22.99 • E-mail [mailbox@rta.nato.int](mailto: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 et 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.rto.nato.int](http://www.rto.nato.int)) et vous abonner à ce service.

**CENTRES DE DIFFUSION NATIONAUX****ALLEMAGNE**

Streitkräfteamt / Abteilung III  
Fachinformationszentrum der Bundeswehr (FIZBw)  
Gorch-Fock-Straße 7, D-53229 Bonn

**BELGIQUE**

Royal High Institute for Defence – KHID/IRSD/RHID  
Management of Scientific & Technological Research  
for Defence, National RTO Coordinator  
Royal Military Academy – Campus Renaissance  
Renaissancelaan 30, 1000 Bruxelles

**CANADA**

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

**DANEMARK**

Danish Acquisition and Logistics Organization (DALO)  
Lautrupbjerg 1-5, 2750 Ballerup

**ESPAGNE**

SDG TECIN / DGAM  
C/ Arturo Soria 289  
Madrid 28033

**ESTONIE**

Estonian Ministry of Defence  
Estonian National Coordinator for NATO RTO  
Sakala 1, Tallinn 15094

**ETATS-UNIS**

NASA Center for AeroSpace Information (CASI)  
7115 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**

Hungarian Ministry of Defence  
Development and Logistics Agency  
P.O.B. 25, H-1885 Budapest

**ITALIE**

General Secretariat of Defence and  
National Armaments Directorate  
5<sup>th</sup> Department – Technological  
Research  
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**

Centralna Biblioteka Wojskowa  
ul. Ostrobramska 109  
04-041 Warszawa

**PORTUGAL**

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

**REPUBLIQUE TCHEQUE**

LOM PRAHA s. p.  
o. z. VTÚLaPVO  
Mladoboleslavská 944  
PO Box 18  
197 21 Praha 9

**ROUMANIE**

Romanian National Distribution  
Centre  
Armaments Department  
9-11, Drumul Taberei Street  
Sector 6  
061353, Bucharest

**ROYAUME-UNI**

Dstl Knowledge and Information  
Services  
Building 247  
Porton Down  
Salisbury SP4 0JQ

**SLOVAQUIE**

Akadémia ozbrojených síl gen.  
M.R. Štefánika, Distribučné a  
informačné stredisko RTO  
Demänová 393, Liptovský Mikuláš 6  
031 06

**SLOVENIE**

Ministry of Defence  
Central Registry for EU and  
NATO  
Vojkova 55  
1000 Ljubljana

**TURQUIE**

Milli Savunma Bakanlığı (MSB)  
ARGE ve Teknoloji Dairesi  
Başkanlığı  
06650 Bakanlıklar  
Ankara

**AGENCES DE VENTE****NASA Center for AeroSpace  
Information (CASI)**

7115 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://ntrs.nasa.gov/search.jsp>  
STAR est édité par CASI dans le cadre du programme  
NASA d'information scientifique et technique (STI)  
NASA Langley Research Center, STI Program Office, MS 157A  
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)



BP 25

F-92201 NEUILLY-SUR-SEINE CEDEX • FRANCE  
Télécopie 0(1)55.61.22.99 • E-mail [mailbox@rta.nato.int](mailto: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.rto.nato.int](http://www.rto.nato.int)) from where you can register for this service.

**NATIONAL DISTRIBUTION CENTRES**

**BELGIUM**

Royal High Institute for Defence – KHID/IRSD/RHID  
Management of Scientific & Technological Research  
for Defence, National RTO Coordinator  
Royal Military Academy – Campus Renaissance  
Renaissancelaan 30  
1000 Brussels

**CANADA**

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

**CZECH REPUBLIC**

LOM PRAHA s. p.  
o. z. VTÚLaPVO  
Mladoboleslavská 944  
PO Box 18  
197 21 Praha 9

**DENMARK**

Danish Acquisition and Logistics Organization  
(DALO)  
Lautrupbjerg 1-5  
2750 Ballerup

**ESTONIA**

Estonian Ministry of Defence  
Estonian National Coordinator for NATO RTO  
Sakala 1, Tallinn 15094

**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)  
Gorch-Fock-Straße 7  
D-53229 Bonn

**GREECE (Point of Contact)**

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

**HUNGARY**

Hungarian Ministry of Defence  
Development and Logistics Agency  
P.O.B. 25, H-1885 Budapest

**ITALY**

General Secretariat of Defence and  
National Armaments Directorate  
5<sup>th</sup> Department – Technological  
Research  
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**

Centralna Biblioteka Wojskowa  
ul. Ostrobramska 109  
04-041 Warszawa

**PORTUGAL**

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

**ROMANIA**

Romanian National Distribution  
Centre  
Armaments Department  
9-11, Drumul Taberei Street  
Sector 6, 061353, Bucharest

**SLOVAKIA**

Akadémia ozbrojených síl gen.  
M.R. Štefánika, Distribučné a  
informačné stredisko RTO  
Demänová 393, Liptovský Mikuláš 6  
031 06

**SLOVENIA**

Ministry of Defence  
Central Registry for EU & NATO  
Vojkova 55  
1000 Ljubljana

**SPAIN**

SDG TECIN / DGAM  
C/ Arturo Soria 289  
Madrid 28033

**TURKEY**

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

**UNITED KINGDOM**

Dstl Knowledge and Information  
Services  
Building 247  
Porton Down  
Salisbury SP4 0JQ

**UNITED STATES**

NASA Center for AeroSpace  
Information (CASI)  
7115 Standard Drive  
Hanover, MD 21076-1320

**SALES AGENCIES**

**NASA Center for AeroSpace  
Information (CASI)**

7115 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://ntrs.nasa.gov/search.jsp>

STAR is published by CASI for the NASA Scientific  
and Technical Information (STI) Program

NASA Langley Research Center, STI Program Office, MS 157A  
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)