NORTH ATLANTIC TREATY ORGANISATION

RESEARCH AND TECHNOLOGY ORGANISATION

AC/323(SAS-054)TP/51

www.rto.nato.int

RTO TECHNICAL REPORT **TR-SAS-054**

Methods and Models for Life Cycle Costing

(Méthodes et modèles d'évaluation du coût de possession)

Final Report of Task Group SAS-054.

Published June 2007

Distribution and Availability on Back Cover

NORTH ATLANTIC TREATY ORGANISATION

RESEARCH AND TECHNOLOGY ORGANISATION

AC/323(SAS-054)TP/51

www.rto.nato.int

RTO TECHNICAL REPORT **TR-SAS-054**

Methods and Models for Life Cycle Costing

(Méthodes et modèles d'évaluation du coût de possession)

Final Report of Task Group SAS-054.

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 June 2007

Copyright © RTO/NATO 2007
All Rights Reserved

ISBN 978-92-837-0072-2

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

	Page
List of Figures	**xi**
List of Tables	**xiv**
List of Acronyms	**xv**
Programme Participants	**xx**
Observing Nations and Organisations	**xxi**
Acknowledgements	**xxii**
Executive Summary and Synthèse	**ES-1**
Overview	**O-1**
O.1 Review of Cost Forecasting Methods	O-1
O.2 Review of Cost Forecasting Models	O-1
O.3 Guidelines for the Collection and Understanding of Cost Related Data for National and Multi-National Programmes	O-1
O.4 Treatment of Uncertainty and Risk	O-2
O.5 Guideline for Multi-National Programmes	O-2
O.6 Review and Possible Enhancement of the NATO Generic Cost Breakdown Structure	O-2
O.7 Awareness of New Developments in Methods and Models	O-2
O.8 Conclusion	O-3
O.9 Key Recommendations	O-3
O.9.1 Life Cycle Costing Methods	O-3
O.9.2 Life Cycle Cost Models	O-4
O.9.3 Data for Life Cycle Costing	O-4
O.9.4 Multi-National Programmes	O-4
O.9.5 NATO Generic Cost Breakdown Structure	O-4
O.9.6 Uncertainty and Risk	O-5
O.9.7 Further Studies	O-5
Chapter 1 – Introduction	**1-1**
1.1 Background	1-1
1.2 Justification	1-1
1.3 Life Cycle Cost Management in NATO	1-2
1.3.1 Life Cycle Cost Management Purpose	1-2
1.3.2 Life Cycle Cost Management Activities	1-2
1.4 Objectives of SAS-054	1-3

1.5 SAS-054 Study Approach 1-3
1.6 Implementation of the Guideline 1-5
1.7 Structure of the Report 1-5

Chapter 2 – The Role of Life Cycle Costing 2-1
2.1 General 2-1
2.2 Phases and the Use of Life Cycle Costing 2-2
2.3 Approach to Life Cycle Costing 2-3
2.3.1 Define the Aims and Objectives 2-4
2.3.2 Establish the Costing Boundary and Assumptions 2-4
2.3.2.1 UK Master Data and Assumptions List 2-5
2.3.2.2 US Cost Analysis Requirements Description 2-6
2.3.3 Develop the Structure of the Life Cycle Cost Framework 2-7
2.3.4 Establish the Data and Populate the Life Cycle Cost Framework 2-8
2.4 Conducting the Cost Analysis 2-11
2.5 Presentation of the Life Cycle Cost Results 2-11
2.6 Financial Threshold 2-13
2.7 Organisation and Ownership of the Life Cycle Costs 2-14
2.8 Typical Applications of Life Cycle Costing 2-14
2.8.1 Determine the Forecast of Future Spending – Defence Budget Planning Applications 2-15
2.8.2 Examining Comparisons between Alternative Solutions 2-15
2.8.3 Supporting the Tender Evaluation Process 2-15
2.9 Assessing Affordability 2-17
2.10 Special Requirements for Multi-National Programmes 2-20
2.10.1 Definitions 2-20
2.10.2 Specifics of Multi-National Programmes 2-20
2.10.2.1 Framework 2-20
2.10.2.2 Added Value 2-20
2.10.2.3 Taking into Account “juste retour” (Fair Return on Investment) 2-21
2.10.3 Organisation 2-21
2.10.3.1 Multi-National Management Structure Models 2-21
2.10.3.2 Consequences on Life Cycle Costing Organisation 2-22
2.10.4 Scope of the LCC Studies in Multi-National Programmes 2-22
2.10.5 Example 2-23
2.10.6 Setting a Common Life Cycle Cost Framework 2-23
2.10.7 Presentation of Results: Currency Issues 2-24

Chapter 3 – Life Cycle Costing in the PAPS Phases 3-1
3.1 General 3-1
3.1.1 Make or Buy 3-1
3.1.2 PAPS Background 3-2
3.2 PAPS Phases 3-3
3.2.1 Mission Need Evaluation Phase 3-3
3.2.2 Pre-Feasibility Phase 3-3
3.2.3 Feasibility Phase 3-4

3.2.4 Project Definition Phase 3-4
3.2.5 Design and Development Phase 3-4
3.2.6 Production Phase 3-4
3.2.7 In-Service Phase 3-5
3.2.8 Disengagement Phase 3-5
3.2.9 Alternative Procurement Phase (Make or Buy Decision) 3-5
3.3 Mission Need and Pre-Feasibility Phase 3-6
3.3.1 Summary Definition of Phase 3-6
3.3.2 Inputs 3-6
3.3.3 Outputs 3-7
3.3.4 Life Cycle Cost Benefits 3-7
3.3.5 Types of Life Cycle Cost Studies 3-7
3.3.6 Methods Employed 3-7
3.3.7 Life Cycle Costing Process 3-7
3.3.8 Risk Assessment 3-8
3.3.9 Examples 3-9
3.3.9.1 Balance of Investment 3-9
3.3.9.2 Cost Benefit Analysis 3-10
3.3.9.3 Cost-Effectiveness Assessment 3-11
3.3.10 References 3-12
3.4 Feasibility and Project Definition Phase 3-13
3.4.1 Summary Definition of Phase 3-13
3.4.2 Inputs 3-13
3.4.3 Outputs 3-13
3.4.4 Life Cycle Cost Benefits 3-14
3.4.5 Types of Life Cycle Cost Studies 3-14
3.4.6 Methods Employed 3-14
3.4.7 Life Cycle Costing Process 3-15
3.4.8 Risk Assessment 3-16
3.4.9 Example 3-16
3.4.10 References 3-17
3.5 Design and Development Phase 3-17
3.5.1 Summary Definition of Phase 3-17
3.5.2 Inputs 3-17
3.5.3 Outputs 3-18
3.5.4 Life Cycle Cost Benefits 3-18
3.5.5 Types of Life Cycle Cost Studies 3-18
3.5.6 Methods Employed 3-19
3.5.7 Life Cycle Costing Process 3-19
3.5.7.1 RFI and CBS from Vendors – LCC Comparison 3-19
3.5.7.2 Cost Drivers – Influencing the LCC 3-20
3.5.7.3 Validate the System Specification 3-20
3.5.7.4 Evaluation and Iteration 3-20
3.5.8 Risk Assessment 3-22
3.5.9 Examples 3-22
3.5.9.1 Analogy Cost Estimating 3-22
3.5.9.2 Parametric Cost Estimating 3-23

3.5.9.3 Historical Trend Analysis 3-24
3.5.9.4 Example of Evaluation of Contract Performance 3-25
3.5.10 References 3-28
3.6 Alternative Procurement Phase (Make or Buy Decision) 3-28
3.6.1 Summary Definition of Phase 3-28
3.6.2 Inputs 3-28
3.6.3 Outputs 3-29
3.6.4 Life Cycle Cost Benefits 3-29
3.6.5 Types of Life Cycle Cost Studies 3-29
3.6.6 Methods Employed 3-29
3.6.7 Life Cycle Costing Process 3-30
3.6.8 Risk Assessment 3-30
3.6.9 Example 3-30
3.6.10 References 3-33
3.7 Production Phase 3-33
3.7.1 Summary Definition of Phase 3-33
3.7.2 Inputs 3-34
3.7.3 Outputs 3-34
3.7.4 Life Cycle Cost Benefits 3-34
3.7.5 Types of Life Cycle Cost Studies 3-34
3.7.6 Methods Employed 3-34
3.7.6.1 Prior to Start of Production 3-34
3.7.6.2 During Production 3-35
3.7.6.3 Post Production 3-35
3.7.7 Life Cycle Costing Process 3-35
3.7.8 Risk Assessment 3-37
3.7.9 Example 3-37
3.7.10 References 3-38
3.8 In-Service Phase 3-39
3.8.1 Summary Definition of Phase 3-39
3.8.2 Inputs 3-39
3.8.3 Outputs 3-39
3.8.4 Life Cycle Cost Benefits 3-40
3.8.5 Types of Life Cycle Cost Studies 3-40
3.8.6 Methods Employed 3-41
3.8.7 Life Cycle Costing Process 3-41
3.8.8 Risk Assessment 3-42
3.8.9 Example 3-43
3.8.10 References 3-43
3.9 National Disengagement 3-44
3.9.1 Summary Definition of Phase 3-44
3.9.2 Inputs 3-44
3.9.3 Outputs 3-45
3.9.4 Life Cycle Cost Benefits 3-45
3.9.5 Types of Life Cycle Cost Studies 3-45
3.9.6 Methods Employed 3-45

3.9.7 Life Cycle Costing Process 3-46
3.9.8 Risk Assessment 3-46
3.9.9 Example 3-47
3.9.10 References 3-47
3.10 NATO Policy for Systems Life Cycle Management and the Future of PAPS 3-47
3.10.1 General Comment 3-47
3.10.2 ISO 15288 Life Cycle Stage Definitions 3-48
3.10.2.1 Concept Stage 3-48
3.10.2.2 Development Stage 3-49
3.10.2.3 Production Stage 3-49
3.10.2.4 Utilisation Stage 3-49
3.10.2.5 Support Stage 3-49
3.10.2.6 Retirement Stage 3-49
3.10.3 References 3-49

Chapter 4 – Methods 4-1
4.1 General 4-1
4.2 Overview of Methods 4-1
4.2.1 Optimisation Methods 4-2
4.2.1.1 Linear Programming 4-2
4.2.1.2 Heuristics 4-2
4.2.2 Simulation Methods 4-2
4.2.2.1 System Dynamics 4-2
4.2.2.2 Discrete Event Simulation 4-3
4.2.2.3 Monte Carlo Simulation 4-3
4.2.3 Calculation/Estimation Methods 4-4
4.2.3.1 Analogy 4-4
4.2.3.2 Parametric 4-5
4.2.3.3 Bayesian Techniques 4-5
4.2.3.4 Engineering (bottom up) 4-8
4.2.3.5 Catalogue or Handbook Estimates 4-9
4.2.3.6 Rules of Thumb 4-9
4.2.3.7 Expert Opinion 4-9
4.2.4 Decision Support Methods 4-9
4.2.4.1 Analytical Hierarchy Process 4-9
4.2.4.2 Multi-Criteria Decision Analysis 4-10
4.2.5 References 4-10
4.3 Summary of Findings 4-11
4.4 Recommendations 4-12
4.4.1 References 4-13

Chapter 5 – Models 5-1
5.1 General 5-1
5.2 Overview of Models 5-1
5.2.1 The Different Types of Models Identified 5-1

5.2.1.1 Estimation Models 5-1
5.2.1.2 Decision Support Models 5-2
5.2.1.3 Simulation Models 5-2
5.2.1.4 Optimisation Models 5-2
5.2.2 The Models Used by the Nations – General Overview 5-2
5.2.3 Models Used in Each Phase 5-3
5.2.3.1 Mission Need Evaluation Phase 5-3
5.2.3.2 Pre-Feasibility Phase 5-4
5.2.3.3 Feasibility Phase 5-4
5.2.3.4 Project Definition Phase 5-4
5.2.3.5 Design and Development Phase 5-4
5.2.3.6 Production Phase 5-5
5.2.3.7 In-Service Phase 5-5
5.2.3.8 Disengagement Phase 5-5
5.3 Recommendations 5-5
5.4 Desired Model Attributes 5-6
5.5 Cost Model Validation – A Practical Procedure 5-7
5.5.1 Preamble 5-7
5.5.2 The Procedure 5-7
5.5.3 Review of Basic Data 5-7
5.5.4 Test Regression 5-7
5.5.5 Calibration Tests 5-7
5.5.6 Prediction Tests 5-7
5.5.7 Mixed Tests 5-8
5.5.8 Frequency/Probability Distributions 5-8
5.5.9 Judging the Comparative Validity of Models 5-8

Chapter 6 – Data Collection 6-1
6.1 Evolution Through the Life Cycle 6-1
6.2 Data Sources 6-1
6.3 Data Documentation, Formats and Standards 6-3
6.4 Data from Suppliers/Contractors 6-4
6.5 Data Normalisation 6-6
6.5.1 Base Year 6-6
6.5.2 Constant Years versus Current Years 6-6
6.5.3 Using Indices 6-7
6.5.4 Exchange Rates 6-7
6.5.5 Inflation 6-8
6.6 References 6-8

Chapter 7 – Uncertainty and Risk 7-1
7.1 Introduction 7-1
7.2 Definitions 7-1
7.3 General Approach 7-2
7.3.1 Overview 7-2

7.4 Collecting Data for Risk Analysis 7-5
7.4.1 Techniques 7-6
7.4.1.1 Scorecards 7-6
7.4.1.2 Historical Data 7-6
7.4.1.3 Expert Opinion 7-6
7.5 Estimation Process 7-7
7.5.1 Baseline Cost Estimate 7-7
7.5.2 Risk-Adjusted Cost Estimate 7-8
7.6 Cost and Budget Risk 7-9
7.6.1 Cost Risk 7-9
7.6.2 Budget Risk 7-10
7.7 Sensitivity Analysis 7-11
7.8 Findings 7-11
7.9 Recommended Presentation of Results 7-12
7.10 References 7-13
Appendix 1: Optimism Bias 7-14

Chapter 8 – Other Related Life Cycle Costing Issues 8-1
8.1 Taxation 8-1
8.2 Discounting and Present Value 8-1
8.2.1 Discounting 8-1
8.2.2 Net Present Value 8-2
8.2.2.1 Example 8-3
8.3 Equivalent Annualised Costs 8-3
8.4 Variation of Price 8-4

Chapter 9 – New Developments in LCC Analysis 9-1
9.1 Reference 9-2

Chapter 10 – Enhance Work of SAS-028: CBS 10-1
10.1 Introduction 10-1
10.2 Rationale 10-1
10.3 Generic Hierarchy 10-1
10.4 Generic Cost Breakdown Structure Form 10-3
10.5 Dimensions 10-3
10.6 Recommended Enhancements to the NATO GCBS 10-4

Chapter 11 – Conclusions 11-1
11.1 General 11-1
11.2 Review of Cost Forecasting Methods 11-1
11.3 Review of Cost Forecasting Models 11-1
11.4 Guidelines for the Collection and Understanding of Cost Related Data for National and Multi-National Programmes 11-2

11.5 Treatment of Uncertainty and Risk 11-3
11.6 Guideline for Multi-National Programmes 11-3
11.7 Awareness of New Developments in Methods and Models 11-4
11.8 Review and Possible Enhancement of NATO Generic Cost Breakdown Structure 11-4

Chapter 12 – Recommendations 12-1
12.1 Key Recommendations 12-1
12.1.1 Life Cycle Costing Methods 12-1
12.1.2 Life Cycle Cost Models 12-1
12.1.3 Data for Life Cycle Costing 12-2
12.1.4 Multi-National Programmes 12-2
12.1.5 NATO Generic Cost Breakdown Structure 12-2
12.1.6 Uncertainty and Risk 12-2
12.2 Further Recommendations 12-3
12.3 Follow-on Activities 12-4

Annex A – Nation's Completed Matrix A-1

Annex B – Examples of Data Forms for Capturing the Costs at the Production Phase B-1

Annex C – Example of a Typical LCC Questionnaire C-1

Annex D – Life Cycle Costing Definitions D-1

Annex E – PAPS Milestone Definitions E-1
E.1 Mission Need Document (MND) E-1
E.2 Outline NATO Staff Target (ONST) E-1
E.3 NATO Staff Target (NST) E-1
E.4 NATO Staff Requirement (NSR) E-1
E.5 NATO Design and Development Objective (NADDO) E-1
E.6 NATO Production Objective (NAPO) E-1
E.7 NATO In-Service Goals (NISEG) E-2
E.8 National Disengagement Intention (NADI) E-2

List of Figures

Figure		Page
Figure 1-1	NATO Life Cycle Cost Management	1-2
Figure 2-1	Traditional LCC Committed versus Incurred Cost Curve	2-1
Figure 2-2	Generic Life Cycle Cost Estimating Process	2-3
Figure 2-3	Typical Life Cycle Cost Boundary	2-5
Figure 2-4	USA Cost Analysis Process	2-7
Figure 2-5	Example of a Typical Life Cycle Cost Framework Structure	2-8
Figure 2-6	Process Flow for Determining LCC Support to Logistic Analysis	2-10
Figure 2-7	Cost Risk Analysis Outputs Example	2-11
Figure 2-8	Example of a Baseline Life Cycle Cost Spend Profile	2-12
Figure 2-9	Example of a Life Cycle Cost Allocation	2-12
Figure 2-10	Recommended Presentation of Cost Estimating Risk Analysis	2-13
Figure 2-11	Example of Time-Period Consideration	2-16
Figure 2-12	LCC and the Tender Evaluation Process	2-17
Figure 2-13	Sample Chart of Funding Streams by Programme	2-18
Figure 2-14	Sample Chart of Funding Streams by Mission Area	2-19
Figure 2-15	Sample Annual Modernisation Funding	2-20
Figure 2-16	Identification of the Options to be Assessed	2-22
Figure 2-17	Models Output Aggregation	2-24
Figure 3-1	PAPS Life Cycle Milestones and Phases	3-3
Figure 3-2	Make or Buy Track PAPS Life Cycle	3-6
Figure 3-3	Simplified Pre-Feasibility Phase Life Cycle Costing Process	3-8
Figure 3-4	Military Balance of Investment Example	3-10
Figure 3-5	Benefits Analysis Example	3-11
Figure 3-6	Cost-Performance Plot Example	3-12
Figure 3-7	Simplified Feasibility and Project Definition Life Cycle Costing Process	3-15
Figure 3-8	End-State Solution	3-16
Figure 3-9	Example Sensor Fidelity to Software Size	3-17
Figure 3-10	Simplified Design and Development Phase Life Cycle Costing Process	3-21
Figure 3-11	Example of Analogy Cost Estimating	3-23
Figure 3-12	Example of Historical Trend Analysis	3-24
Figure 3-13	Example of EVM Calculations	3-26
Figure 3-14	Example of EVM Process	3-27

Figure 3-15	LCC Data Process	3-31
Figure 3-16	Availability Precedence	3-32
Figure 3-17	LCC Evaluation Results	3-32
Figure 3-18	LSC Evaluation Results	3-33
Figure 3-19	Simplified Production Phase Life Cycle Costing Process	3-36
Figure 3-20	Learning Curve Example	3-38
Figure 3-21	Simplified In-Service Phase Life Cycle Costing Process	3-42
Figure 3-22	The Interface and Menu Components of EDCAM	3-43
Figure 3-23	Simplified Disengagement Phase Life Cycle Costing Process	3-46
Figure 3-24	"Translation" from PAPS Phases to ISO 15288 Stages	3-48
Figure 4-1	Example of Typical Distribution Types	4-3
Figure 4-2	Example of Monte Carlo Output	4-4
Figure 4-3	Bayesian Application to Cost Estimating	4-6
Figure 4-4	Summary of Methods Used by the Nations	4-12
Figure 5-1	Analysis of Nations' Matrices	5-3
Figure 5-2	Comparison of Two Models	5-8
Figure 6-1	Development of Master Data and Assumptions List	6-5
Figure 7-1	Risk Matrix	7-2
Figure 7-2	Process of Estimating Risk and Uncertainty	7-3
Figure 7-3	Baseline Cost Estimate	7-8
Figure 7-4	Risk-Adjusted Cost Estimate	7-9
Figure 7-5	Cost Risk Analysis Output	7-10
Figure 7-6	Budget Risk Analysis Output	7-10
Figure 7-7	Example of Sensitivity Analysis Tornado Chart	7-11
Figure 7-8	Summary of Methods and Models Used to Measure Risk and Uncertainty	7-12
Figure 7-9	Recommended Presentation of Cost Estimating Risk Analysis	7-13
Figure 7-10	Application of Optimism Bias	7-15
Figure 9-1	Prioritising using Portfolio Analysis	9-1
Figure 10-1	Proposed Generic Hierarchy Cost Breakdown Structure	10-2
Figure 10-2	Example of Aggregated Cost Elements	10-3
Figure A-1	Completed Matrix from Denmark	A-1
Figure A-2	Completed Matrix from France	A-2
Figure A-3	Completed Matrix from Germany	A-3
Figure A-4	Completed Matrix from Greece	A-4
Figure A-5	Completed Matrix from Italy	A-5

Figure A-6	Completed Matrix from Norway	A-6
Figure A-7	Completed Matrix from Sweden	A-7
Figure: A-8	Completed Matrix from Switzerland	A-8
Figure A-9	Completed Matrix from The Netherlands	A-9
Figure A-10	Completed Matrix from Turkey	A-10
Figure A-11	Completed Matrix from the United States of America	A-11
Figure A-12	Completed Matrix from the United Kingdom	A-12
Figure B-1	UK Contractor Data Sheet – Appendix A	B-1
Figure B-2	UK Contractor Data Sheet – Appendix B	B-3
Figure B-3	USA Functional Cost Hour and Progress Curve Report (DD Form 1921-1 Front)	B-4
Figure B-4	USA Functional Cost Hour and Progress Curve Report (DD Form 1921-1 Back)	B-5
Figure B-5	USA Cost Data Summary Report (DD Form 1921)	B-6
Figure B-6	USA Software Resources Data Report – Initial Government Report (Page 1)	B-7
Figure B-7	Software Resources Data Report – Initial Government Report (Page 2)	B-8
Figure B-8	Software Resources Data Report – Initial Developer Report (Page 1)	B-9
Figure B-9	Software resources Data Report – Initial Developer Report (Page 2)	B-10
Figure B-10	Software Resources Data Report – Final Developer Report (Page 1)	B-11
Figure B-11	Software Resources Data Report – Final Developer Report (Page 2)	B-12

List of Tables

Table		Page
Table 1-1	Summary Matrix Questions for Each Participating Nation	1-4
Table 4-1	Method Categorisation	4-1
Table 6-1	Sources of Data	6-2
Table 7-1	Optimism Bias Estimate Uplift Percentages	7-14

List of Acronyms

AACP	Allied Acquisition Practices Publications
AACP-1	Guidance Manual for Cooperative Programme Arrangements
AAP	Allied Administrative Publication
AAP-20	Handbook on the Phased Armaments Planning System
AAP-48	Handbook to NATO System Life Cycle Management Volume 1 & 2 (Initial Draft), February 2006
ABC	Activity Based Cost
AC/327	NATO Life Cycle Management Group (LCMG)
ACAT	Acquisition Category
ACWP	Actual Cost of Work Performed
AGS	Alliance Ground Surveillance System
AHP	Analytic Hierarchy Process
ALP-10	Guidance on Integrated Logistic Support (ILS) for Multinational Equipment Projects
ANEP-41	NATO standard for shipbuilding Work Breakdown Structures
AoA	Analysis of Alternatives
APB	Acquisition Programme Baseline
ARM	Availability, Reliability and Maintainability
AWACS	Airborne Warning and Control System
BCWS	Budgeted Cost of Work Scheduled
BWA	German Defence Materiel Administration
CAIG	Cost Analysis Improvement Group
CALS	Continuous Acquisition and Life Cycle Support
CARD	Cost Analysis Requirements Description
CBA	Cost Benefit Analysis
CBS	Cost Breakdown Structure
CCDR	Contractor Cost Data Reporting
CDB	Cost Data Base
CDIP	Cooperation on Defence Implementations of PLCS
CER	Cost Estimating Relationship
CM(62)18	NATO Council Resolution C-M(62)18 on Regulations for NATO Production and Logistics Organizations
CNAD	Conference of National Armaments Directors
COEIA	Combined of Operational Effectiveness and Investment
CONOPS	Concept of Operations
COTS	Commercial Off-The-Shelf [models]
CPI(h)	Cost Performance Index
CSDR plan	Cost and Software Date Reporting Plan
CV	Cost Variance
DCARC	US Defense Cost and Resource Center
DEX	Data EXchange Sets

DGA	French Defence Materiel Administration
DGAT	Direzione Generale Degli Armamenti Terrestri (Italy)
DoD	US Department of Defense
DOE	US Department of Energy
DOTMLPF Solutions	Doctrine, Organization, Training, Materiel, Leadership and Education, Personnel and Facilities Solutions (US DoD)
EAC	1) Estimate at Completion or Estimated Cost of Contract at Completion 2) Equivalent Annual Cost
EDCAM	Educational Cost Effectiveness Analysis Model
ERP	Enterprise Resource Planning
EVM	Earned Value Management
FAA	Federal Aviation Administration (US)
FACET	Family of Advanced Cost Estimating Tools, HVR Consulting Services Ltd.
FFI	Norwegian Defence Research Establishment
FMV	Swedish Defence Materiel Administration
FOI	Swedish Defence Research Agency
FOM	Figure of Merit
FREMM	Frégates Européennes Multi-Missions
FWA	Factor Weighting Analysis
FY	Fiscal Year
FYDP	Future Years Defence Programme
GCBS	Generic Life Cycle Cost Breakdown Structure
GFX	Government Funded Equipment / support
GSE	Government Supplied Equipment
GWOT	Global War on Terrorism
i.a.w.	in accordance with
IH	In-house
ILS	Integrated Logistic Support
IPO	International Programme Office
IPT	Integrated Product Team
IPTL	Integrated Project Team Leader
ISO	International Standards Organisation
ISO 10303-239	Industrial automation systems and integration – Product data representation and exchange – Part 239: Application protocol: Product life cycle support
ISO 15288	ISO standard (published in October 2002) to deal with system life-cycle processes; hardware, software and human interfaces
ISP	Integrated Support Plan
ITT	Invitation to Tender
JSF	Joint Strike Fighter
KSLOC	Thousands of Sources Lines Of Code

LCC	Life Cycle Cost
LCCA	Life Cycle Cost Analysis
LCMG	Life Cycle Management Group (AC/327)
LCMP	Life Cycle Management Plan
LOC	Life Operation Cost
LORA	Level of Repair Analysis
LRU	Line Replaceable Unit
LSA	Logistic Support Analysis
LSAR	Logistic Support Analysis Record
LSC	Life Support Costs
MACE	Multi Attribute Choice Elucidation
Maint & Mgmt	Maintenance and Management
MANPRINT Plan	Manpower and Personnel Integration Plan
MCDA	Multi Criteria Decision Analysis
MDAL	Master Data and Assumptions List (UK)
MDAP	Major Defence Acquisition Programme
MIL	Generic Top Level Domain Name for U.S. military
MND	Mission Need Document
MoD	Ministry of Defence (UK)
MOEs	Measures of Effectiveness
MOPs	Measures of Performance
MoU	Memorandum of Understanding
MTBF	Mean Time Between Failures
MTTR	Mean Time To Repair
MWT	Mean Waiting Time
NADDO	NATO Design and Development Objective
NADI	National Disengagement Intention
NAMSA	NATO Maintenance and Supply Agency
NAPO	NATO Production Objective
NATO	North Atlantic Treaty Organisation
NC3A	NATO Command, Control and Consultation Agency
NC3O	NATO Consultation, Command and Control Organisation
NCDM	NATO CALS Data Model
NH-90	Twin engine, 10.6 ton multi-role helicopter, developed to meet naval and tactical transport helicopter
NHSP	Nordic Standard Helicopter Programme
NIAG	NATO Industrial Advisory Group
NISEG	NATO In-Service Goals
NPDM	NATO Product Data Model
NPSC	NATO Project Steering Committee
NPV	Net Present Value
NSHP	Nordic Standard Helicopter Programme
NSR	NATO Staff Requirement
NST	NATO Staff Target

O&S	Operation and Support
OA	Operational Analysis
OASIS	Organization for the Advancement of Structured Information Standards
OCCAR	Organisation Conjoint de Coopération en matière d'Armement
ONST	Outline NATO Staff Target
OPTEMPO	Methodology to prepare budget requests that accurately reflect Operations and Maintenance requirements
OSD	Office of the Secretary of Defense
PAPS	Phased Armaments Programming System
PEO	Programme Executive Officer
PERT	Programme Evaluation and Review Technique
PESTEL analysis / techniques	Political, Economic, Social, Technological, Environmental and Legal analysis / techniques
PfP	Partnership for Peace
PHST	Packaging, Handling, Storage and Transportation
PLCC	Programme Life Cycle Cost
PLCS	Product Life Cycle Support
PM	Project Manager
PMB	Performance Measurement Baseline
PPP	Purchasing Power Parities
PV	Present Value
QDR	Quadrennial Defense Review (US)
R&D	Research & Development
R&M	Reliability and Maintainability
RDL	Reference Data Libraries
RDT&E	Research, Development, Test, and Evaluation
RFI	Request for Information
RFP	Request for Proposal
RFQ	Request for Quotation
RTA	Research and Technology Agency
RTG	Research Task Group
RTO	Research and Technology Organisation
SAS	Studies, Analysis and Simulation Panel / Working Group
SAS ET-AH	Exploratory Team on Methods and Models for Life Cycle Costing
SAS-028	Cost Structure and Life Cycle Costs (LCC) for Military Systems
SAS-054	Methods and Models for Life Cycle Costing
SAS-057	Information Operations In Smaller Scale Contingencies – Analysis and Capability Requirements
SAS-063	Benchmarking Studies and Capability Costing
SCAF	Society of Cost Analysis and Forecasting
SCEA	Society of Cost Estimating and Analysis
SE	Synthetic Environment
SLC	System Life Cycle

SLCM	System Life Cycle Management
SLOC	Source Lines Of Code
SME	Subject Matter Experts
SOI	System Of Interest
SPI(h)	Schedule Performance Index
SRDR	Software Sources Data Report
STANAG	NATO Standardization Agreement
STANAG 4661	ISO 10303-239 standard for exchange of life cycle data, put forward by NATO to be adopted as STANAG 4661
STEP	Standard of Exchange for Product Model Data
SV	Schedule Variance
T1	First Unit Cost
TAP	Technical Activity Proposal
TAT	Turnaround Time
TLCC	Total Life Cycle Cost
TNO	Contract Research Organisation in The Netherlands
TOA	Total Obligation Authority
TOC	Total Ownership Cost
TOR	Terms of Reference
TR	Technical Report
UAV	Unmanned Aerial Vehicle
UPC	Unit Production Cost
VAMOSC	Visibility And Management of Operation and Support Costs
VAT	Value-Added Tax
VSW	Very Shallow Water
WBS	Work Breakdown Structure
WLC	Whole Life Cost
WT_A	Waiting Time
WT_{LRU}	Waiting Time Line Replacable Unit

Programme Participants

Nation	Representative	Organisation
Denmark	Dr. Thomas E. Pedersen	Danish Defence Research Establishment, Denmark
France	Vincent Auger	MoD, DGA, Paris, France
Germany	Kai-Uwe Schwengber	BWB, Koblenz, Germany
	Walter Boos	BWB, Koblenz, Germany
Greece	Ltc Panagiotis Paganis	Hellenic Army General Staff, Athens, Greece
Italy	LtCol Massimo Pica	MoD, DGAT, Rome, Italy
	Enrico Bononi	SELEX Sistemi Integrati, Rome, Italy
Norway	Pål-Remy Østbye	FFI, Norwegian Defence Research Establishment, Norway
	Morten Hjelm	Norwegian Defence Materiel Agency, Norway
OCCAR	Frank Ramaroson	ILS2 Officer, PM Support Div, Bonn, Germany
Sweden	Lotta Björnström	FOI, Swedish Defence Research Agency, Stockholm
	Ulf Jonsson	FOI, Swedish Defence Research Agency, Stockholm
	Peter Wickberg	FOI, Swedish Defence Research Agency, Stockholm
	Fredrik Boström	FMV, Swedish Defence Material Administration, Stockholm
Switzerland	Reto Zogg	Planning Staff Swiss Armed Forces, Bern, Switzerland
The Netherlands	Marcel Smit	TNO, The Hague, The Netherlands
Turkey	LCdr Erhan Akdeniz	Turkish Naval Forces Command, Ankara, Turkey
	Lt Baris Kucukali	Turkish Naval Forces Command, Ankara, Turkey
	Lt Alper Koprulu	Turkish General Staff, Ankara, Turkey
	Capt Mustafa Pektas	Turkish Air Force, Ankara, Turkey
	Lt Mehmet Gumus	Turkish General Staff, Ankara, Turkey
USA	Dr. Brian Flynn	US DoD, Naval Center for Cost Analysis, USA
	Russell Vogel	US DoD, Cost Analysis Improvement Group, USA
United Kingdom	Terry Johns	UK MoD, Pricing and Forecasting Group, Bristol, UK
	Arthur Griffiths	HVR Consulting Services Ltd, Alton, Hants, UK

Observing Nations and Organisations

Nation	Representative	Organisation
Belgium	Prof. Wally Struys	Royal Military Academy, Belgium
Czech Republic	Pavel Rohovsky	MoD, Armaments Division, Praha, Czech Republic
Georgia	Georgi Rusiashvili	Fircroft Engineering Services Ltd, Tiblisi, Georgia
AC/327 SG B WG 3	Maj Ilie Tita	MoD, Department for Armaments, Romania
	Prof. Ticusor Ciobotaru	Military Technical Academy, Romania

Acknowledgements

We would like to thank all the participation nations and, in particular, those members of the programme committee for their contribution which will be of benefit to all NATO and PfP nations.

We would also like to recognise the contribution of Mr. Marcel Smit for his Chairmanship of the study and to Mr. Arthur Griffiths who acted as Secretary and Editor of the report.

REPORT DOCUMENTATION PAGE

1. Recipient's Reference	2. Originator's References	3. Further Reference	4. Security Classification of Document
	RTO-TR-SAS-054 AC/323(SAS-054)TP/51	ISBN 978-92-837-0072-2	UNCLASSIFIED/ UNLIMITED

5. Originator

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

6. Title

Methods and Models for Life Cycle Costing

7. Presented at/Sponsored by

Final Report of Task Group SAS-054.

8. Author(s)/Editor(s)	9. Date
Multiple	June 2007

10. Author's/Editor's Address	11. Pages
Multiple	226

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

Armed forces procurement
Budgeting
COO (Cost of Ownership)
Cost analysis
Cost comparison
Cost estimates
Economic life analysis
Life (durability)
Life cycle costs
Life cycles
Logistics planning
Logistics support
Logistics support analysis
Maintainability
Methodology
Military planning
Models
Service life

14. Abstract

This report is the product of the System Analysis and Studies (SAS) Task Group SAS-054 review of NATO and Partner nations' cost forecasting methods and models. The Task Group's core objectives were to understand NATO and Partner nations' methods and models for life cycle costing, and to promulgate best practice within the NATO Phased Armaments Programming System (NAPS). The SAS-054 report provides a comprehensive view on the application and use of life cycle costing from an early conceptual phase in the product life cycle through to the disposal phase. It provides illustrations on the types of life cycle cost studies that can be conducted and examples to demonstrate the benefits of such analysis. The treatment of uncertainty and risk within the context of developing the life cycle cost estimate is also explained within the report. The report concludes with a number of recommendations to improve the use and understanding of life cycle costing in the decision making process.

NORTH ATLANTIC TREATY ORGANISATION

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

RESEARCH AND TECHNOLOGY ORGANISATION

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)
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, 9e étage
Ottawa, Ontario K1A 0K2

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

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

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

ISLANDE
Director of Aviation
c/o Flugrad
Reykjavik

ITALIE
General Secretariat of Defence and National Armaments Directorate
5th 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
Centralny Ośrodek Naukowej Informacji Wojskowej
Al. Jerozolimskie 97
00-909 Warszawa

PORTUGAL
Estado Maior da Força Aérea
SDFA – 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 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)
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://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

BP 25

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

RESEARCH AND TECHNOLOGY ORGANISATION

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
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, 9th 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

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

ICELAND
Director of Aviation
c/o Flugrad, Reykjavik

ITALY
General Secretariat of Defence and National Armaments Directorate
5th 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
Centralny Ośrodek Naukowej Informacji Wojskowej
Al. Jerozolimskie 97
00-909 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

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)
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://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 978-92-837-0072-2