



Keith A. Rigby

Aircraft Systems

Integration of

Air-Launched Weapons

Aerospace Series

Editors Peter Belobaba, Jonathan Cooper,
Roy Langton and Allan Seabridge

 **WILEY**

AIRCRAFT SYSTEMS INTEGRATION OF AIR-LAUNCHED WEAPONS

Aerospace Series List

Design and Analysis of Composite Structures: With Applications to Aerospace Structures, Second Edition	Kassapoglou	April 2013
Aircraft Systems Integration of Air-Launched Weapons	Rigby	April 2013
Design and Development of Aircraft Systems, Second Edition	Moir and Seabridge	November 2012
Understanding Aerodynamics: Arguing from the Real Physics	McLean	November 2012
Aircraft Design: A Systems Engineering Approach	Sadraey	October 2012
Introduction to UAV Systems, Fourth Edition	Fahlstrom and Gleason	August 2012
Theory of Lift: Introductory Computational Aerodynamics with MATLAB and Octave	McBain	August 2012
Sense and Avoid in UAS: Research and Applications	Angelov	April 2012
Morphing Aerospace Vehicles and Structures	Valasek	April 2012
Gas Turbine Propulsion Systems	MacIsaac and Langton	July 2011
Basic Helicopter Aerodynamics, Third Edition	Seddon and Newman	July 2011
Advanced Control of Aircraft, Spacecraft and Rockets	Tewari	July 2011
Cooperative Path Planning of Unmanned Aerial Vehicles	Tsourdous et al.	November 2010
Principles of Flight for Pilots	Swatton	October 2010
Air Travel and Health: A Systems Perspective	Seabridge et al.	September 2010
Unmanned Aircraft Systems: UAVS Design, Development and Deployment	Austin	April 2010
Introduction to Antenna Placement and Installations	Macnamara	April 2010
Principles of Flight Simulation	Allerton	October 2009
Aircraft Fuel Systems	Langton et al.	May 2009
The Global Airline Industry	Belobaba	April 2009
Computational Modelling and Simulation of Aircraft and the Environment: Volume 1	Diston	April 2009
Platform Kinematics and Synthetic Environment Handbook of Space Technology	Ley, Wittmann Hallmann	April 2009
Aircraft Performance Theory and Practice for Pilots	Swatton	August 2008
Aircraft Systems, Third Edition	Moir and Seabridge	March 2008
Introduction to Aircraft Aeroelasticity and Loads	Wright and Cooper	December 2007
Stability and Control of Aircraft Systems	Langton	September 2006
Military Avionics Systems	Moir and Seabridge	February 2006
Design and Development of Aircraft Systems	Moir and Seabridge	June 2004
Aircraft Loading and Structural Layout	Howe	May 2004
Aircraft Display Systems	Jukes	December 2003
Civil Avionics Systems	Moir and Seabridge	December 2002

AIRCRAFT SYSTEMS INTEGRATION OF AIR-LAUNCHED WEAPONS

Keith A. Rigby
BAE Systems, UK



A John Wiley and Sons, Ltd, Publication

This edition first published 2013
© 2013, John Wiley & Sons Ltd.

Registered Office

John Wiley & Sons Ltd, The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ,
United Kingdom

For details of our global editorial offices, for customer services and for information about how to apply for permission to reuse the copyright material in this book please see our website at www.wiley.com.

The right of the author to be identified as the author of this work has been asserted in accordance with the Copyright, Designs and Patents Act 1988.

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, except as permitted by the UK Copyright, Designs and Patents Act 1988, without the prior permission of the publisher.

Wiley also publishes its books in a variety of electronic formats. Some content that appears in print may not be available in electronic books.

Designations used by companies to distinguish their products are often claimed as trademarks. All brand names and product names used in this book are trade names, service marks, trademarks or registered trademarks of their respective owners. The publisher is not associated with any product or vendor mentioned in this book. This publication is designed to provide accurate and authoritative information in regard to the subject matter covered. It is sold on the understanding that the publisher is not engaged in rendering professional services. If professional advice or other expert assistance is required, the services of a competent professional should be sought.

Library of Congress Cataloging-in-Publication Data

Rigby, Keith A.

Aircraft systems integration of air launched weapons / by Keith A. Rigby.

pages cm

Includes bibliographical references and index.

ISBN 978-0-470-97118-5 (cloth)

1. Air weapons. 2. Air-to-surface missiles. 3. Airplanes, Military--Armament. 4. Airplanes, Military--Design and construction. 5. Systems integration. 6. Aeronautics--Systems engineering.

I. Title.

UG1270.R54 2013

623.4'51--dc23

2012047732

A catalogue record for this book is available from the British Library.

Set 10/12pt Times by SPi Publisher Services, Pondicherry, India

Contents

Series Preface	xi
Preface	xiii
Acknowledgments	xv
List of Abbreviations	xvii
1 Introduction to Weapons Integration	1
1.1 Introduction	1
1.2 Chapter Summaries	2
1.2.1 <i>The Systems Integration Process</i>	2
1.2.2 <i>Stores Management System Design</i>	2
1.2.3 <i>The Global Positioning System</i>	3
1.2.4 <i>Weapon Initialisation and Targeting</i>	3
1.2.5 <i>The Role of Standardisation in Weapons Integration</i>	3
1.2.6 <i>Interface Management</i>	4
1.2.7 <i>A Weapons Integration Scenario</i>	4
1.2.8 <i>'Plug and Play' Weapons Integration</i>	5
1.2.9 <i>Weaponised Unmanned Air Systems</i>	5
1.2.10 <i>Reducing the Cost of Weapons Integration</i>	6
1.3 Weapons	6
1.3.1 <i>Types of Weapon</i>	6
1.3.2 <i>Targets</i>	6
1.3.3 <i>Weapon Requirements</i>	7
1.3.4 <i>Lethality</i>	7
1.3.5 <i>Precision</i>	8
1.3.6 <i>Stand-Off Range</i>	10
1.3.7 <i>Typical Weapon Configurations</i>	11
1.3.8 <i>Implications for the Launch Aircraft</i>	11
1.4 Carriage Systems	14
1.4.1 <i>Mechanical Attachments</i>	14

1.4.2	<i>Downward Ejection</i>	14
1.4.3	<i>Forward Firing</i>	15
1.4.4	<i>Multi-weapon Carriage Systems</i>	15
	Further Reading	16
2	An Introduction to the Integration Process	17
2.1	Chapter Summary	17
2.2	Introduction	17
2.3	The V-Diagram	18
2.4	Responsibilities	18
2.5	Safety	20
2.6	The Use of Requirements Management Tools in the Systems Engineering Process	24
2.7	Weapons Integration Requirements Capture	24
2.8	The Need for Unambiguous, Clear and Appropriate Requirements	26
2.9	Minimising Requirements	29
	Further Reading	30
3	Requirements Analysis, Partitioning, Implementation in Aircraft Subsystems	31
3.1	Chapter Summary	31
3.2	Introduction	31
3.3	System Architecture	33
3.4	Requirements Decomposition	34
3.5	Requirements Partitioning	35
3.6	Subsystem Implementation	36
3.7	Maturity Reviews	37
3.8	Right-Hand Side of the V-Diagram	38
3.9	Proving Methods	38
3.10	Integration	41
3.11	Verification	42
3.12	Validation	42
3.13	The Safety Case and Certification	42
	Further Reading	45
4	Armament Control System and Global Positioning System Design Issues	47
4.1	Chapter Summary	47
4.2	Stores Management System Design	48
4.2.1	<i>SMS Design Requirements</i>	48
4.2.2	<i>Other System Components</i>	50
4.2.3	<i>Typical System Architectures</i>	53
4.2.4	<i>Training System</i>	55
4.3	GPS: Aircraft System Design Issues	59
4.3.1	<i>GPS Overview</i>	59
4.3.2	<i>Satellite Acquisition Concepts</i>	64
4.3.3	<i>Acquisition Strategies</i>	65

4.3.4	<i>GPS Signal Distribution</i>	65
4.3.5	<i>Aircraft Requirements</i>	67
4.3.6	<i>Aircraft Implementation Concepts</i>	68
4.3.7	<i>Cost of Complexity</i>	70
	Further Reading	70
5	Weapon Initialisation and Targeting	71
5.1	Chapter Summary	71
5.2	Targeting	71
5.3	Aiming of Ballistic Bombs	72
5.4	Aircraft/Weapon Alignment	73
5.5	Aiming of Smart Air-to-Ground Weapons	74
5.6	Air-to-Air Missiles	76
5.6.1	<i>Sensors</i>	76
5.6.2	<i>Engagement Modes</i>	77
5.6.3	<i>Air-to-Air Weapons Training</i>	78
	Further Reading	79
6	Weapon Interface Standards	81
6.1	Chapter Summary	81
6.2	Benefits of Standardisation	81
6.3	MIL-STD-1760 AEIS	82
6.3.1	<i>MIL-STD-1760 Interface Points</i>	83
6.3.2	<i>Connectors</i>	83
6.3.3	<i>Signal Sets</i>	85
6.3.4	<i>GPS RF Signal Distribution</i>	85
6.3.5	<i>Data Protocols</i>	90
6.3.6	<i>Data Entities</i>	94
6.3.7	<i>Time Tagging</i>	94
6.3.8	<i>Mass Data Transfer</i>	95
6.3.9	<i>High-Speed 1760</i>	96
6.4	Standardisation Conclusions	96
	Further Reading	97
7	Other Weapons Integration Standards	99
7.1	Chapter Summary	99
7.2	AS5725 Miniature Mission Store Interface	99
7.2.1	<i>Interface Points</i>	99
7.2.2	<i>Connector</i>	101
7.2.3	<i>Signal Set</i>	101
7.3	AS5726 Interface for Micro Munitions	103
7.3.1	<i>Interface Points</i>	103
7.3.2	<i>Connectors</i>	104
7.3.3	<i>Signal Set</i>	104
7.4	Other Weapons Integration Standards	106
7.4.1	<i>Generic Aircraft–Store Interface Framework</i>	106

7.4.2	<i>Mission Data Exchange Format</i>	108
7.4.3	<i>Common Launch Acceptability Region Approach</i>	109
	Further Reading	110
8	Interface Management	111
8.1	Chapter Summary	111
8.2	Introduction	111
8.3	Management of the Aircraft/Store Interface	112
8.4	Approaches to Interface Documentation	114
8.5	Interfaces Documented in the ICD	115
8.6	Controlling the Interface of Store Variants	119
8.7	Information Exchange between Design Organisations	120
8.8	Process for Managing Integration Risk	120
	Further Reading	124
9	A Weapons Integration Scenario	125
9.1	Chapter Summary	125
9.2	Introduction	125
9.3	The Weapons Integration Scenario	126
9.4	The V-Diagram Revisited	129
9.5	Systems Integration Activities	130
9.6	Safety	132
9.6.1	<i>Aircraft/System Hazards</i>	136
9.6.2	<i>Weapon Hazards</i>	139
9.7	Systems Requirements Decomposition, Design and Implementation	140
9.7.1	<i>Weapon System Integration Requirement</i>	140
9.7.2	<i>Functional Definition and Development/Interface Definition</i>	140
9.7.3	<i>Weapon Interfacing</i>	141
9.7.4	<i>Data Flows between Aircraft Subsystems</i>	143
9.8	Loading to Dispersion Sequence	143
9.8.1	<i>Weapon Loading</i>	145
9.8.2	<i>System Power-Up/Store Discovery</i>	145
9.8.3	<i>Build Inventory</i>	146
9.8.4	<i>Weapon BIT/System Power-Down</i>	147
9.8.5	<i>Download Target Data/Power-Down Weapons</i>	148
9.8.6	<i>Taxi/Take-Off/On-Route Phase</i>	149
9.8.7	<i>Weapon Selection and Priming</i>	149
9.8.8	<i>Update Target Data</i>	150
9.8.9	<i>Steer to Target LAR/Confirm in LAR</i>	151
9.8.10	<i>Initiate Release Sequence</i>	151
9.8.11	<i>Weapon Release Phase</i>	153
9.8.12	<i>Selective/Emergency Jettison</i>	154
9.8.13	<i>Carriage Store Control</i>	155
9.8.14	<i>Training Capability</i>	156
9.8.15	<i>Implications of Aeromechanical Aspects – Weapon Physical Alignment</i>	156
	Further Reading	158

10	A Weapons Integration Scenario: System Proving and Certification	159
10.1	Chapter Summary	159
10.2	Introduction	159
10.3	Simulators and Emulators	160
10.4	Avionic Weapons	160
10.5	Interface Proving	160
10.6	Rig Trials	161
10.7	Avionic Trials	162
10.8	Electromagnetic Compatibility	162
10.9	Airworthiness and Certification	163
10.10	Declaration of Design and Performance/Statement of Design	164
10.11	Certificate of Design	164
10.12	Safety Case	165
10.13	Airworthiness Flight Limitations	165
10.14	Release to Service	165
10.15	User Documentation	165
10.16	Weapon System Evaluation	166
10.17	Conclusion	167
	Further Reading	167
11	Introduction to ‘Plug and Play’ Weapons Integration	169
11.1	Chapter Summary	169
11.2	Systems Integration Considerations	169
11.3	The Journey to ‘Plug and Play’ Weapons Integration	171
11.4	‘Plug and Play’ Technologies	172
11.5	Adoption of ‘Plug and Play’ Technology	172
11.6	Introduction to Aircraft, Launcher and Weapons Interoperability	173
11.7	ALWI Study	174
11.8	ALWI-2 Study	176
11.9	ALWI Common Interface Study	179
	11.9.1 <i>Technical Architecture</i>	180
	11.9.2 <i>Greater Interoperability through a Common ICD Approach</i>	181
	11.9.3 <i>Common Store Control Service</i>	181
	11.9.4 <i>Model-Driven Architecture Approach</i>	183
	11.9.5 <i>Implementation Considerations</i>	185
11.10	ALWI Conclusions	186
	Further Reading	187
12	Open Systems	189
12.1	Chapter Summary	189
12.2	Introduction	189
12.3	The Contracting and Industry Environment	190
12.4	Current Systems	191
12.5	A Typical Mission Systems Upgrade Programme	192
12.6	ASAAC Architecture	193
12.7	ASAAC and ‘Plug and Play’	195

12.8	Certification Issues	198
12.9	Easing the Upgrade Programme	200
	Further Reading	201
13	The Universal Armament Interface	203
13.1	Chapter Summary	203
13.2	Introduction	203
13.3	Objectives of UAI	204
13.4	Fundamental Principles of UAI	207
13.5	Platform/Store Interface	209
13.6	Mission Planning	210
13.7	Launch Acceptability Region	211
13.8	Integration Work Flow	211
13.9	UAI Interface Management	213
13.10	Certification Tools	214
13.11	Benefits	215
13.12	NATO UAI	216
13.13	'Plug and Play' Conclusions	216
	Further Reading	217
14	Weaponised Unmanned Air Systems	219
14.1	Chapter Summary	219
14.2	Introduction	219
14.3	Distributed Weapon System	220
14.4	System Architecture Partitioning	222
14.5	Conclusions	226
	Further Reading	226
15	Reducing the Cost of Weapons Integration	227
15.1	Chapter Summary	227
15.2	Introduction	227
15.3	The Cost Landscape	229
15.4	Reducing the Cost of Weapons Integration – Other Initiatives	231
15.4.1	<i>Streamlined Integration Processes</i>	232
15.4.2	<i>Common Goals for the ADO and WDO</i>	232
15.4.3	<i>Employment of New Technology Which Eases Integration</i>	233
15.4.4	<i>The Need for Exports</i>	233
15.4.5	<i>Spiral Introduction of Capability</i>	234
15.4.6	<i>Organisational Re-structuring</i>	234
15.4.7	<i>Adoption of International Standards</i>	234
15.5	Conclusions	234
15.6	The Future	236
	Further Reading	237
	Index	239

Series Preface

The Aerospace Series has concerned itself largely with the design of aerospace vehicles and their systems, comprehensively covering aspects of structural and system design in theoretical and practical terms. There has been reference to military aircraft types in the books of the Series, sometimes as developments of commercial aircraft for surveillance or transport roles, and other times as specific combat types. However, there has been no detailed consideration of one aspect that is quite specifically applicable to military types – the carriage and release of air launched weapons.

In this book, the author takes a systems engineering view of the weapon and platform as an integrated whole for both manned and unmanned aircraft. The importance of considering the integration of the weapon with the airframe and with the aircraft systems is stressed as it is vital to the achievement of a safe and successful launch with a high probability of target destruction. This aspect of integration is important to the introduction of precision weapons with a high degree of accuracy to reduce the incidence of collateral damage, as well as making best use of costly weapons.

It is important for engineers and designers to visualise the totality of a system in order to gain an understanding of all that is involved in the establishment of requirements and the certification process to arrive at a coherent design of vehicle and infrastructure. Understanding the impact of external weapons installation on aircraft performance and handling, and the needs of the weapon for navigation and attitude information, is key to understanding how to aim, fuze and release a weapon for maximum effect. This understanding enables developments in new aircraft types and new weapon types to be understood and adapted so that the most effective weapon system can be selected and developed for a particular aircraft in order to respond to changing threats.

This book is a comprehensive treatise on the subject of air launched weapons and will be of great value to all design engineers, support engineers, air crew and armourers working on armed military aircraft. The message is reinforced by the introduction of a worked example of integration of a smart weapon with the airframe. It also provides a good background to people

who have an interest, professional or casual, in the design of aircraft weapon systems. It is worth noting that the book carefully avoids any areas of security classification, thereby making the book accessible to a wide audience.

Peter Belobaba, Jonathan Cooper and Allan Seabridge

Preface

For any military conflict where Western air forces are involved, the public is accustomed to media coverage of weapons being targeted against the enemy. Whether this is an Air-to-Ground missile being aimed at a particular window in a building or a smart bomb destroying a strategically located bridge, the public understand that in modern warfare precision weapons can provide surgical attack capabilities whilst minimising collateral damage and harm to non-combatants.

However, the terminal accuracy of a guided weapon significantly depends on its priming prior to release. Simply, the launch aircraft and weapon together form a complex system where the performance of each component is interdependent on the performance of the other.

It is unusual for a weapon to be designed specifically for operation with a single aircraft type; it will generally be designed to provide a particular military capability when operated with a range of aircraft. The Weapon Design Organisation will generally define an idealised set of requirements to be placed on the launch aircraft such that if they are satisfied, the weapon can achieve its specified performance. However, although the Weapon Design Organisation has responsibility for the design, development and certification of the weapon, generally, it is the Aircraft Design Organisation that has responsibility for the design, development and certification of the total aircraft and for certification of the aircraft/weapon combination. As the aircraft may not be able to satisfy the set of ideal requirements placed on it by the weapon, the terminal performance of the weapon may be degraded.

Whenever a weapon has to be integrated with an aircraft, there will be a need for the Aircraft and Weapon Design Organisations to collaborate to satisfy the needs of the Government agency (the Contracting Agency) which contracts for the integrated capability. Whilst this may bring many organisational interaction challenges, the pure engineering activities which need to be undertaken are many and complex.

For the purposes of this book, weapons integration is divided into systems integration activities and aeromechanical activities (e.g. covering aerodynamics, structures and the air-borne environment). Whilst all activities must be undertaken to realise the certified integrated product, this book concentrates on the aircraft systems integration aspects of air-launch