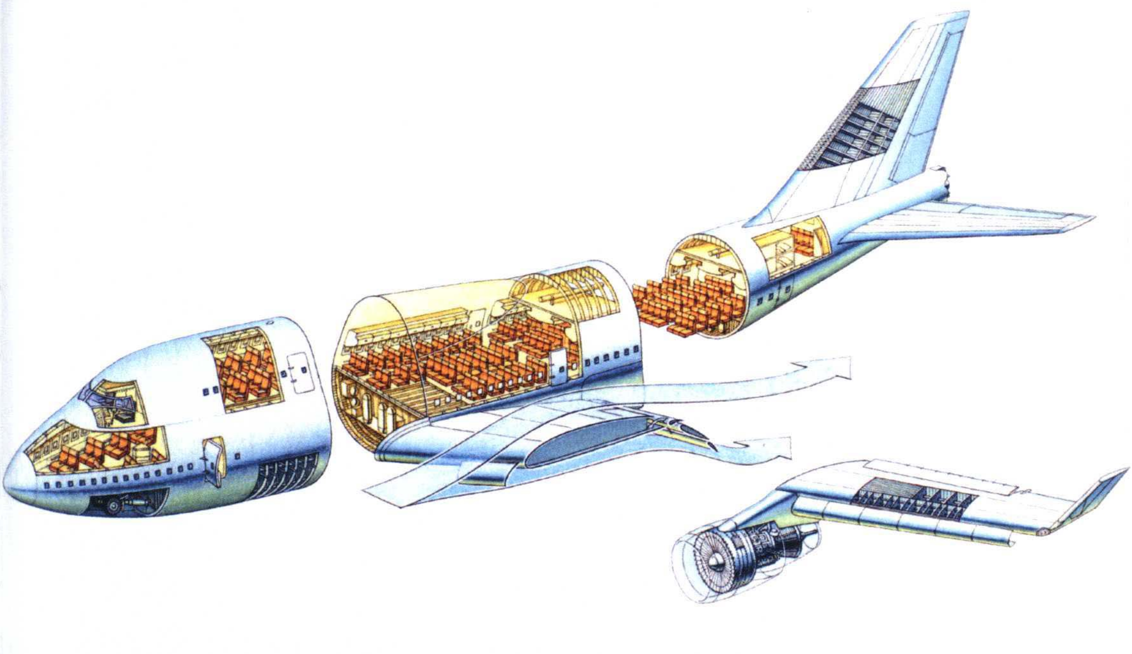
Systems [redacted]ering for [redacted]ercial Aircraft

Second Edition

A Domain-Specific Adaptation



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ASHGATE

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A Domain-Specific Adaptation

Second Edition

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SYSTEMS ENGINEERING FOR COMMERCIAL AIRCRAFT

For as the body is one, and hath many members, and all the members of the body, being many, are one body ... For the body is not one member, but many. ... But now are they many members, yet but one body. And the eye cannot say unto the hand, I have no need of thee, nor again the head to the feet, I have no need of you. ... And whether one member suffer, all the members suffer with it; or one member be honoured, all the members rejoice with it. [I Corinthians 12: 12–26, Holy Bible, *King James (Authorized) Version]*[1]

1 Note: The above quotation is included for its applicability to systems theory and not for any theological reason.

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Acronyms and Abbreviations

Term	Definition
AC	Advisory circular
AC	Alternating current
ACARS	ARINC communication addressing reporting system
ADI	Attitude direction indicator
AFM	Airplane flight manual
AIT	Analysis and integration team
ALAR	Approach and landing accident reduction
APU	Auxiliary power unit
ARINC	Aeronautical Radio Incorporated
ARP	Aerospace recommended practice (SAE)
ASA	Airplane state awareness
ASAP	Aviation safety action plan
ATA	Air Transport Association of America
ATC	Air traffic control
AVOID	Airborne volcanic object identifier and detector
BCD	Baseline concept document
BFE	Buyer furnished equipment
BITE	Built-in test equipment
BWB	Blended wing-body
CAST	Commercial Aviation Safety Team
CCA	Common cause analysis
CDE	Chief design engineer
CDR	Critical design review
CEO	Chief executive officer
CFD	Computational fluid dynamics
CFIT	Controlled flight into terrain
CM	Configuration management
CMR	Certification maintenance requirement
CONOPS	Concept of operations
COTS	Commercial off-the-shelf products

Term	Definition
c.p.	Center of pressure
CRM	Cockpit (or crew) resource management
CSD	Central speed drive
CSE	Chief systems engineer
DC	Direct current
DCAS	Digital core avionics system
DF	Development fixture
DFMA	Design for manufacture and assembly
DME	Distance measurement equipment
DOC	Direct operating cost
DOORS	Dynamic Object-Oriented Requirement System
DOS	Director of safety
ECS	Environmental control system (or subsystem)
EDF	Electronic development fixture
ELB	Emergency locator beacon
ELT	Emergency locator transmitter
EMI	Electro-magnetic interference
ESE	Enterprise systems engineering
ESR	Engineering safety review
EWO	Engineering work order
FAA	Federal Aviation Administration
FAR	Federal aviation regulation
FBL	Fly-by-light
FBW	Fly-by-wire
FCA	Functional configuration audit
FDA	Food and Drug Administration
FEA	Finite element analysis
FFBD	Functional flow block diagram
FFRR	First flight readiness review
FFR	First flight review
FHA	Functional hazard assessment
FMS	Flight management system
FOD	Foreign object debris
FOQA	Flight operational quality assurance
FTA	Fault tree analysis
G&A	General and administrative [costs]

Term	Definition
GMT	Greenwich mean time
GPS	Global positioning system
GPWS	Ground proximity warning system
HBPR	High by-pass ratio
HF	High frequency
HIRF	High-intensity radiation field
HSCT	High-speed civil transport
HSI	Horizontal situation indicator
HUD	Heads-up display
ICA	Initial cruise altitude
ICD	Interface control drawing (or document)
IDEF0	Integrated definition for function modeling—type 0
IDG	Integrated drive generator
IEEE	Institute of Electrical and Electronic Engineering
IFR	Instrument flight rules
ILS	Instrument landing system
IMACH	Improved methods for aircraft cargo handling
INCOSE	International Council on Systems Engineering
INS	Inertial navigation system
IPD	Integrated product development
IPT	Integrated product team
IVATF	International Volcanic Ash Task Force
JAA	Joint Aviation Authorities
JAR	Joint airworthiness requirements
LRU	Line replaceable unit
LSS	Large-scale system
LSSI	Large-scale system integration
MAP	Maximum allowable probability
MCBF	Mean cycles between failures
MCBUR	Mean cycles between unscheduled removals
MEL	Minimum equipment list
MEW	Manufacturer's empty weight
MMEL	Master minimum equipment list
MMH/1000FH	Maintenance man-hours per 1000 flight hours
MN$/1000FH	Maintenance cost per 1000 flight hours
MSAW	Minimum safe altitude warning

Term	Definition
MT$/1000FH	Material cost per 1000 flight hours
MTBF	Mean time between failures
MTBUR	Mean time between unscheduled removals
MTOW	Maximum take-off weight
MTTR	Mean time to repair
MVA	Minimum vectoring altitude
NDI	Non-development item
NEA	Nitrogen enriched air
NOX	Nitrous oxide
NTSB	National Transportation Safety Board
OEM	Original equipment manufacturer
OSHA	Occupational Safety and Health Administration
PBW	Power-by-wire
PCA	Parametric cost analysis
PCA	Physical configuration audit
PCA	Propulsion controlled aircraft
PDR	Preliminary design review
PRA	Probabilistic risk analysis
PSAC	Plan for software aspects of certification
PSE	Product systems engineering
PSSA	Preliminary system safety assessment
QFD	Quality function deployment
RAS	Requirements allocation sheet
RATs	Ram air turbine
RI	Runway incursion
RNAV	Area navigation
RNP	Required navigation procedures
RTCA	Radio Technical Commission for Aeronautics (former name of RTCA, Inc.)
SAE	Society of Automotive Engineers
SATCOM	Satellite communications
SCM	Software configuration management
SCS	Software configuration index
SDR	System design review
SE	Systems engineering
SEBoK	Systems Engineering Body of Knowledge

Term	Definition
SEIT	Systems engineering and integration team
SELCAL	Selective calling
SEMP	SE management plan
SFC	Specific fuel consumption
SOP	Standard operating procedure
SoS	System of systems
SOW	Statement of work
SSE	Service systems engineering
SQA	Software quality assurance
SRR	System requirements review
SSA	System safety assessment
SVR	System verification review
TAWS	Terrain avoidance warning system
TBD	To be determined (for a requirement)
TCAS	Traffic collision avoidance system
TEAM	Technology evaluation and adaptation methodology
TPM	Technical performance measure
TQM	Total quality management
TRL	Technology readiness levels
UER	Unscheduled engine removals
VFR	Visual flight rules
VGSI	Visual glide slope indicator
VHF	Very high frequency
VMC	Visual meteorological conditions
VOR	VHF omni-directional radio
VSCF	Variable-speed constant frequency

Symbols

AR	Aspect ratio
C_D	Drag coefficient
C_{D0}	Lift-independent drag coefficient
C_L	Lift coefficient
$CL^2/\prod ARe$	Induced drag
C_{LIC}	Initial cruise lift coefficient
C_{Lmax}	Maximum lift coefficient
C_{Lto}	Take-off lift coefficient
ΔC_{Dc}	Compressibility drag coefficient
e	Lift efficiency
Fb	Block fuel
L/D	Lift to drag ratio
$\Lambda_{c/4}$	Sweepback angle at quarter chord
M_{div}	Divergence Mach number
R	Total range
R_{cl}	Climb range
R_{cr}	Cruise range
SFC	Specific fuel consumption
$t/c)_{ave}$	Average thickness to chord ratio
U	Aircraft utilization factor
V_b	Block speed
$W/S)_{IC}$	Initial cruise wing loading
$W/S)_{to}$	Take-off wing loading
W_0	Initial cruise weight
W_1	$W_0 - W_f$
W_f	Weight of fuel
W_{to}	Weight at take-off
W_{wing}	Wing weight
$W_{fuselage}$	The fuselage weight
$W_{landing\ gear}$	The landing gear weight
$W_{nacelle\ \&\ pylon}$	The nacelle and pylon weight
W/T	Thrust loading

W_{TS}	The tail section weight
W_{fuel}	The fuel weight
$W_{payload}$	The payload weight
$W_{fixed\ equipment}$	The fixed equipment weight

Preface

There have been many developments in the commercial aircraft domain since the publication of the first edition in 1997. From the technology point of view, there have been many innovations, such as the introduction of composite materials and flight envelope protection, both discussed in Chapter 2, among other developments. With respect to safety, the emergence of the Commercial Aircraft Safety Team (CAST), an international consortium of manufacturers, regulators, employee groups, and airlines has served both to track developments in safety and also to suggest improvements in procedures which have reduced the fatality rate dramatically. From a management point of view, the increased use of outsourcing discussed in Chapter 14, has created a challenge for which greater rigor in supplier management is required. This chapter discusses outsourcing in the context of large-scale system integration (LSSI), an advanced topic in the systems engineering lexicon.

In addition to developments in the commercial aircraft domain since 1997, systems engineering has continued to grow in scope and maturity both as a general concept and also in the commercial aircraft domain. The publication of the *Systems Engineering Body of Knowledge* (SEBoK) edited by Pyster (2012) has expanded the scope of systems engineering into three categories: product systems engineering (PSE), enterprise systems engineering (ESE), and service systems engineering (SSE). The discussion of outsourcing in Chapter 14 falls more into the ESE category. Within the commercial aviation domain two important documents have been published: First is the Federal Aviation Administration (FAA) *Systems Engineering Manual* (2014). Secondly, the Society of Automotive Engineers (SAE) guideline ARP 4754A (2010) lays out in a concise way how systems engineering applies to aircraft development with a focus on safety and certification.

This book is not intended to replace the above standards and guidelines or to be a definitive interpretation of them. Rather it is the intent to be a "pointer" to these documents, to show how they can fit into a systems engineering context, and to adapt to these processes as discussed below. Furthermore, this book is not intended to be a manual or handbook; rather it is intended to be a guide to understanding.

If there is a central theme of this book it is that the commercial aircraft domain requires attention to the adaptation of the systems engineering process to that domain. Chapter 13 is devoted entirely to the challenges of adaptation. You may have noticed that this edition is subtitled *A Domain-Specific Adaptation*. These challenges result from the unique demands of the market and the technologies in that domain. In addition, an important fact is that there is already considerable systems engineering in this domain, and the developer can take advantage of that fact by incorporating only those aspects that do not already exist. That chapter also describes how an *existing* organization can perform systems engineering to maximum advantage.

Another goal of this edition is to persuade the developer that systems engineering is not the burdensome process it is often perceived to be in other domains, but rather a logical approach to system development.

An important issue in modern commercial aircraft development is the existence of risks. Although the first edition devoted a subsection to this subject, this edition expands that discussion to an entire chapter, Chapter 15, to the principles of risk management and typical risks that the developer may encounter. With respect to risks, this book does not mention specific aircraft developers, specific aircraft, or specific incidents except to the extent that they are mentioned in accident reports by, for example, the National Transportation Safety Board (NTSB).

A final topic not discussed extensively in other texts with respect to commercial aircraft is *resilience* in Chapter 16; an exception is Hollnagel et al. (2011). Resilience is different from safety in that while safety is concerned with the prevention of failures, resilience deals with the anticipation, withstanding, and recovery from any kind of adverse disruption.

It is hoped that you will find this edition both useful as well as informative regarding the commercial aircraft domain in the context of systems theory and in particular systems engineering.

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