



# Airworthiness Certification of Fighter Aircraft



**K Nagaraj**

**Defence Research & Development Organisation  
Ministry of Defence, India**

# **Airworthiness Certification of Fighter Aircraft**

# AIRWORTHINESS CERTIFICATION OF FIGHTER AIRCRAFT

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K Nagaraj

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# Contents

<i>Foreword</i>	<i>xi</i>
<i>Preface</i>	<i>xiii</i>
<i>Acknowledgements</i>	<i>xv</i>
<i>Terminology and Institutions</i>	<i>xvii</i>
<i>List of Acronyms</i>	<i>xxi</i>
<i>Introduction</i>	<i>xxix</i>
<b>CHAPTER 1: TECHNOLOGY DEVELOPMENT</b>	<b>1</b>
<b>CHAPTER 2: PROJECT INITIATION AND DEVELOPMENT</b>	<b>3</b>
2.1 Feasibility Study	3
2.2 Project Definition	5
<b>CHAPTER 3: CONCEPTS OF AIRWORTHINESS CERTIFICATION</b>	<b>9</b>
3.1 Introduction	9
3.2 Airworthiness Certification	9
<b>CHAPTER 4: AB-INITIO DESIGN, DEVELOPMENT, AND PRODUCTION</b>	<b>13</b>
4.1 Introduction	13
4.2 Pre-requisites	13
4.3 Evaluation of Design	14
4.4 Review Systems	16
4.5 Methodology to Deal with Defects During Development	17
4.6 Transition from Development to Production	20
<b>CHAPTER 5: FACETS OF AIRCRAFT DESIGN</b>	<b>23</b>
<b>CHAPTER 6: AERODYNAMICS</b>	<b>25</b>
6.1 Air	25
6.2 Pressure	25

6.3	Density	25
6.4	Airflow	27
6.5	Aircraft Aerodynamics	28
6.6	Aerodynamic Forces in Flight Manoeuvres	43
6.7	Stability and Handling of Aircraft	48
<b>CHAPTER 7: STRUCTURES</b>		<b>65</b>
7.1	Configuration Study	65
7.2	Air Load Estimation and Wind Tunnel Tests	65
7.3	Structural Design and Analysis	67
7.4	Static Strength Analysis	67
7.5	Fuselage Analysis	67
7.6	Wing Analysis	68
7.7	Horizontal Tail Analysis	69
7.8	Vertical Tail Analysis	69
7.9	Validation of the Total Aircraft	78
7.10	Excitation Procedures	82
7.11	Aerodynamic Effects	87
<b>CHAPTER 8: ELECTRICAL SYSTEM</b>		<b>91</b>
8.1	Overview of Aircraft Electrical System	91
8.2	Wiring	93
8.3	Electro Magnetic Compatibility	94
8.4	Electrical Power System Requirements	95
8.5	Load Characteristics	98
<b>CHAPTER 9: HYDRAULIC SYSTEM</b>		<b>101</b>
<b>CHAPTER 10: FLIGHT CONTROL SYSTEM</b>		<b>107</b>
10.1	Flight Control Actuation System	113
10.2	System Design	113
10.3	Electro-Hydraulic Servo-Valves	114
10.4	Direct Drive Valves	114
10.5	Comparison of EHSV with DDV Servo Actuators	114
10.6	Built-in Test/Redundancy Management	119
<b>CHAPTER 11: NAVIGATION SYSTEM</b>		<b>121</b>
11.1	Doppler Navigation System	122
11.2	Very High Frequency Omni Range	126

11.3	Tactical Air Navigation System	128
11.4	Inertial Navigation Systems	128
11.5	Automatic Direction Finder	130
<b>CHAPTER 12: COMMUNICATION SYSTEM</b>		<b>131</b>
12.1	Very High Frequency/Ultra High Frequency Technology	131
12.2	Radio Communication	131
12.3	Antennae	133
12.4	Sources of Noise	135
12.5	Reducing the Effects of Noise and Interference	136
<b>CHAPTER 13: LANDING GEAR SYSTEM</b>		<b>139</b>
<b>CHAPTER 14: FUEL SYSTEM</b>		<b>145</b>
<b>CHAPTER 15: OXYGEN SYSTEM</b>		<b>147</b>
15.1	On-board Oxygen Generation Systems	149
<b>CHAPTER 16: ENVIRONMENTAL CONTROL SYSTEM</b>		<b>153</b>
16.1	Bleed Subsystem	154
16.2	Air Conditioning Subsystem	154
16.3	Cabin Distribution Subsystem	155
<b>CHAPTER 17: BRAKE PARACHUTE SYSTEM</b>		<b>157</b>
<b>CHAPTER 18: WEAPON SYSTEM</b>		<b>159</b>
18.1	Fixed Gun Installation	160
18.2	Tests Required to Prove the Gun Installation	162
18.3	Integrated Weapon System	167
<b>CHAPTER 19: ESCAPE SYSTEM</b>		<b>169</b>
19.1	Means of Escape	169
<b>CHAPTER 20: SOFTWARE SYSTEM</b>		<b>173</b>
20.1	Software Development Process	173
20.2	Software Development Activities	174
20.3	Process Improvement Models	177
20.4	Formal Methods	178
<b>CHAPTER 21: PROPULSION SYSTEM</b>		<b>179</b>
21.1	Thrust Augmentation	180

<b>CHAPTER 22: STANDARDS AND SPECIFICATIONS</b>	<b>183</b>
22.1 Types of Specifications	183
22.2 Implementation of Specifications/Standards	185
<b>CHAPTER 23: DRAWINGS</b>	<b>187</b>
23.1 Drawing Standard	187
23.2 Types of Drawings	190
23.3 Master Record System for Drawings	191
<b>CHAPTER 24: DESIGN EVALUATION FOR AIRWORTHINESS</b>	<b>193</b>
24.1 Introduction	193
24.2 Aerodynamics	195
24.3 Electrical System	205
24.4 Systems Clearance	210
24.5 Hydraulic System	221
24.6 Installation	242
24.7 Ergonomics	248
24.8 Aircraft Lighting	249
24.9 Life Support Systems	249
24.10 Avionics Architecture and Avionics Subsystems	252
24.11 Armament/Stores Integration	254
24.12 Safety Interlocks	255
24.13 Computer	257
<b>CHAPTER 25: SIMULATION</b>	<b>261</b>
25.1 Types of Simulators	261
25.2 Techniques of Simulation	262
<b>CHAPTER 26: SAFETY ASSESSMENT OF AIRCRAFT SYSTEMS</b>	<b>265</b>
26.1 Hazard Risk Assessment	267
26.2 Flight Worthiness Evaluations	267
26.3 Software Safety Assessment	268
26.4 Software Development: Safety Assessment	270
26.5 New Hazards	271
<b>CHAPTER 27: GROUND TESTS</b>	<b>275</b>
27.1 Aerodynamics	276
27.2 Armament Stores	280
27.3 Ground Firing Tests	283



<b>CHAPTER 28: DOCUMENTATION</b>	<b>289</b>
28.1 General Requirements	289
28.2 Structures	290
28.3 Flight Control System	291
28.4 Propulsion and Propulsion Systems	293
28.5 Pilot–Vehicle Interface	294
28.6 Avionics	295
28.7 Electrical System	296
28.8 Computer and Software	297
28.9 Armament Stores	298
<b>CHAPTER 29: FLIGHT CLEARANCE CERTIFICATE</b>	<b>301</b>
29.1 Introduction	301
29.2 Standard of Preparation of Aircraft	302
<b>CHAPTER 30: FLIGHT TESTS</b>	<b>307</b>
30.1 Flight Test Instrumentation	307
30.2 Flight Tests	308
30.3 Evaluation of Test Results and Acceptance	310
<b>CHAPTER 31: RELEASE TO SERVICE</b>	<b>317</b>
<b>CHAPTER 32: CONTINUED AIRWORTHINESS</b>	<b>319</b>
32.1 Modifications	320
32.2 Aircraft Level Aspects	323
32.3 Weapon System Augmentation	324
32.4 Licence-Built Aircraft	328
<b>CHAPTER 33: INCIDENTS, DEFECTS, AND ACCIDENT INVESTIGATION</b>	<b>331</b>
33.1 Aircraft Accidents	331
<b>CHAPTER 34: INDIGENOUS DEVELOPMENT</b>	<b>335</b>
34.1 Items Having Licence Agreement	336
34.2 Approval of Non-Critical Items	336
34.3 Consumables: Approval of Fuel, Oil, and Lubricants	339
<b>CHAPTER 35: LIST OF DOS AND DON'TS</b>	<b>343</b>
35.1 Dos	343
35.2 Don'ts	345

<b>CHAPTER 36: CERTIFICATION IN FOREIGN COUNTRIES</b>	<b>347</b>
36.1 United States of America	348
36.2 United Kingdom	348
36.3 France	349
36.4 Russia	350
36.5 Conclusions	350
<i>List of References</i>	353
<i>Index</i>	363

## Preface

This monograph is written for use by students pursuing the aeronautical engineering degree course; fresh entrants into the certification group; personnel engaged in the design, development of fighter aircraft with the objective of meeting the user's requirement; R&D scientists; certification groups; and user services.

Airworthiness means different things to different people. It is an essential prerequisite if the product has to be of utility to the user services for deployment in an operational scenario, in both military and civilian usage. However, unlike in the civilian sector, airworthiness certification has not got the recognition that is the due of such a vital and important subject in the military sphere.

This publication highlights the aspects of airworthiness certification that have to be assimilated into all facets of design, development, production and service life cycle of an aircraft and airborne store. It is of particular significance during design and development, since a product can only be as good as it has been designed, and all other factors will only help to achieve the capabilities built into the product by design. This monograph also attempts to bring out the fact that if corrective actions are required, they can be extremely difficult, if not impossible, to introduce and implement at later stages, due to the constraints of time and cost. Thus, the deficiency may have to be carried forward till the aircraft is phased out of service.

The certification personnel will have to meet several challenges in the concurrent design, development and certification scenario. This publication, therefore, deals in some depth with the design and design evaluation aspects. It also brings in the practical experience in aircraft system design of the author, who had the privilege of working for five years in the HF-24 design team of Dr Kurt Tank, the famous German designer, who set up a design team at the invitation of the then Prime Minister, Pandit Jawaharlal Nehru.

It is an extremely challenging and rewarding experience to be involved in an ab initio design and development project, and to process the activities of concurrent certification and accord flight clearance for the first flight and a block of initial flights. This task is all the more exciting if the aircraft incorporates state-of-the-art technologies for which certification standards are scant and have to be evolved

as the work progresses. The author was privileged to shoulder this awesome responsibility and accord such a flight clearance for the Light Combat Aircraft (LCA).

The material presented in this monograph is, out of compulsion, only a small part of the mammoth activity that goes under the generic title of Airworthiness and Certification. The scope of activities and nuances involved are too vast and intensive to be consolidated in one publication. What has been presented, therefore, is of such a nature and depth that will enable the interested and the practitioner alike to grasp the overall approaches to aircraft design and airworthiness certification, and to benefit from the experience of the author in this field for over three-and-a-half decades. The author will derive immense pleasure and feel rewarded if a large number in the aeronautical community read the book and benefit from the contents.

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A publication of this magnitude and content requires a good deal of effort in typing, compilation, data collection, proofreading, countless number of revisions and other miscellaneous types of work. The author gratefully acknowledges with thanks the efforts of Shri Edwin Oliban, who has helped in preparing this document as per schedule and in an extremely presentable form.

K Nagaraj

## List of Acronyms

ADFS	Automatic Direction Finder System
AFCS	Automatic Flight Control System
AGC	Automated Gain Control
AGS	Automatic Gain Control
AM	Amplitude Modulation(ed)
AMAGB	Aircraft-Mounted Accessory Gear Box
APC	Aircraft–Pilot Coupling
APU	Auxiliary Power Unit
ASI	Air Speed Indicator
ASR	Air Staff Requirements
AST	Air Staff Target
ASTE	Aircraft and System Testing Establishment
ATE	Automated Test Equipment
ATP	Acceptance Test Procedure
AVCS	Active Vibration Control System
BEL	Bharat Electronics Limited
BIT	Built-In Test
BLOS	Beyond-the-Line-of-Sight
BRD	Base Repair Depot
CAA	Civil Aviation Authority
CAD	Computer-Aided Draughting and Design
CAI	Compression After Impact
CAS	Calibrated Air Speed
CCDL	Cross Channel Data Link
CCM	Close Combat Missile

*Airworthiness Certification of Fighter Aircraft*

CCS	Configuration Control System
CCV	Control Configured Vehicle
CD	Coefficient of Drag
CDMA	Code Division Multiple Access
CDR	(i) Crash Data Recorder; (ii) Critical Design Review
CFC	Carbon Fibre Composites
CFD	Computational Fluid Dynamics
CFRP	Carbon Fibre Reinforced Plastic
CEMILAC	Centre for Military Airworthiness and Certification
CG	Centre of Gravity
CIDS	Critical Item Development Specifications
CL	(i) Centre of Lift; (ii) Coefficient of Lift
CMMI	Capability Maturity Model Integration
COD	Certificate of Design
COTS	Commercially-off-the-shelf
CP	Centre of Pressure
CRE	Chief Resident Engineer
CRI	Chief Resident Inspector
CSCI	Computer Software Configuration Item
CSDO	Central Security Development Organisation
CSI	Critical Safety Items
CW	Continuous Wave
DDPIL	Design Development Production and Information of Electronic Equipment
DDPMAS	Design, Development and Production of Military Aircraft and Airborne Stores
DDV	Direct Drive Valves
DFCS	Digital Flight Control System
DGAQA	Directorate General Aeronautical Quality Assurance
DGCA	Director General, Civil Aviation
DFCC	Digital Flight Control Computer

*List of Acronyms*

DI	Defect Investigation
DME	Distance Measuring Equipment
DOD	Department of Defense
DOF	Degree of Freedom
DRDO	Defence Research and Development Organisation
DRI	Dynamic Responses Index
DS	Direct Sequence
ECS	Environmental Control System
EDM	Electro Discharge Machining
EHSV	Electro-Hydraulic Servo Valves
EMC	Electro Magnetic Compatibility
EMI	Electro Magnetic Interference
EMP	Electro Magnetic Pulse
EMRU	Electro Magnetic Release Unit
ENSIP	Engine Structural Integrity Programme
ERU	Ejector Release Unit
FAA	Federal Aviation Agency
FAR	Federal Aviation Regulations
FBW	Fly-By-Wire
FCA	Functional Configuration Audit
FCC	Flight Clearance Certificate
FCS	Flight Control System
FDR	Flight Data Recorder
FEM	Finite Element Analysis
FH	Frequency Hopping
FLIR	Forward Looking Infrared
FM	Frequency Modulation (ed)
FMCW	Frequency Modulated Continuous Wave
FMEA	Failure Mode and Effect Analysis
FMECA	Failure Mode, Effects, and Critical Analysis
FOC	Final Operational Clearance



FOD	Foreign Object Damage
FOL	Fuel Oil Lubricants
FOV	Field-of-View
FRACAS	Failure Report and Corrective Action System
FRF	Frequency Responses Functions
FRR	Flight Readiness Review
FTA	Fault Tree Analysis
FTI	Flight Test Instrumentation
GFRP	Glass Fibre Reinforced Plastic
GPS	Global Position System
GRT	Ground Resonance Test
GSQR	General Staff Quality Requirements
GVT	Ground Vibration Test
HAL	Hindustan Aeronautics Limited
HF	High Frequency
HSI	Hardware Software Integration
HT	Horizontal Tail
IAF	Indian Air Force
IAS	Indicated Air Speed
ICD	Interface Control Documents
ICs	Interface Controls
IEEE	Institution of Electrical and Electronic Engineers
IMU	Inertial Measurement Unit
IN	(i) Indian Navy; (ii) Inertial Navigation
IOC	Initial Operational Clearance
IVV	Independent Verification and Validation
JAA	Joint Airworthiness Agency
JAC	Joint Airworthiness Committee
JTRC	Joint Technical Requirements Committee
LCC	Local Concession Committee
LCSO	Electronic Components Standardisation Organisation

*List of Acronyms*

LEP	Laser Eye Protection
LES	Leading Edge Slat(s)
LLI	Lower Limit of Inflammability
LMC	Local Modification Committee
LMS	Liquid Measurement System
LOP	Line of Position
LOX	Liquid Oxygen
LRU	Line Replacable Unit
LSP	Limited Series Production
LTC	Local Technical Committee
LTCC	Local Type Certification Committee
LVDT	Linear Variable Displacement Transformer
MAG (Avn)	Maintenance Advisory Group (Aviation)
MC-CDMA	Multi-Carrier CDMA
MCV	Main Control Valve
MDC	Miniature Detonation Cord
MLPCB	Multi Layer Printed Circuit Board
MOD	Ministry of Defence
MPI	Mean Point of Impact
MRI	Master Resource Index
msec	Millisecond
MWL	Maximum Wear Limit
NASA	National Aeronautics and Space Administration
NASDO	Naval Aircraft Servicing Development Organisation
NBC	Nuclear–Biological–Chemical
NF	Notch Filter
NFTE	National Flight Test Engineers
NFTP	National Flight Test Pilots
NSQR	Naval Staff Quality Requirements
NTIS	National Technical Information Service
NVIS	Night Vision Imaging System

NVM	Non-Volatile Memory
OBOGS	On-Board Oxygen Generating System
ODM	Operating Data Manual
OHP	Operational Height Programme
OLFRF	On-Line Frequency Response Functions
PCA	Physical Configuration Audit
PCB	Printed Circuit Board
PDP	Project Definition Phase
PDR	Preliminary Design Review
PIDS	Prime Item Development Specifications
PIO	Pilot-Induced Oscillation
PLOC	Probability of Loss of Control
POR	Power Output Requirement
PPOL	Partial Pressure of Oxygen
PSA	Pressure Swing Adsorption
psi	Pounds Per Square Inch
PSU	Public Sector Undertaking
PTO	Power Takeoff
QR	Quality Requirements
RAT	Ram Air Turbine
RCMA	Regional Center for Military Airworthiness
RSD	Release to Service Document
RSS	Relaxed Static Stability
RTO	Reject Takeoff
RTRS	Rail Track Rocket Sledge
RTS	Real-Time Simulator
SA to RM	Scientific Advisor to Raksha Mantri
SAE	Society for Automotive Engineers
SATCOM	Satellite Communication
SB	Service Bulletin
SC	Structural Coupling

SCT	(Ground) Structural Coupling Test
SDD	Software Design Documents
SDIMP	Software Development Integrity Master Plan
SDLC	Software Development Life Cycle
SDP	Software Development Plans
SEPG	Software Engineering Process Group
SI	Servicing Instruction
SIT	System Integration Testing
SNR	Signal-to-Noise Ratio
SOF	Safety of Flight
SOP	Standard of Preparation
SOV	Solenoid Operated Valve
SOW	Statement of Work
SPICE	Software Process Improvement and Capability Determination
SR	Staff Requirements
SRR	System Requirement Review
SRS	(i) Standard Repair Scheme; (ii) Software Requirements Specifications
STI	Special Technical Instructions
STLDD	Software Top-Level Design Documents
STTE	Specific Type Test Equipment
TACAN	Tactical Air Navigation System
TACSAT	Tactical Satellite
TBO	Time Between Overhaul
TCs	Type Certificates
TEMP	Test and Evaluation Master Plan
TH	Time Hopping
TRANSEC	Transmission Security
TRU	Transformer Rectifier Unit
TTL	Total Technical Life
UHF	Ultra High Frequency

*Airworthiness Certification of Fighter Aircraft*

UON	Urgent Operating Notice
USAF	United States Air Force
USN	Urgent Servicing Notice
VCF	Vehicle Control Function
VHF	Very High Frequency
VOR	Very High Frequency Omni Range
VT	Vertical Tail
VTO	Visiting Technical Officer
XP	Extreme Programming

## Introduction

The aeronautical industry took shape in India in 1940, with the establishment of Hindustan Aeronautics Limited (HAL) as a private enterprise by late Walchand Hirachand on land generously sanctioned by Shri Krishnarajendra Wodeyar, the then king of Mysore, for overhauling USAF aircraft. It was consolidated through takeover by the Government of India in 1942. The impetus for indigenous design and development was given by the HT 2 basic trainer project. Although this all-metal aircraft was primarily meant for use by the Indian Air Force, it was certified by DGCA, under the overall guidance of Dr S Neelakantan, since there was no Military Certification Agency in existence at that time. All design clearance activities were undertaken by HAL.

The Directorate of Technical Development and Production (Air) [DTD&P (Air)] was subsequently formed by the Ministry of Defence, Government of India, under the leadership of Dr S Neelakantan, to look after the Military Aircraft Airworthiness Certification aspects, including overseeing of company inspection. The first branch office of DTD&P (Air) was started in 1958 at Bengaluru within the premises of HAL, structured similar to airworthiness groups in the UK. The design and inspection related functions were separated in 1960, and entrusted to Chief Resident Engineer (CRE) and Chief Resident Inspector (CRI) respectively, in view of the increased aeronautical activities taken up in the country. CRE (Engines) was formed to look after the clearance activities of the engines, and brought out the requirements for re-type tests similar to UK procedures.

In 1968, the CREs were brought under the functional and administrative control of DRDO, reporting to SA to RM, through the Director of Aeronautics. The CRIs remained under DTD&P (Air), reporting to the Secretary, Defence Production. During this period, the Marut (HF 24) design activities, started under the leadership of Prof Kurt Tank, reached its peak. However, in-depth interactions/involvement of CREs for the design clearance activities were lacking. After the crash of HF 24 aircraft with reheat version of modified engine, the active participation of CRE (Aircraft) was considered essential and ensured with the concept of involvement in all activities of design and development, leading to clearance of the aircraft for development flights on a flight-by-flight basis as a mandatory requirement. These requirements were subsequently extended to other

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## About the Book

This publication fills a very important niche in the broad spectrum of activities between design / development and release to service of a military fighter aircraft. That niche involves the expertise, knowledge, and ability to absorb and implement concepts / nuances of technologies adopted by the designers and certificated. The task is complex and demands a good grasp of the subject, considering the fact that a modern fighter aircraft encompasses a multitude of disciplines that have to be integrated into a system that will meet the requirements of safety and operational effectiveness. The role and responsibility of the certification authority are further exacerbated in the concurrent design and certification model adopted in India.

The text is the outcome of decades of hands-on experience of the author in the design evaluation of the aircraft and its systems for safety and performance parameters, and in implementing the process of airworthiness certification of a variety of fighter aircraft, engines, systems, software and hardware. It would be impossible to incorporate, into a publication of this nature, all the details of various aspects involved in airworthiness certification of a fighter aircraft. However, an attempt has been made to bring out the knowledge required in the design of individual disciplines, evaluation techniques to be adopted, and the interactive nature of the work.

The text has been structured in such a fashion as to give to the casual reader a glimpse of airworthiness certification activities, and to the practitioner, a detailed exposure to this complex subject.

## About the Author

Krishnamurthy Nagaraj graduated in electrical engineering from the University of Mysore in 1961, and thereafter obtained the Masters Degree in Avionics and Control Engineering from Cranfield Institute of Technology, UK. As designer in the Aircraft Design and Engineering department of Hindustan Aeronautics Limited, he worked in the HF 24 design group of Dr Kurt Tank. In 1969, he joined the Airworthiness Certification group of DRDO and rose to become the Chief Executive of CEMILAC. He has certified the mid-life upgrades on the Jaguar and Kiran aircraft, supported various other aircraft, and spurred the indigenous development of aircraft stores. He retired in 2001, after successfully certifying the Light Combat Aircraft for the first ten flights.

He was presented the Life Time Achievement Award in 2003–04 by the Society for Aerospace Quality and Reliability. In 2015, he was felicitated for contributing to the safety of the country by the Union Ministers for Defence and for Chemicals, Fertilisers & Pharmaceuticals at an event organised by the Adama Chetana Foundation.

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