NORTH ATLANTIC TREATY ORGANIZATION

SCIENCE AND TECHNOLOGY ORGANIZATION

AC/323(SCI-236)TP/964

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STO AGARDograph 300 **AG-300-V32**
Flight Test Technique Series – Volume 32

Flight Test Safety and Risk Management

(Sécurité des essais en vol et gestion du risque)

This AGARDograph has been sponsored by the SCI Flight Test Technical Team (FT3) of the Systems Concepts and Integration Panel (SCI) of STO.

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The NATO Science and Technology Organization

Science & Technology (S&T) in the NATO context is defined as the selective and rigorous generation and application of state-of-the-art, validated knowledge for defence and security purposes. S&T activities embrace scientific research, technology development, transition, application and field-testing, experimentation and a range of related scientific activities that include systems engineering, operational research and analysis, synthesis, integration and validation of knowledge derived through the scientific method.

In NATO, S&T is addressed using different business models, namely a collaborative business model where NATO provides a forum where NATO Nations and partner Nations elect to use their national resources to define, conduct and promote cooperative research and information exchange, and secondly an in-house delivery business model where S&T activities are conducted in a NATO dedicated executive body, having its own personnel, capabilities and infrastructure.

The mission of the NATO Science & Technology Organization (STO) is to help position the Nations' and NATO's S&T investments as a strategic enabler of the knowledge and technology advantage for the defence and security posture of NATO Nations and partner Nations, by conducting and promoting S&T activities that augment and leverage the capabilities and programmes of the Alliance, of the NATO Nations and the partner Nations, in support of NATO's objectives, and contributing to NATO's ability to enable and influence security and defence related capability development and threat mitigation in NATO Nations and partner Nations, in accordance with NATO policies.

The total spectrum of this collaborative effort is addressed by six Technical Panels who manage a wide range of scientific research activities, a Group specialising in modelling and simulation, plus a Committee dedicated to supporting the information management needs of the organization.

- 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 Panels and Group are the power-house of the collaborative model and are made up of national representatives as well as recognised world-class scientists, engineers and information specialists. In addition to providing critical technical oversight, they also provide a communication link to military users and other NATO bodies.

The scientific and technological work is carried out by Technical Teams, created under one or more of these eight bodies, for specific research activities which have a defined duration. These research activities can take a variety of forms, including Task Groups, Workshops, Symposia, Specialists' Meetings, Lecture Series and Technical Courses.

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AGARDograph Series 160 & 300

Soon after its founding in 1952, the Advisory Group for Aerospace Research and Development (AGARD) recognized the need for a comprehensive publication on Flight Test Techniques and the associated instrumentation. Under the direction of the Flight Test Panel (later the Flight Vehicle Integration Panel, or FVP) a Flight Test Manual was published in the years 1954 to 1956. This original manual was prepared as four volumes: 1. Performance, 2. Stability and Control, 3. Instrumentation Catalog, and 4. Instrumentation Systems.

As a result of the advances in the field of flight test instrumentation, the Flight Test Instrumentation Group was formed in 1968 to update Volumes 3 and 4 of the Flight Test Manual by publication of the Flight Test Instrumentation Series, AGARDograph 160. In its published volumes AGARDograph 160 has covered recent developments in flight test instrumentation.

In 1978, it was decided that further specialist monographs should be published covering aspects of Volumes 1 and 2 of the original Flight Test Manual, including the flight testing of aircraft systems. In March 1981, the Flight Test Techniques Group (FTTG) was established to carry out this task and to continue the task of producing volumes in the Flight Test Instrumentation Series. The monographs of this new series (with the exception of AG237 which was separately numbered) are being published as individually numbered volumes in AGARDograph 300. In 1993, the Flight Test Techniques Group was transformed into the Flight Test Editorial Committee (FTEC), thereby better reflecting its actual status within AGARD. Fortunately, the work on volumes could continue without being affected by this change.

Since that time The Flight Test Editorial Committee has had a number of changes of identity which have in recent years been closely associated with a series of Task Group identities bearing the acronym FT3. This period has also seen FT3 migrate from the Air Vehicle Technology Panel to The Systems Concepts and Integration Panel reflecting the changing nature and focus of NATO Flight Testing. This AGARDograph is sponsored by FT3 against their current Task Group, SCI-305 Flight Test Technical Team (FT3).

An Annex at the end of each volume in both the AGARDograph 160 and AGARDograph 300 series lists the volumes that have been published in the Flight Test Instrumentation Series (AG 160) and the Flight Test Techniques Series (AG 300), plus the volumes that were in preparation at that time.

Flight Test Safety and Risk Management

(STO-AG-300-V32)

Executive Summary

Through a series of Case Studies this AGARDograph brings together the Flight Test Safety and Risk Management Practices of a number of representative NATO Flight Test Organisations. It then provides an assessment of the content of the studies looking for common and best practice in this critical area of Flight Testing.

Contributions have been made by:

- BAE Systems Air – Warton – GBR
- Boeing Test and Evaluation UK – GBR
- Canadian Forces – Aerospace Engineering Test Establishment – AETE – CAN
- NASA Armstrong Flight Research Center – USA
  - Edwards Air Force Base – California
  - Plant 42 Palmdale – California
- NLR – Netherlands National Aerospace Centre – Amsterdam – NLD
- SAAB AB – Aeronautics Business Area – Flight Test and Verification – Linköping – SWE
- Turkish Air Force Flight Test Center – 401st Test Squadron – Eskişehir – TUR
- United States Naval Aviation – Naval Air Systems Command – NAVAIR
  - Patuxent River, Maryland – USA

It is the result of an activity, SCI-236, initiated by the NATO STO Flight Test Technical Team, FT3, to capture, assess and disseminate the Flight Test Safety and Risk Management Practices deployed amongst the Member Nations.

Through its application both the NATO and wider Flight Test Community will have access to information that will help to manage flight test risk to the levels and standards that are expected today.

Sécurité des essais en vol et gestion du risque

(STO-AG-300-V32)

Synthèse

Par le biais d'une série d'études de cas, la présente AGARDographie réunit les pratiques de sécurité des essais en vol et de gestion du risque d'un certain nombre d'organisations représentatives de l'OTAN en la matière. Elle fournit ensuite une évaluation du contenu des études, en recherchant les meilleures pratiques communes dans ce domaine critique des essais en vol.

Les entités suivantes ont apporté leur contribution :

- BAE Systems Air – Warton – GBR
- Boeing Test and Evaluation UK – GBR
- Forces canadiennes – Centre d'essais techniques (Aérospatiale) – CETA – CAN
- NASA Armstrong Flight Research Center – USA
  - Base aérienne d'Edwards – Californie
  - Installation 42 Palmdale – Californie
- NLR – Centre national aérospatial des Pays-Bas – Amsterdam – NLD
- SAAB AB – Branche aéronautique – Essai en vol et vérification – Linköping – SWE
- Centre d'essais en vol des forces aériennes turques – 401e escadron d'essais – Eskişehir – TUR
- United States Naval Aviation – Naval Air Systems Command – NAVAIR
  - Patuxent River, Maryland – USA

Cette évaluation résulte de l'activité du SCI-236, entamée par l'équipe technique des essais en vol de la STO de l'OTAN (FT3), visant à recueillir, évaluer et diffuser les pratiques de sécurité des essais en vol et de gestion du risque déployées parmi les pays membres.

Ainsi, l'OTAN et la communauté des essais en vol dans son ensemble auront accès à des informations qui aideront à gérer le risque des essais en vol aux niveaux et selon les normes actuellement attendues.

Acknowledgements

In addition to the Case Study Authors, both the Lead Author and the FT3 AGARDOgraph Champion wish to recognise the support offered through the SCI Panel Staff, Ms Carlotta Rossi, and the STO Editorial Team who made our lives a whole lot easier as this document came to fruition.

Foreword

It is self-evident that all Flight Test Activities should be conducted safely and without hazarding the aircraft, the crew or third parties and property on the ground. Far more so than with any other system, airborne test incidents have the ability to rapidly escalate in seriousness, leading to the potential loss of aircraft and crew.

The history of flight testing from the days of mythology and antiquity to the present day is littered with accidents many of which could have been avoided if effective safety management practices had been deployed.

Would Icarus have come to such an untimely end if he hadn't operated outside of the cleared flight envelope, flying too close to the sun, and melting the wax that secured the feathers to his wings? Might King Bladud not have plummeted to earth when his wings of chicken feathers failed to support him in his attempt to fly leaping from The Temple of Apollo in London in 852 BC? It being a well-known fact that chickens cannot fly, a clear design error.

But for all these failures there have also been successes. The Montgolfier Brothers conducted early unmanned flights and then flights with animals before themselves ascending in their balloon in 1783. The Wright Brothers through theoretical study and wind tunnel tests progressed from kites to gliders and eventually manned powered flight with The Flyer in 1903. Each had adopted a structured approach to design, development and flight testing that allowed them to manage risk and achieve success.

Since that historic day at Kitty Hawk in 1903 the art and science of flight testing has progressed to become the highly complex and structured activity we see today. Accidents and incidents have happily become far less common but sadly they do still occur and more often than is acceptable. To counter this ever-present threat the International Flight Test Community has established approaches that identify and then mitigate flight test risk.

Some of these are described and assessed in the following pages. These have been offered freely by Organisations that wish to contribute to the never ending search for the Holy Grail of Safe Flight Testing.

Through this AGARDograph it is hoped that a small contribution may be made to enhancing the safety of future flight testing across the NATO Nations and the International Flight Test Community. If it successfully guides one programme away from a potential mishap then all of the effort will have been worthwhile.

Test Safely, and remember, sometimes NO is the right answer.

Dennis Morley, Warton, Lancashire, England, December 2019.

Preface

Some years ago, the members of the NATO Science and Technology Organisation Flight Test Technical Team (FT3) were discussing approaches to managing Flight Test Safety and Risk and the systems deployed by the represented organisations. There was an opinion that the members' organisations were performing this task in very similar ways but this could not be substantiated. Through these discussions there was a growing view that there would be value in formally capturing these approaches and to make these findings available to the wider flight test community in order to enhance Flight Test Safety and Risk Management. This led to the formation of Task Group SCI-236, sponsored by the Systems Concepts and Integration Panel, whose mission was to collect the evidence and to record the findings.

This AGARDograph is the result. It assesses the current state of practice in the field of Flight Test Safety and Risk Management and provides a number of observations on the approaches taken.

It consists of four chapters:

- Chapter 1 is the introductory element which gives the background to Task Group SCI 236 and the approach taken in developing the AGARDograph. It describes the Document Structure and emphasises the critical importance of Safety Culture.
- Chapter 2 is a series of Case Studies produced by a number of Flight Test Organisations describing, in a broadly common format, their approach to Flight Test Safety and Risk Management and the methods they deploy to achieve safe flight testing.
- Chapter 3 provides Observations and Discussion based upon the Case Studies with the intent of identifying:
  - Common themes and approaches;
  - Novel approaches; and
  - Best practice.
- Chapter 4 is a brief concluding section that provides an overview of findings.

Biographical Sketches

JEREMY NEWSOME

Mr. Jeremy Newsome is Head of Flight Test Engineering at BAE Systems, Warton, United Kingdom. He has 28 years of experience in development Flight Testing across a range of manned and unmanned aircraft, including Tornado, Nimrod, Harrier, Hawk, HERTI, Mantis and Taranis. He holds a Bachelor of Engineering Degree in Aeronautical Engineering and is a Member of the Royal Aeronautical Society Flight Test Group. He has led flight trials teams on Tornado, Harrier and Unmanned Air Systems in both the United Kingdom and at a number of international trials locations. He has been BAE Systems Head of Flight Test Engineering since 2015 and is a Member of the NATO STO Flight Test Technical Team.

DENNIS MORLEY

Mr. Dennis MORLEY is a Flight Test Engineer with some 45 years of experience in the field. He holds an Honours Degree in Mechanical Engineering, is a UK Chartered Engineer and a Member of the Royal Aeronautical Society. He has worked for BAE Systems and its predecessor companies at a number of sites and on over 30 aircraft programmes. He has led the Flight Test Teams on the Buccaneer, UK Phantom, Tornado, Hawk, Harrier and UAVs and has also been actively involved with Typhoon, Nimrod MRA4 and F35 Lightning II. He retired in 2015 as Chief Flight Test Engineer BAE Systems Military Aircraft. He is a past Member of the NATO STO Flight Test Technical Team, the Royal Aeronautical Society Flight Test Group and the Board of the European Chapter of the Society of Flight Test Engineers. In retirement he is an Aerospace Consultant specialising in Test and Evaluation.

DEAN MOORE

Mr. Dean MOORE is the Flight Test Engineer (FTE) Lead for Boeing Test & Evaluation UK. Dean joined Boeing in September 2013 and led the development of the Contractor Flying Organization approvals with the UK regulator for Chinook and C-17. Prior to joining Boeing, Dean worked for QinetiQ at MoD Boscombe Down with his last post being the Principal FTE Tutor at the Empire Test Pilots' School (ETPS), 2009 to 2013. He previously worked on a range of fixed & rotary wing programs including Puma Mk2, CONDOR II Technology Demonstration Programme, Typhoon, Chinook and C-130J. Dean holds an MSc in Flight Dynamics (Cranfield University) & BEng in Aerospace Engineering (University of Hertfordshire) and graduated from No.25 Flight Test Engineers Course at ETPS. He is also a Boeing Associate Technical Fellow, Fellow of the Royal Aeronautical Society and member of the NATO Flight Test Technical Team.

PERRY COMEAU

As a Royal Canadian Air Force (RCAF) helicopter pilot, Lt Col Perry Comeau flew operationally internationally as well as operational test and evaluation on the CH124 SeaKing. Completed test pilot training at United Stated Naval Test Pilot School and was a test pilot on many projects on the CH124 SeaKing, CH146 Griffon and CH149 Cormorant. He participated in the development and acceptance of the CH148 Cyclone aircraft and simulator, including as the Combined Test Force Lead of several test pilots and system evaluators. As Lieutenant Colonel, became the Senior Test Pilot for AETE overseeing all developmental and engineering flight test for all fixed, rotary and UAVs in the Canadian Armed Forces. After 28 years, he retired as a Lieutenant Colonel and joined the National Research Council's Flight Research Laboratory as a Research Engineering Test Pilot. He has a Bachelor of Science in Physics, and a Bachelor in Computer Engineering.

BRADFORD A. NEAL

Mr. Bradford A. Neal is currently the Chief Engineer at NASA's Armstrong Flight Research Center providing independent technical guidance and oversight to flight test programs and projects. Mr. Neal has more than 35 years of experience in flight research, test and operations at NASA. He leads the AFRC airworthiness and flight safety review process, reviewing and approving flight research and test activities such as X-59 and X-57. Mr. Neal began his career as an operations engineer, performing integration and mission operations for projects such as the SR-71 Linear Aerospike Experiment, X-31, X-43 and the Stratospheric Observatory for Infrared Astronomy (SOFIA).

PATRICK C. STOLIKER

Mr. Patrick C. Stoliker is currently the Deputy Center Director at the NASA Armstrong Flight Research Center and maintains daily involvement in the flight activities. Mr. Stoliker has more than 35 years' experience in flight test and flight research between his time in industry and at NASA. Mr. Stoliker began his career as a flight controls engineer at Northrop and came to NASA to work the X-31 program. He has served as the chairman for multiple flight readiness reviews including the X-43, X-38, and Global Observer aircraft.

ARUN KARWAL

Mr. Arun Karwal is a Research Test Pilot at the Dutch Royal Netherlands Aerospace Centre NLR. He holds a Master of Science degree from Delft University of Technology Aerospace Engineering and is a graduate of the Royal Netherlands Air Force Officers Training School and KLM Flight Academy. He has 25 years of experience in research flight test at NLR as test pilot flying the NLR laboratory aircraft on a wide range of research missions. He combines his work at NLR with a career as airline pilot where he presently is a Commander on the Boeing 777 and 787 with a major airline. Arun has logged over 13,000 flight hours, holds an EASA Cat 1 Flight Test Rating and is a Member of the Society of Experimental Test Pilots.

CHRISTIAN BUCK

Mr, Christian Buck is a Senior Advisor within Flight Test Engineering at Flight Test and Verification, Business Unit Aeronautics, SAAB AB, Sweden. This includes governing processes, methods and tools for verification and validation at Saab Aeronautics. Mr. Buck has 30 years of experience in development and systems testing of advanced military combat aircraft systems. Most of the engineering and test leader work has been on the Gripen fighter system, from envelope expansion of the early digital fly by wire control system, through weapons integration testing, to an iterative development process based on continues integration, model validation and flight test.

CHRISTIAN RICE

Mr. Christian Rice, Chief Test Engineer Air Test and Evaluation Squadron Two One. Mr. Rice is a 1987 graduate of U.S. Naval Test Pilot School, holds a B.S. in Aerospace and Ocean Engineering from Virginia Tech and a M.S. in Aviation Systems from the University of Tennessee. He has over 35 years of experience in developmental flight test in rotary wing and tilt rotor manned and unmanned aircraft, directly contributing to all current and developmental USN, USMC, and USCG rotorcraft. Mr. Rice has been the Chief Test Engineer since 2002.

JONATHAN STEVENSON

Mr. Jonathan Stevenson is the Operations Officer, Naval Test Wing Atlantic, Patuxent River, Maryland. Mr. Stevenson has 30 years of aviation experience with over 4000 flight hours in 74 different aircraft, including more than 2000 hours in the F 14, 1500 hours in the F/A 18 and 600 arrested landings.

Mr. Stevenson holds a Bachelor of Science Degree in Mechanical Engineering and is a 1997 graduate of the U.S. Air Force Test Pilot School. He has16 years of flight test experience as an experimental test pilot in the F-14, F/A-18 and EA-18G and is a flight instructor with the U.S. Naval Test Pilot School. Mr. Stevenson provides oversight of all flight test and test pilot training at Patuxent River orchestrating complex operations on 130 unique fixed- and rotary-wing, manned and unmanned aircraft.

JOSEPH A. MORTENSEN

Mr. Joseph A. Mortensen is the Director, Research, Development, Test, and Evaluation Strategy and Management for Naval Air Systems Command. He has 22 years in aircraft and weapon system development, test and evaluation. Mr. Mortensen is a retired Marine Corps Colonel with 27 years of aviation experience that included 12 years as a test pilot and served as Commander, Naval Test Wing Atlantic and Commanding Officer/Chief Test Pilot, Air Test and Evaluation Squadron 23. Mr. Mortensen holds an Interdisciplinary Bachelor of Science Degree in Engineering and Master of Science Degree in Aviation Systems. He is a 1992 graduate of the U.S. Naval Test Pilot School and completed a fellowship with the Asia Pacific Center for Security Studies. Mr. Mortensen is an Associate Fellow of the Society of Experimental Test Pilots.

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List of Acronyms and Nomenclature

AA	Airworthiness Authority
ADB	Aircraft Discrepancy Books
AETE	Aerospace Engineering Test Establishment
AGARD	Aerospace Research and Development
AIA	Aircraft Investigative Authority
AFRC	Armstrong Research Flight Center
AFSRB	Airworthiness and Flight Safety Review Board
ALARP	As Low As Reasonably Practicable
AM(MF)	Accountable Manager Military Flying
APM(T&E)	Assistant Program Manager for T&E
AoA	Angle of Attack
AOHL	Airfield Operating Hazard Logs
AOSS	Angle of Side Slip
ARB	Airworthiness Review Board
ASMC	Air Supply and Maintenance Centre
ASMP	Air System Management Plan
ATP	Advanced Turbo Prop
AvP	Aviation Publication
AVT	Applied Vehicle Technology Panel
BAe	British Aerospace
BC	Before Christ
BCA	Boeing Commercial Airplanes
BDS	Boeing Defense Space and Security
BH	Branch Head
BT&E	Boeing Test and Evaluation
CAD(S)	Cartridge Activated Device(s)
CAN	Canada
CAS	Chief of the Air Staff
Cat	Category
CF	Canadian Forces
CFAOS	Contractor Flying Approved Organization Scheme
CFD	Computational Fluid Dynamics
CFIT	Controlled Flight Into Terrain
CO	Commanding Officer
COTS	Commercial Off The Shelf
CTE	Chief Test Engineer
CTP	Chief Test Pilot
DAP	Data Acquisition Plan
DATR	Dryden Aeronautical Test Range
DFO	Director Flight Operations
DND	Department of National Defence
DOD	Department of Defense
DRP	Data Reduction Plan
DT&E	Development Test and Evaluation
DTAES	Directorate of Technical Airworthiness and Engineering Support
Def Stan	UK Defence Standard

EASA	European Union Aviation Safety Agency
EDT	External Directed Team
EFP	Experimental Flight Permit
EHS	Environment Health and Safety
EMC	Electro Magnetic Compatibility
ERB	Executive Review Board
ET&T	Engineering Test and Technology
FAA	Federal Aviation Administration
FBW	Fly By Wire
FCC	Federal Communications Commission
FCF	Functional Check Flight
FCS	Flight Control System
FEA	Finite Element Analysis
FLL	Flight Loads Laboratory
FLOPS	Flight Operations
FOD	Foreign Object Debris
FRRB	Flight Readiness Review Board
Ft	Feet
FT3	Flight Test Technical Team
FTA	Flight Test Authority
FTC	Flight Test Crew
FTCR	Flight Test Control Room
FTE	Flight Test Engineer
FTEC	Flight Test Editorial Committee
FTI	Flight Test Instrumentation
FTM	Flight Test Manager
FTMARR	Flight Test Mission Assurance Readiness Review
FTP	Flight Test Programme
FTTG	Flight Test Techniques Group
FVP	Flight Vehicle Integration Panel
FW	Fixed Wing
GBR	Great Britain
GCS	Ground Control System
GFTD	Government Flight Test Director
GLAT	Government Lot Acceptance Tests
HAM	Hazard Action Matrices
HERP	Hazard of Electromagnetic Radiation to Personnel
HERO	Hazard of Electromagnetic Ordnance
HoFTE	Head of Flight Test Engineering
HRM	Hazard Risk Matrix
IBST	Integrated Battlespace Systems Test
IFR	Instrument Flight Rules
IMC	Instrument Meteorological Conditions
IPT	Integrated Project Team
ISEET	Integrated Systems Experimentation, Evaluation and Test
ISO	International Standards Organisation
IST	Information Systems Technology Panel
IT	Information Technology
ITT	Integrated Test Team

LOI	Letter of Instruction
LTE	Lead Test Engineer
MAA	Military Aviation Authority
MoD	Ministry of Defence
MRA	Maritime Reconnaissance and Attack
MRP	MAA Regulatory Publications
MSL	Mean Sea Level
NASA	National Aeronautics and Space Administration
NAVAIR	Naval Air Systems Command
NAVAIRINST	Naval Air Systems Command Instruction
NATO	North Atlantic Treaty Organization
NATOPS	Naval Aviation Training Procedures Standardization
NLD	the Netherlands
NMSG	NATO Modelling and Simulation Group
NOTAM	Notice to Airmen
NOTMAR	Notice to Mariners
Nz	Normal Acceleration
OA	Operational Airworthiness
OAA	Operational Airworthiness Authority
OT&E	Operational Test and Evaluation
PCO	Project Control Office
PE	Project Engineer
PO	Project Officer
PP	Project Pilot
PPM	Project Planning Memorandum
PTLC	Product Test Life Cycle
QMS	Quality Management System
R&D	Research and Development
RA	Regulatory Article
RAF	Royal Air Force
R/C	Radio Controlled
RF	Radio Frequency
RSO	Range Safety Officer
RTB	Return to Base
RTPS	Real Time Processing System
RW	Rotary Wing
S&MA	Safety and Mission Assurance
S&T	Science and Technology
SA	Situational Awareness
SAR	Search and Rescue
SAS	Systems Analysis and Studies Panel
SCI	Systems Concepts and Integration Panel
SDE	Senior Design Engineer
SET	Sensors and Electronics Technology Panel
SH	Section Head
SOAW	Staff Officer Airworthiness
SOF	Safety of Flight

SOFT	Safety of Flight Test
SOT	Safety of Test
SQEP	Suitably Qualified and Experienced Personnel
SRB	Safety Review Board
STE	Senior Test Engineer
STO	Science and Technology Organization
STOVL	Short Take Off Vertical Landing
STP	Senior Test Pilot
SUAS	Small Unmanned Air System
SWE	Sweden
T&E	Test and Evaluation
TAA	Technical Airworthiness Authority
TAM	Technical Airworthiness Authority
TECT	Test and Experimentation Coordination Team
TES	Test and Evaluation Squadron
TFX	Turkish National Fighter Aircraft
THA	Test Hazard Analysis
TM	Telemetry
TPERT	Test Planning Execution and Reporting Tool
TPID	Test Planning Introduction Document
TPM	Test Programme Management
TRB	Technical Review Board
TRR	Test Readiness Review
TSPI	Time Space Position Information
TUEC	Test Uçuşu Emniyet Kurulu (FT Safety Review)
TUR	Turkey
TurAF	Turkish Air Force
TUTEC	Test Uçuşu Teknik Kurulu (FT Technical Board)
TWSDC	Technology and Weapon Development Command
UA	Unacceptable Risk
UAS	Unmanned Air System
UAV	Unmanned Aerial Vehicle
UCAS	Unmanned Combat Air System
UK	United Kingdom
US	United States
USA	United States of America
USMC	United States Marine Corps
USN	United States Navy
USNTPS	US Naval Test Pilot School
USO	Unit Safety Officer
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions
VSTOL	Vertical/Short Take Off and Landing
XAMEO	Experimental Aircraft Maintenance Engineering Officer

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Chapter 1 – INTRODUCTION

1.1 BACKGROUND

It is self-evident that all Flight Test Activities should be conducted safely and without hazarding the aircraft, the crew, or third parties and property on the ground. Far more so than with any other system airborne incidents have the ability to rapidly escalate in seriousness, leading to the potential loss of aircraft and crew.

To counter this ever-present threat the International Flight Test Community has established approaches that identify and then mitigate flight test risk.

This AGARDograph shares practice in this critical area of Flight Testing. Through its application both the NATO and wider Flight Test Community will have access to information that will help to manage flight test risk to the levels and standards that are expected today.

1.2 DOCUMENT STRUCTURE

This AGARDograph consists of four chapters:

- Chapter 1 is the introductory element which gives the background to Task Group SCI 236 and the approach taken in developing the AGARDOgraph. It describes the Document Structure and emphasises the critical importance of Safety Culture.
- Chapter 2 is a series of Case Studies produced by a number of Flight Test Organisations describing, in a broadly common format, their approach to managing Flight Test Safety and the methods they deploy to achieve safe flight testing. Contributions are made by:
    - BAE Systems Air – Warton – GBR
    - Boeing Test and Evaluation UK – GBR
    - Canadian Forces – Aerospace Engineering Test Establishment – AETE – CAN
    - NASA Armstrong Flight Research Center – USA
        - Edwards Air Force Base – California
        - Plant 42 Palmdale – California
    - NLR – Netherlands National Aerospace Centre – Amsterdam – NLD
    - SAAB AB – Aeronautics Business Area –Flight Test and Verification – Linköping – SWE
    - Turkish Air Force Flight Test Center – 401st Test Squadron – Eskişehir – TUR
    - United States Naval Aviation – Naval Air Systems Command – NAVAIR
    - Patuxent River, Maryland – USA
- Chapter 3 provides Observations and Discussion based upon the Case Studies with the intent of identifying:
    - Common themes and approaches;
    - Novel approaches; and
    - Best practice.
- Chapter 4 is a brief concluding section that provides an overview of findings.

1.3 SAFETY CULTURE

This AGARDograph describes and assesses the approaches to Flight Test Safety and Risk Management of a number of organisations with the aim of capturing practice so that others may benefit. A number of Flight Test Safety and Risk Management Systems are described with focus being applied to the standard Why, What, How, Who, Where and When question set with emphasis on:

- Higher Level Requirements;
- People;
- Processes; and
- Facilities and Tools.

The sum total of these is the Organisation's Safety Management System described in a mechanistic way and while this is highly relevant and important it comes to nothing if the organisation lacks an effective Safety Culture.

Culture is characterised by the way things are done in an organisation and Safety Culture is a measure of how an organisation addresses safety related issues. A good Safety Culture is all pervasive and places safety in a paramount position at all levels of the organisation. It is reflected in organisational attitudes and influences all major decisions. Within Flight Test, where catastrophic outcomes are always a possibility, it is vital that the organisation nurtures a Safety Culture which at all times challenges situations where risk can arise and addresses them. An effective Safety Culture is founded on a number of attributes:

- Leadership – Managers proactively demonstrate that safety is a core value of the organisation and are actively and visibly involved in safety management. They establish and live the values of the Safety Policy.
- Staff Involvement and Attitude – Staff take a personal responsibility for safety and understand that prevention is better than cure. They both understand and 'buy into' the policy and operate in accordance with approved procedures and practices.
- Commitment – Everyone is empowered to take decisions that affect safety without any fear of censure. A just culture where anyone can exercise the 'NO' vote without fearing reprisal.
- Competency – Is developed at all levels. It is prized and rewarded.
- Policies, Processes and Systems – Are deployed that naturally support the flight test activity and its safe conduct. Not just in terms of delivery but also in terms of monitoring and reporting safety performance and initiating appropriate improvement actions.

The very fact that a number of Flight Test Organisations have contributed to this work and are willing to share practice is testimony to their seriousness in addressing safety issues not only within their own business but also in the wider Flight Test Community. A review of the individual papers reveals organisations that strive to excel in pursuing safe flight testing with examples of how they react to the challenges of developing their own Safety Culture.

The papers perhaps concentrate more on the harder issues of Competency, Organisations and Processes and are a little light on the softer issues associated with establishing the required Safety Culture of Leadership, Staff Involvement, Attitude and Commitment but the critically important underlying theme of driving safety is clear.

An analysis of Flight Test Accidents often reveals a breakdown in the Safety Culture under programme cost and time pressures especially where management fail to live the values. We should all challenge ourselves with the questions of how would we behave when such pressures arise? and how would our Safety Culture withstand the stress test? Many otherwise fine flight test organisations with excellent safety management systems have failed when these pressures arise. All of the systems can be in place and operated by competent trained staff but will come to naught if the culture breaks down under pressure.

There is no silver bullet here. It is about how the organisation lives its values. Processes and People are powerful enablers but the Safety Culture is the glue that binds it all together. Management are key to developing this and must regard it as much a part of their role as programme delivery.

Whilst the following sections provide information on what others have done to develop and deploy Flight Test Safety Management Systems and are useful guidance on practice the development of the Safety Culture, very much belongs to you, the reader, and your organisation. There is no prescription which gives you an instant answer but without a healthy Safety Culture your search for safety is far less likely to succeed.

Chapter 2 – CASE STUDIES

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2.1 BAE SYSTEMS – AIR

2.1.1 Nature of Flight Test Activity

BAE Systems Air is a Manufacturer of Combat Aircraft, Military Trainers and Unmanned Air Systems (UAS). It currently has no Civil Programmes or Rotary Types in its product portfolio. Its current products consist of:

- Typhoon;
- Tornado;
- Hawk;
- F35 Lightning II;
- Taranis Unmanned Combat Air System (UCAS) Demonstrator; and
- PHASA 35 High Altitude Long Endurance UAS.

In support of these it undertakes flight testing using State of the Art Facilities and Tools across the whole of the product life cycle. This activity encompasses Experimental, Developmental and Production Flight Test. The Organisation has Flight Test Capabilities covering:

1) **Airframe** – Handling and Performance, Stability and Control, High Angle of Attack, Spinning, Flutter Vibration and Loads;
2) **Systems Integration** – General Systems, Avionic Systems, Weapon Systems; and
3) **Weapons Test** – Carriage, Jettison, Releases and Firings.

2.1.2 Background

The BAE Systems Flight Test Centre at Warton has a proud heritage that can be traced back to the earliest days of aviation in the United Kingdom. It's Corporate Knowledge and Experience originates from a large number of predecessor Flight Test organisations that have been at the forefront of aeronautical development for the last 100 years.

Following industry consolidation, it is now the only Flight Test Centre operating within the Company but it has absorbed the experiences and skills of its forebears. In recent years these have most notably been drawn from the fast jet and VSTOL experiences of the Dunsfold Flight Test Centre – Hunter, Harrier, Sea Harrier and Hawk and the large aircraft experiences of the Woodford Flight Test Centre – BAe 146, Jetstream, ATP and Nimrod.

The Warton Unit itself has a history that begins with the Canberra Bomber of 1949, this continued with the Lightning Fighter of the 1950s and International Co-operative projects commencing with the Anglo-French Jaguar in 1968. The Tri National Tornado followed in 1974. A series of Fly By Wire (FBW) Demonstrators, the FBW Jaguar and Experimental Aircraft Programme, led the way to the Typhoon of 1994. The Hawk and Harrier were also brought into the site's Flight Test portfolio following company reorganisation in the late 1980s and early 2000s. In recent years the Nimrod MRA4 Maritime Patrol Aircraft and a series of UAS Demonstrators have also been tested as has the F35 Lightning II where the organisation has provided domain expertise to the STOVL testing, supporting the US contractor, Lockheed Martin.

Current Warton activity centres on Typhoon, Tornado and Hawk development for the RAF and International Customers, the Production of the Typhoon and Hawk and continuing experimental UAS work.

The Organisation conducts some of its trials on a joint basis with customers, partners and the UK Government's Official Test Centres. Where these trials take place under BAE Systems governance these Test Partner's operate within the Flight Test Engineering procedure set.

In support this work a common Flight Test Safety Management System has been developed and deployed.

2.1.3 Regulatory Framework

2.1.3.1 External

BAE Systems Air and its forebears have historically had the UK Armed Forces as their principal customer. The Quality Management Systems deployed have therefore primarily been designed to satisfy the requirements of the UK Ministry of Defence (MoD) and latterly the Military Aviation Authority (MAA). These have then been reused to support partnership and export activities. For many years this meant that within the Flight Test domain the controlling instruments were Def Stan 05-123 for Flight Testing and AvP 67 for Test Flying and the origins of the deployed Flight Test Safety Management System and Quality Management System lie with these documents.

Following the loss of Nimrod Aircraft XV230 and the subsequent Haddon-Cave Nimrod Review changes were instituted in the UK MoD that created a new MAA to control military flight safety. Def Stan 05-123 and AvP 67 were withdrawn and replaced by new, Regulatory Article documents. Many aspects of these are similar to those replaced. The primary new Document Sets are contained in MAA Regulatory Publications (MRP), Series 1000 is General, Series 200 covers Flying and incorporates AvP67 and Series 5000 covers Design and Modification Engineering and incorporates Def Stan 05-123.

It is also a requirement of UK MoD that Approved Suppliers have a Quality Management System that satisfies the provisions of ISO 9000.The deployed Flight Test Safety Management System satisfies the requirements of the current MAA Regulations and ISO 9000.

2.1.3.2 Internal

Within BAE Systems safety at all levels is of the highest priority. To support this, the Company has a mandatory Safety Policy that describes how safety will be managed across all of the Company's activities and who is accountable. A specific element considers activities that are considered especially hazardous. Flight Testing and Flying are two of the identified elements. The Head of Flight Test Engineering (HoFTE) is named as the accountable person for Flight Test and the Director of Flight Operations (DFO) is accountable for Flying. Test Flying is addressed as a sub-element of Flying.

2.1.3.2.1 Flight Test Policy

Within BAE Systems Flight Testing is governed to satisfy a simple set of policies that are applied to everything that we do, covering Safety and Effectiveness.

- Safety shall be of paramount importance in all Flight Test activities. This shall be achieved by all Flight Test Project teams operating to a common Flight Test Process utilising Flight Test Engineers who are defined as Suitably Qualified and Experienced Personnel (SQEP) using approved Flight Test Facilities and Tools.
- All Flight Test Project teams shall constantly challenge methods of working in order to improve safety, timeliness and cost efficiency. This shall be achieved by all Projects operating within a common Flight Test Management System supported by focused cross Project reviews addressing all aspects of the Flight Test Management System performance.

2.1.3.2.2 Flight Test Safety Management System

The deployed Flight Test Safety Management System brings together elements of Flight Test with Test Flying, which itself is a sub-element of Flying. To satisfy this combined requirement the accountable managers, Head of Flight Test Engineering and Director of Flight Operations/Accountable Manager (Military Flying) (AM(MF)), have agreed that they will operate a single system that is agreed and managed by both. Administration is the responsibility of Flight Test Engineering

The deployed system consists of two complementary elements:

1) A generic common set of processes, facilities and tools operated by SQEP Flight Test Engineers and Aircrew that are used to support all of our Flight Test activities.
2) A specific Flight Test Safety Review process that is applied to every proposed flight trial to ensure that risk is identified and mitigated to an As Low As Reasonably Practical (ALARP) and Tolerable level.

2.1.4 Organisation and People

2.1.4.1 Engineering

Within BAE Systems Air delivery is the responsibility of project based teams and an aircraft type is typically a project focus. Within the UK System the Design Authority for an aircraft type is the Manufacturer who is given this responsibility by the MAA following assessment of organisation's ability to safely and effectively manage and develop the design. This leads to certain members of the Design Staff being named and approved by the UK MAA to fulfil certain duties in relation to the discharge of the Design Authority.

For Flight Test Engineering the accountable person is the Flight Test Manager (FTM) who is named on the Company's Design Approval Certificate. The FTM has a team working for him who deliver the engineering aspects of the Flight Test Programme.

Each Flight Test Manager is responsible for establishing a Team Construct that is best suited to satisfying the needs of their project. There is no fixed organisational model. There is however commonality of roles and role responsibilities across the teams and to the assessment and approval of individuals to fulfil their duties.

Each Team consists of two principal skill streams – Operations and Specialists.

Operations staff are responsible for managing a particular test aircraft, planning the details of a sortie in conjunction with the test aircrew and specialists, defining the required aircraft standard to the Hangar Team, Preparing Test Cards, leading the Briefing and Debriefing of the crew and leading the Telemetry Team when used.

Specialists are expert in a particular test domain, e.g., Handling, Weapons, Sensors, etc. and work closely with Design Departments to establish the detail requirements for a particular flight trial. They capture the required tests in the Flight Test Plan and act as the lead for the Flight Test Engineering aspects of both Design Review and Trials Safety Review. They support in the telemetry room and at briefing and debriefing. Post-flight they are responsible for analysis and reporting.

Against a mandatory procedure, that is part of the common process set, the Flight Test Manager defines what roles and document approvals can be discharged by all members of his staff. Each Flight Test Engineer has a personal SQEP Record, which is agreed and approved by the HoFTE and the DFO/AM(MF). This is to satisfy the UK MAA Regulatory requirement that personnel involved in the planning and execution of Test and Evaluation (T&E) activities are SQEP against specific T&E categories (in accordance with the MAA MRP).

This delivery accountability is paralleled by a Governance Stream led by an organisation separated from the delivery streams that is responsible for the definition of the controlling standards that shall be used by the project and the monitoring and review of the projects to ensure compliance. Within BAE Systems Air the accountable person for Flight Test is the Head of Flight Test Engineering, supported by the Flight Test Managers.

2.1.4.2 Flight Operations

Within BAE Systems Air flying is the responsibility of Flight Operations. Test Flying is a significant proportion of their workload.

The accountable person is the Director of Flight Operations (DFO) who reports to the Engineering Director. He is identified as the responsible person not only by the Company but also as the AM(MF) by the MAA. DFO is responsible for the Governance of Flying.

He controls the Flying Operations Manual (inclusive of associated Flying Orders) for BAE Systems Air which describe the processes to be followed during flying operations. These orders also identify those individuals approved to perform various types of flight test.

DFO is supported by two Chief Test Pilots. One for Combat Aircraft and a second for Strategic Aircraft and UAS. They in turn are supported by a team of Test Pilots, Test Aircrew and Flight Test Observers who focus on particular aircraft types.

2.1.5 Process and Procedure

2.1.5.1 Common Procedure

In many areas of Engineering within BAE Systems projects develop their own specific practices that satisfy generic standards established by the relevant Governing Authority. This leads to different projects having different methods of work. In Flight Test Engineering this is not the case. It has been long established that Flight Test Engineering will operate common process, facilities and tools across all projects. These are owned and governed by the HoFTE on behalf of the projects and managed between the projects and HoFTE. This means that irrespective of project Flight Test Engineers only need to operate one method of working. This is judged to enhance safety and efficiency and also minimises retraining on transfer between Project Teams.

2.1.5.2 Flight Test Process

The basic Flight Test process deployed within BAE Systems Air is recognisable to any practising Flight Test Engineer and comprises four stages, with associated documentation.

Initial Planning: Every major Flight Test Programme commences with Initial Planning. Its aim is to support Business Winning at understood levels of commercial and technical risk and the positioning of the Team to do the detailed work. It is critically important to establishing a Flight Test Programme that can be delivered safely and effectively. The principal outcomes of Long-Term Planning are twofold:

- The preparation of an Outline Test Plan for the flight trials, that has sufficient detail to support task estimating in pursuance of a Contract Bid.
- An assessment of the commercial and technical risk inherent in the Outline Test Plan, which will allow initial risk contingency and risk management measures to be established.

Detailed Planning: Provided the Initial Planning is effective and bid is successful the task will proceed to the Detail Planning Phase, inclusive of Trials Definition and Aircraft Preparation.

- This is the Phase where the detailed planning of the activities necessary to deliver the trials is undertaken. It is also the phase where those activities that must be completed ahead of Test Conduct, e.g., Flight Test Instrumentation design and manufacture, Data Processing system design, detailed Flight Test Plan preparation, Risk Assessment and Management, etc. are performed.
- It should be recognised that it is not uncommon for this Phase to proceed at commercial risk ahead of Contract Award in order to mitigate overall programme risk. For a major programme this activity commences many years before First Flight.
- Detailed Flight Test Risk Review and Safety Management are performed during this Phase and the outcome is a fully risk mitigated Flight Test Plan approved and authorised for use.
- Within BAE Systems the approval and authorisation Levels for the Flight Test Plan are dictated by the Trial Risk Category. High Risk Trials are authorised by DFO/AM(MF) and HoFTE. Lower categorizations are addressed at lower levels in the Organisations.
- The final activity is Test Readiness Review where all aspects of trial preparedness are considered ahead of the trial. Clearly Test Safety is a major mandatory consideration. The outcome of this Phase is Approval to Fly.

Trials Execution: The Execution Phase is that part of the Flight Test Programme where the Test Flying is conducted. For a Major Programme it will involve Envelope Expansion and High Risk Flight Trials.

- The key controlling document is the Test Card Set for a given sortie. Within BAE Systems these are produced by the Flight Test Operations Team in conjunction with the Test Aircrew.
- Each sortie is subject to formal brief by the relevant approved person with all involved parties. A Briefing Witness is nominated for each brief who is responsible for ensuring the brief is fit for purpose and that all sortie elements have been adequately covered. At the conclusion of the brief he presents a completed checklist to the aircraft captain to be signed off to declare the crew are satisfied with the Sortie Brief. The Briefing Witness has the authority to suspend a sortie which is judged to be inadequately prepared.

- Where sorties are supported by Telemetry the Team are present at the brief.
- Formal debrief follows each Sortie. Any safety-related issues receive priority assessment and where necessary are escalated.

Analysis and Reporting: On completion of the flying tasks the Flight Test team will move into this final phase of the process.

- Analysis is that part of the Flight Test Programme where test data is processed and assessed both to enable trials continuation and to support reporting.
- In the Flight Test Domain this will involve not only processing data from the test aircraft but also other sources especially those which provide independent "Truth" Data.
- Immediate post-flight analysis focuses on test progression and safety-related issues and arisings.
- Reporting covers all of those activities where information and data are released from the Flight Test Organisation to others. It may be released internally within the Project or externally to Customers.
- Identification and capture of safety-related issues and their escalation for resolution is a priority of short term reporting.
- Where residual safety issues remain, the Final Report must clearly identify the scale and impact of the issue and make recommendations for mitigating and controlling the risk.

2.1.5.3 Flight Test Safety Review Process

For many years BAE Systems at Warton did not have a specific procedure that managed Flight Test Safety Review. It was left to the normal operation of the flight test process to fulfil this function as a by-product.

In the early 2000s it was identified that the company was not following best practice in this area and a specific process was introduced following research into the approaches taken by other organisations. Since that time, the basis of the system implemented remains, though it has evolved to encompass changes in MAA Regulatory requirements, embracing the top level concept of a Test and Evaluation (T&E) 'Approval Board'.

BAE Systems adopted an approach where trials are pre-assessed by a Risk Categorisation Meeting and given an indicative Risk Categorisation. This dictates different levels of Risk Review and Risk Management dependent on the allocated category. This has the advantage of allocating lower categorizations to trials of a routine low risk nature, e.g., Radio Trials, thereby avoiding the burden of full blooded High Risk Trials Review in all cases.

2.1.5.3.1 Outline of the Test and Evaluation Approval Board

The aim of the T&E Approval Board is to understand and, where required, assist in mitigating the risks associated with all planned flight testing activities to ALARP and Tolerable. Risk Categorization is a continuous process from the inception of a trial to completion.

The outcome of the board will be the Approval from AM(MF) to proceed to trials execution. This Approval does not require AM(MF) signature, but instead is granted when the T&E Approval Board process has been followed and the Flight Test Programme (FTP) is signed by all required signatories.

The first stage of the T&E Approval Board, which for 'within scope' T&E activities will occur at an early stage of the planning process, is identification of the MAA T&E Category (in accordance with Regulatory Article RA2370) and initial risk categorization of the trial at the Trials Risk Categorization meeting.

At the Trials Risk Categorization meeting a brief outline of each planned trial will be given by the relevant Flight Test Manager or their nominee. Trials will be categorized and identified against Intolerable, High, Medium and Low risk categories using the experience of the assessors and with reference to the Risk Matrix (see Table 2-1.1 in Section 2.1.5.4.3).

A Lead FTE and a Flight Operations Project Pilot (both of whom will act as Trial Supervisors) will be appointed based on both the agreed Risk and T&E Category, and their competency for conduct of the trial, i.e., they must each be SQEP in their respective role.

A pre-defined Trials Log Sheet, is employed both as a prompt to ensure all major risk areas are discussed and also as a record of the categorizations made, the reasons for the decision and any guidance offered to the associated Safety Review, Trials Readiness Review and FTP authors for Low Risk Trials.

The subsequent stages of the T&E Approval Board depend on the initial risk categorization defined. The stages are:

- Concept Review (for trials initially Categorized as High Risk)
- Safety Review (for trials initially Categorized as High and Medium Risk)
- Agreeing and mitigating the risks in the FTP to ALARP and Tolerable
- Approval and Authorisation of the FTP

A flowchart showing the T&E Approval Board process is given in the Appendix (Figure 2-1.1).

2.1.5.3.2 Participation

The assessment team will be senior staff from Flight Test Engineering, Flight Operations, Continuing Airworthiness Management Organisation and Type Airworthiness.

At the outset of each collaborative trial which involves service aircrew the service will be represented primarily via Officer Commanding 41 Test and Evaluation Squadron who will be involved in the Initial Risk Categorisation and their involvement will continue through any Safety Review stage. The initial Risk Category will be continuously reviewed against all MoD or other partner specific requirements and mitigation together with company requirements; the composite solution will be applied as necessary.

The initial Risk Categorisation attributed to a trial or activity may be changed during the Safety Review Process or the Trials Readiness Review and also during production of FTPs, if appropriate mitigations or new risks are identified, or if trials results indicate the need. This principle of continuous review is to be encouraged but the trial re-categorization must, as a minimum be formally endorsed by the project Flight Test Manager and appropriate CTP or DFO, but ideally through the T&E Board.

2.1.5.3.3 Trial Risk Categories

Guidelines for the definitions of the risk categories are as follows:

1) **Intolerable**
   Loss of manned or high value aircraft and/or injuries or fatalities are likely during conduct of the trial. A trial categorized as Intolerable will not be allowed to proceed. The hazards must be re-evaluated and mitigated to an acceptable risk level prior to re-presenting for Categorisation.

3) **High Risk**
A high degree of uncertainty exists. Though remote, potential does exist for loss of manned or high value aircraft and/or loss of life due to predicted risk, unforeseeable or imperfectly understood actions.

Examples might be:

- High AoA / carefree handling;
- Some engine handling work;
- Concept demonstrator flying;
- First-of-type flying;
- Low level work with degraded situational awareness; or
- The deliberate investigation of major emergency situations.

4) **Medium Risk**
Uncertainties exist, but experience from similar trials can be used in mitigation. Potential exists for aircraft, collateral damage or risk to life or injury; risk of catastrophic failure is considered improbable.

Examples might be:

- Initial carriage/handling/release of unfamiliar stores/weapons;
- Flutter;
- airfield handling and take-off/landing performance definition; or
- Some low level work.

5) **Low Risk**
Few uncertainties exist and risk of catastrophic failure is considered incredible. Within or close to established envelopes and with manoeuvres familiar to the test fraternity.

Examples might be:

- Routine air tests;
- Software/hardware revalidation;
- Incremental configuration expansion;
- Handling/carriage/release of comparable stores;
- Data gathering trials within the cleared flight envelope; and
- Most small Unmanned Air System (sUAS) trials.

All the above definitions are guidelines only; the risk categorisation team will be the final arbiters of the category in all cases.

2.1.5.3.4 Risk Matrix

During the Risk Categorization and Safety Review cycle, Risk to Life will be considered as an embedded part of the assessment methodology. This is achieved through the application of a Risk Matrix that not only addresses Risk to Life, but also complements our Risk Categorization and Safety Review Activities.

The Matrix is based on standard industry practice and similar to the 6 x 4 matrix used by QinetiQ and the Air Warfare Centre to assess trials risk (Table 2-1.1).

Table 2-1.1: Risk Matrix.

Severity			
Catastrophic	**Critical**	**Marginal**	**Negligible**
Loss of life or aircraft.	Major damage or severe injury.	Minor damage or minor injury.	Less than minor damage/ injury.

Probability					
Frequent	**Probable**	**Occasional**	**Remote**	**Improbable**	**Incredible**
Will occur often during the trial.	Will occur during the trial.	Could possibly occur during the trial.	Unlikely to occur during the trial.	Very Unlikely to occur during the trial.	Extremely Unlikely to occur during the trial.
Numerous	P = 1	$1 > P \geq 10^{-2}$	$10^{-2} > P \geq 10^{-4}$	$10^{-4} > P \geq 10^{-6}$	$P < 10^{-6}$

Risk				
	Catastrophic	**Critical**	**Marginal**	**Negligible**
Frequent	INTOLERABLE	INTOLERABLE	INTOLERABLE	HIGH
Probable	INTOLERABLE	INTOLERABLE	HIGH	MEDIUM
Occasional	INTOLERABLE	HIGH	MEDIUM	MEDIUM
Remote	HIGH	MEDIUM	MEDIUM	LOW
Improbable	MEDIUM	MEDIUM	LOW	LOW
Incredible	LOW	LOW	LOW	LOW

Numerical Probabilities are indicative of per event/trial and should be used as guidance to support decision making and should not diminish the qualitative view of the subject matter experts.

Physical Severity (loss of manned or high value aircraft) and Human Severity (Risk to Life) should be considered with equal weighting to establish a baseline risk level.

2.1.5.3.5 Progression Through to Trials Approval

Once a trials activity has been categorized progression to approval is dependent on the Risk Category.

1) **Low Risk Trials**

   For low risk trials it is the responsibility of the FTP Author, FTE and FLOPS Trial Supervisors, Approver, Authoriser and to assess trials specific risks as captured in the Safety Considerations section of the FTP using the Risk Matrix.

   Any residual risks classed higher than 'Low' will trigger a re-categorization. It is the responsibility of the Flight Test and Flight Operations Trial Supervisors to raise the requirement to trigger this re-categorization.

2) Medium Risk Trials

Medium Risk trials require a formal Safety Review to be convened by the project team (FTE and Flight Ops Trial Supervisors) when they feel sufficient data and information is available. During the Safety Review, specific trial hazards will be assessed against the Risk Matrix. This review will be Co-Chaired by the relevant Flight Test Manager and Chief Test Pilot, with attendees including:

- Airframe/Systems Sponsor. (or their formally appointed nominees);
- Chief Airworthiness Engineer;
- Continuing Airworthiness Management Organisation;
- Test Partners (joint trials);
- FTE and FLOPS Trial Supervisors;
- Contributing Flight Test Engineers;
- Airframe/System Advisors; and
- Independent Subject Matter Experts as appropriate.

The Safety Review will analyse the trial from a risk point of view. Emphasis will be placed on:

- Identifying hazards (e.g., CFIT, UAS exiting a danger area, inadvertent store release, etc.) to assess their severity and probability. These hazards may be either subject trial specific or Flight Test generic – both are equally important in identifying, assessing and mitigating overall trials risk.
- Establishing Contributors/Control Measures and Mitigations/Outcomes for the identified hazards.
- Establishing that the residual risk is at acceptable levels using the Risk Matrix as guidance.

Following the Safety Review, if any risks have a residual rating higher than the overall Trial Risk, the trial must be re-categorized.

In the event of unexpected test arisings during a trial phase, it may be necessary to reconvene the Safety Review meeting before the trial resumes (responsibility FTM and/or Flight Ops Trial Supervisor).

Formal minutes are issued from the review and actions arising from a Safety Review must be closed prior to the relevant testing being performed. It is regarded as best practice for all actions to be closed at the point of trials FTP authorisation.

3) High Risk Trials

Prior to detailed planning for trials categorized as high risk a Concept Review will be convened as soon as possible to identify and understand initial hazards, to establish test policy and to agree the strategic way ahead. This will inform and direct detailed test planning.

This Concept Review will be Co-Chaired by the relevant Flight Test Manager and Chief Test Pilot, with attendees including:

- FTE and FLOPS Trial Supervisors;
- Chief Airworthiness Engineer;
- Continuing Airworthiness Management Organisation;
- Contributing Flight Test Engineers;
- Test Partners (joint trials); and
- Independent Subject Matter Experts as appropriate.

The output of this meeting (formal minutes) will provide discussion and agreement of the strategic way ahead supporting the detailed trials planning, along with some direction/actions with respect to hazard definition / understanding and potential options for mitigation.

The High Risk Safety Review will be held in similar timescales to the medium risk review i.e., when the trials team has the relevant information and feels ready, but with sufficient time to amend the FTP if necessary.

This High Risk Review will be Co-Chaired at HoFTE and DFO level with attendees including:

- Chief Test Pilot;
- Flight Test Manager;
- Airframe/Systems Sponsor. (or their formally appointed nominees);
- Chief Airworthiness Engineer;
- Continuing Airworthiness Management Organisation;
- Test Partners (joint trials);
- FTE and FLOPS Trial Supervisors;
- Contributing Flight Test Engineers;
- Airframe/System Advisors; and
- Independent Subject Matter Experts as appropriate.

The objectives and output from this review will be the same as for the Medium Risk Review.

2.1.5.3.6 Flight Test Programme

Regardless of the categorization of the trials activity a Summary Table will be added to the FTP that identifies the following, for each hazard.

- Identified Hazard.
- FTP Section cross reference.
- Residual severity.
- Indicative probability.
- Residual Risk Level from Matrix.

Trials are ‘Approved’ once the whole Trials Approval Process (see Appendix 2-1.9) has been completed and the FTP is Approved and Authorised at the appropriate level.

2.1.6 Facilities and Tools

In order to minimise costs a common set of Facilities and Tools is used by the projects. This has clear benefits in relation to test safety as it minimises the need to retrain and requalify when staff move between projects and means that operator experience and expertise gained on one project is readily transferrable to another.

In this context Tools include: Telemetry, Process and Procedures and Practice.

This is particularly relevant to trials of a High Risk nature as we are currently performing fewer of these than in previous years. Links with other BAE Systems Air facilities are use (i.e., with Simulation) where necessary in order to ‘work-up’ Flight Test and Flight Ops personnel for specific trials activities.

Currently no structured toolsets are deployed to help manage, assess and mitigate risk. Several databases are in place to manage the Review Process and to capture Arisings and Occurrences. These are used to monitor overall system performance and to identify areas requiring attention.

2.1.7 Discussion and Observations

N/A

2.1.8 Conclusions and Recommendations

N/A

2.1.9 Appendix

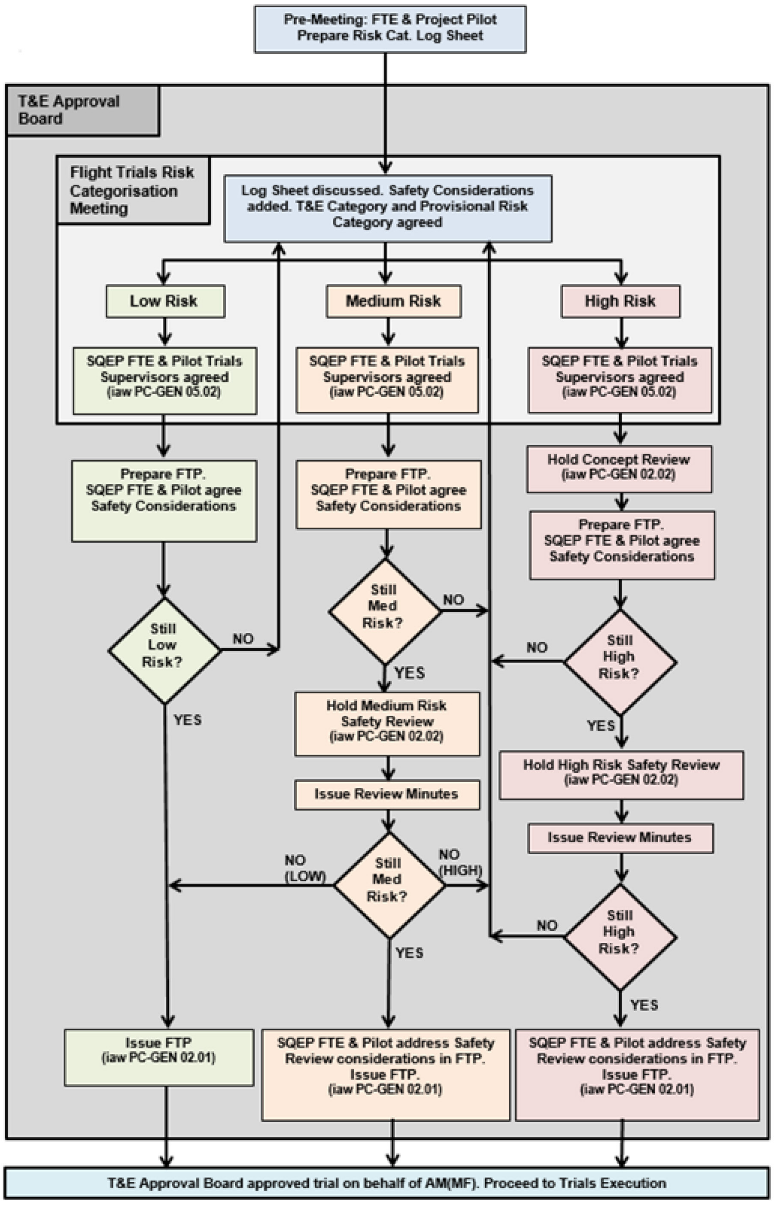


Figure 2-1.1: BAE Systems 'T&E Approval Board' Flowchart.

2.2 BOEING TEST AND EVALUATION UK

2.2.1 Nature of Flight Test Activity

Boeing is the world's largest aerospace company and leading manufacturer of commercial jetliners and defence, space and security systems. The Company supports airlines and government customers in 150 countries. Flight test activity includes production, maintenance and experimental test activity on a range of civil and military platforms.

As the centrally-managed test and evaluation organisation of The Boeing Company, Boeing Test and Evaluation (BT&E) verifies and validates the Company's products and services, ensuring they operate as designed and meet the rigorous requirements of regulatory agencies and Boeing customers. Boeing Test and Evaluation employs approximately 6,000 employees. The organisation has lab and flight operations at more than 60 sites in 23 states in the United States, with its largest operational centres in Seattle; Southern California; St. Louis; Philadelphia; Mesa, Ariz.; and Patuxent River, Md. BT&E also has a number of global centres including the UK, India and Australia. Flight operations personnel conduct an average of approximately 600 flights per month, conducting flight tests for experimental and production aircraft. Flight testing of new airplanes can occur anywhere in the world, wherever weather conditions exist that will test the airplane to its performance limits.

2.2.2 Background

2.2.2.1 Boeing Commercial Airplanes

Boeing Commercial Airplanes is committed to being the leader in commercial aviation by offering airplanes and services that deliver superior design, efficiency and value to our customers and a superior flying experience to their customers. Today, there are more than 10,000 Boeing commercial jetliners in service; airplanes that fly farther on less fuel, airplanes that reduce airport noise and emissions, airplanes that provide passenger-preferred comfort while delivering superior bottom-line performance to operators. Boeing Commercial Airplanes, a business unit of The Boeing Company, is headquartered in Seattle, Washington and employs more than 83,000 people worldwide.

2.2.2.2 Military Aircraft

Boeing Military Aircraft, the largest business within Defence, Space and Security, employs more than 12,000 people throughout the United States and around the world. Based in St. Louis, Missouri, the business, has four divisions: Autonomous Systems; Global Strike; Mobility, Surveillance and Engagement; and Vertical Lift. Boeing Military Aircraft is the world leader in military aviation. Noteworthy products include the F/A-18E/F Super Hornet strike fighter, EA-18G Growler airborne electronic attack aircraft and F-15 air superiority fighters; the AH-64 Apache attack helicopter; the advanced, multi-mission H-47 Chinook tandem rotor helicopter; the innovative V-22 Osprey tiltrotor; the multi-mission maritime patrol aircraft P-8 Poseidon; the autonomous air vehicle ScanEagle; and Weapon Systems including the Joint Direct Attack Munition, Small Diameter Bomb and Harpoon Block II.

2.2.3 Regulatory Framework

Boeing has company-wide policy and processes under which all test activity is conducted complies with national legal and regulatory requirements. This enables standard practices to be employed anywhere in the world. This Case Study describes the overarching process and policy for T&E Safety Management and its specific application to the UK Military Aviation Authority's (MAA) Contractor Flying Approval Organisation Scheme (CFAOS). This was initially achieved to enable in-country delivery and T&E of the UK Chinook fleet. It has since been expanded to include C-17 operations, Remotely Piloted Air Systems (under a civil approval) and continues to develop to enable support to Boeing air systems operated by the UK government.

2.2.3.1 Quality Management System

The BT&E Quality Manual applies to all BT&E locations providing test proposals, test planning, test design, test build, test execution, post-test activities, and other aerospace-related services transferred from or requested by other Boeing entities through inter-organisational work transactions or other methods used to deliver customer work statement requirements to BT&E. BT&E process management methods establish interrelationships of system processes through the value streams defining process ownership, functional disciplines, and operational capabilities. The Product Test Life Cycle (PTLC) model shown in Figure 2-2.1 represents the iterative processes and interactions within a test program that may be scaled and tailored for individual tests and program needs. BT&E leadership ensures that QMS processes are developed and maintained to support meeting quality objectives and customer requirements. BT&E maintains an independent QMS compliant with AS9100, customer, and regulatory requirements. Changes to the QMS occur in a controlled manner to ensure the integrity of BT&E products and services.

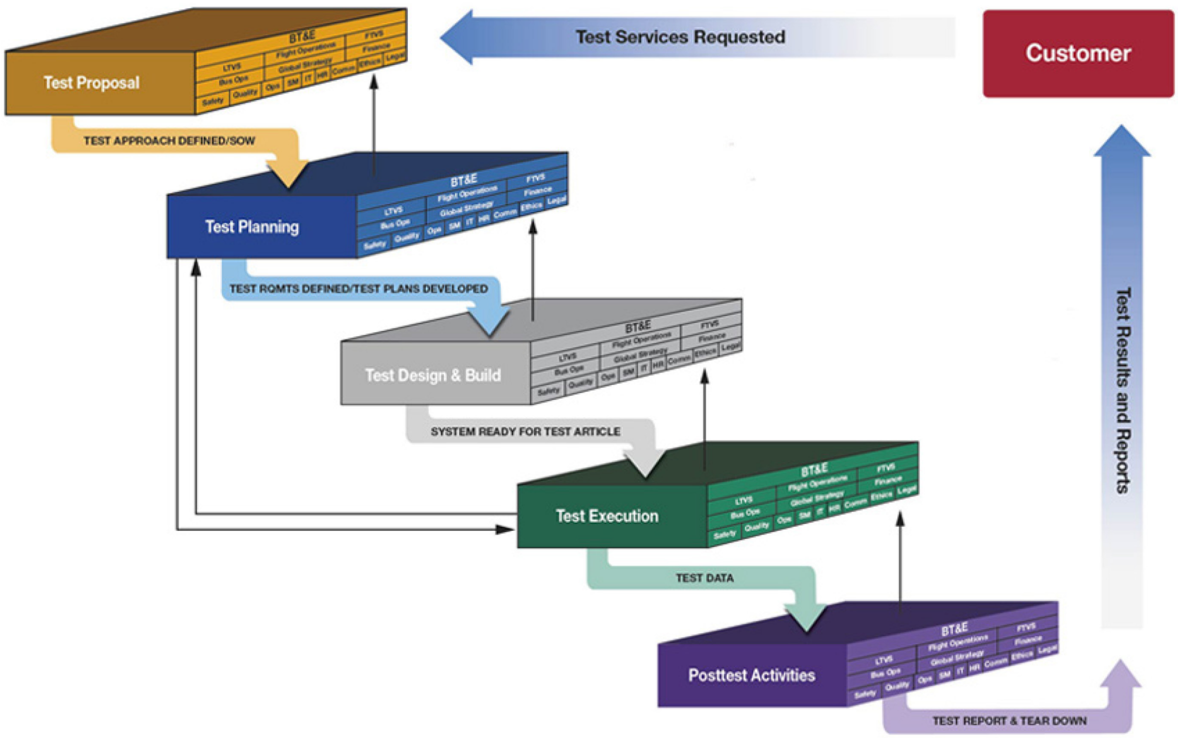


Figure 2-2.1: Product Test Life Cycle.

2.2.3.2 Product Test Life Cycle

The PTLC, as depicted in Figure 2-2.1, consists of a series of test phases which encompass the preparation, execution, and reporting of a test project/test program. The PTLC is iterative in nature and may be repeated at various levels and should be scaled and tailored as required for individual test project/test program needs. The structured planning ensures that the risk in conducting T&E activities are substantiated with a demonstrable benefit to the business and customer, either the Boeing responsible Design Organisation or the end user.

2.2.3.3 BT&E Safety Policy

The mission of BT&E is to execute safe, efficient, and effective test and evaluation services across The Boeing Company. The following states the BT&E safety commitment:

> *In Boeing Test & Evaluation, we build trust by validating Boeing products and services to meet the highest standards of safety, quality, and reliability. We are committed to continually improving our products and services and our Safety Management System.*

That commitment includes:

- Providing employees with a safe and healthy workplace while reducing occupational health and safety risks.
- Promoting individual and joint accountability for maintaining safe and efficient operations and for creating our zero-injury safety culture together through employee engagement.
- Proactively assessing, investigating, and mitigating test hazards, safety concerns, and incidents to resolve risk early and prevent recurrence.
- Preventing pollution and conducting operations in compliance with applicable laws, regulations, and Boeing requirements.

The BT&E safety commitment relies on adherence to the policies and procedures governing commercial and military flight safety, ensuring safe testing and that our customers receive the best quality and most reliable product and services.

2.2.3.4 Safety Management System

The BT&E SMS Manual outlines the policy, plans, and procedures used by BT&E employees to continuously improve process effectiveness of BT&E's safety cultures. The BT&E Quality Management System (QMS) provides the business management framework for the SMS, and the QMS complements the SMS. BT&E gathers requirements to perform tests from Boeing Commercial Airplanes (BCA), Boeing Defence, Space and Security (BDS) and other business partners including those in Engineering Test and Technology (ET&T). The BT&E team integrates aviation and space (aviation), system, and occupational safety functions along with environmental management into one integrated management system. Working alongside BCA, BDS and ET&T partners, the BT&E team and Safety functions have the following responsibilities in three main categories, depicted in Figure 2-2.2:

- Aviation safety ensures:
  - The technical airworthiness and the operational integrity of aircraft under BT&E's control; and
  - The conduct of flight operations in a safe and effective manner.
- System safety ensures that an acceptable level of safety is achieved for a system and product in test and in its intended operational environment throughout its intended life span.
- Environment, Health and Safety (EHS) ensures a safe and environmentally sound workplace for Boeing personnel in enterprise facilities. EHS also ensures safety in the activities that are carried out in accordance with occupational safety and environmental requirements, including procedures, personal protective equipment, and the presence of precautions related to those activities.

For the UK regulatory framework an additional supplementary Air Safety Management Plan was generated to identify the way in which this safety management system was applied to specific regulations applicable to UK operations; such as generic risk management, occurrence reporting and Post-Crash Management (or Pre-Mishap Planning in US terminology).

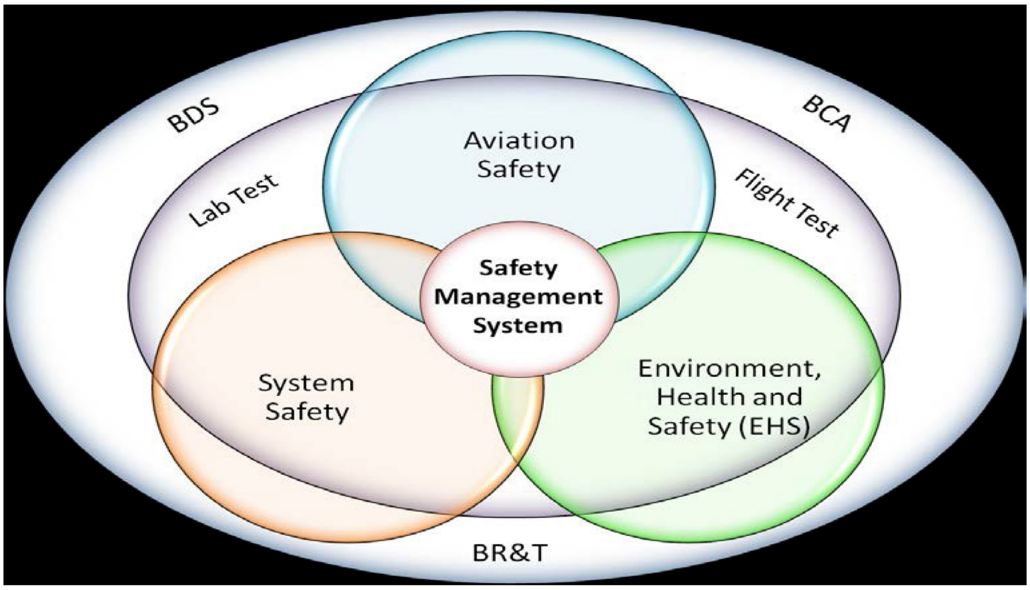


Figure 2-2.2: BT&E Integrated Safety Management System.

2.2.4 Organisation and People

2.2.4.1 Engineering

Boeing Engineering brings together Company-wide process to ensure first-time quality so we can deliver on our customer expectations in quality, schedule, and cost. Engineering Excellence promotes adoption of Best Practices and development of new capabilities that:

- Improve performance on development programs;
- Strengthen engineering accountability; and
- Create the engineering workforce of the future.

2.2.4.2 Test Program Managers (TPM)

TPMs are accountable to Programs and the BT&E Directors as the BT&E representatives with responsibility to:

- Manage test work statement commitments and performance including cost, schedule, technical and safety.
- Provide test program performance, risk & opportunity status and plans to program, business unit, and/or site leadership.

2.2.4.3 Test Value Stream

Laboratory or Flight Test Value Stream Leaders are accountable to the Test Program Managers and BT&E Directors and have responsibility to:

- Execute and provide status of lab or flight test work statement commitments and performance including cost, schedule, technical, and safety.
- Coordinate, integrate and provide guidance and oversight of all value stream test activities.
- Plan and manage all resources required to execute the test statement of work. Ensuring competency of the test team involved in test execution.

Note: In most cases on smaller programs the same person will perform the TPM role and a value stream role.

2.2.4.4 Flight Operations

Flight Operations includes all aircrew including experimental Test Pilots, Production Test Pilots, Flight Engineers, Load Masters and other supporting aircrew. The Flight Operations organisation is arranged with Chief Pilots for specific aircraft models/types (e.g., CH-47) reporting to Chief Pilots for specific operational roles (e.g., Commercial Airplanes). These Chief Pilots report to a Vice President for Flight Operations for BT&E, and in the UK regulatory context, the Accountable Manager Military Flying (AM(MF)). The AM(MF) is the Risk owner for all Boeing Flight Operations under the MAA regulation and is to ensure that the Risks are Tolerable and As Low As Reasonably Practicable (ALARP). The AM(MF) is supported by selected Chief Pilots holding specific Post Holder roles. Flight Operations are responsible for:

- Authorisation and supervision of BT&E operations;
- Qualification and competency of personnel engaged in flight operations and test;
- Implementation of Flight Safety and its promotion;
- Test Planning with Flight Test Value Stream Engineers; and
- Execution of Flight Operations including all test operations.

2.2.5 Process and Procedure

2.2.5.1 Test Planning

Effective test planning is a key to gathering the required test data to support the verification and validation of the system under test. It also develops how the data will be gathered safely and substantiates the need to complete the test activity. Boeing has different levels of Test Planning in order to develop overall test programs and then detailed aspects of the test activities. The PTLC provides guidance and templates for the detail required at all levels of test planning.

2.2.5.2 Test Hazard Analysis

The primary mechanism for determining and documenting T&E hazards and subsequently risk is the Test Hazard Analysis (THA). Test specialists including Test Engineers, Test Aircrew, Safety Engineers and other subject matter experts help to identify the hazards associated with the operating of a test asset during specific test manoeuvres/activities. The THA are subject to peer and independent review at an appropriate level to the risk of the T&E activity. The THA details the following:

- Test Title;
- Test Plan/Manoeuvre reference;
- Hazard Title;
- Hazard Cause;
- Effect;
- Pre-mitigation risk level (accident severity and likelihood);
- Minimising procedures and comments; and
- Post mitigation risk level.

The UK Military Regulatory Publication requires all T&E activity to have an associated Risk Assessment.

2.2.5.3 Risk Management Process

The identification and subsequent management of Risks follows a simple step by step process, shown below. The Boeing UK flight operation has included T&E with a range of stakeholders in Combined or Integrated Test Teams. This has been a vital element in deliver of capability to the end user within the UK Service release process. The following steps are taken in the risk identification process:

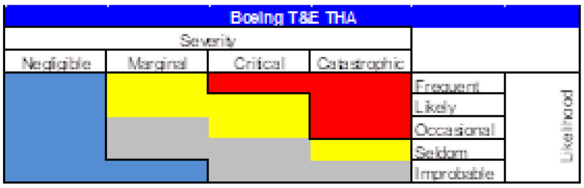
- Risk Identification;
- Risk Assessment;
- Risk Control and Decision Making;
- Implement controls; and
- Supervise/Revise.

2.2.5.4 Risk Matrix

Boeing T&E uses a 4 x 5 risk matrix to sentence risk levels (Table 2-2.1) this sentences risk into four categories of increasing levels of risk which are Blue, Grey, Yellow and Red. Depending upon the risk level the management of that Risk may be referred further up the management chain to confirm that the Risk is Tolerable and ALARP. Key to this is the exposure to the risk for test or more routine operations; i.e., that higher risk may be tolerated for specific test events weighing the value and benefit in taking that risk such as demonstrating new novel flight systems or characteristics. The Boeing Risk Matrix differs from that of the UK MAA Hazard Risk Matrix (HRM), as shown in Table 2-2.1. Whilst there are differences there is a general alignment of Risk Levels and equivalence which had to be documented in a UK Air Safety Management Plan (ASMP) and accepted by the MAA.

Table 2-2.1: UK MAA and Boeing Risk Matrices.

MAA HRM					
		Severity			
		Minor	Major	Critical	Catastrophic
Likelihood	Frequent	M	H	VH	VH
	Occasional	L	M	H	VH
	Remote	L	L	M	H
	Improbable	L	L	L	M



MAA definition	MAA Likelihood
Likely to occur at least several times per year	Frequent
Likely to occur one or more times per year	Occasional
Likely to occur one or more times in 10 years	Remote
Unlikely to occur in 10 years	Improbable

BT&E Likelihood	BT&E Definition
Frequent	Likely to occur immediately or within the period of the test
Likely	Probably will occur within the period of the test
Occasional	May occur within the period of the test
Seldom	Unlikely but possible to occur during the test
Improbable	So unlikely that it is assumed occurrence may not be experienced

MAA Definition	MAA Severity
3 or more MoD fatalities or 1 member of the public	Catastrophic
1 or 2 MoD fatalities or large number of major injuries	Critical
Major injuries to any person	Major
Reportable injuries (3 + days absence from work)	Minor

BT&E Severity	BT&E Definition
Catastrophic	May cause death or aircraft loss
Critical	May cause severe injury or major aircraft damage
Marginal	May cause minor Injury or minor aircraft damage
Negligible	Will not result in injury or aircraft damage.

2.2.5.5 Flight Test Mission Assurance Readiness Review (FTMARR)

The purpose of the FTMARR is to provide independent Boeing management approval to proceed with flight test in a safe, effective and efficient manner. The review covers three key aspects of the system to b operated and tested; Design, Build and Operation. The FTMARR process prescribes the key board members for the review, its preparation, conduct and documenting. The outcome of the FTMARR is a Boeing Authorisation to Test documenting the outcome of the review and any pertinent limitations or restrictions associated with the approval to operate the system for test.

2.2.5.6 Test Readiness Review

The Test Readiness Review (TRR) provides a forum for all test stakeholders to review the test configuration and concur that it is safe to proceed with the test. It contains a comprehensive description of all facets of the test. The TRR chair and review/panel members should be selected in accordance with the test program/customer requirements. The overall TRR approach is tailored depending on the size/type of program, contractual requirements, user/customer requirements/involvement, type of test/verification required, and other programmatic requirements. Indeed, for complex test programs with a number of elements or aircraft a number of separate TRRs may be completed. A standard checklist is provided to support the conduct of the TRR and the success completion of the review is documented by the TRR chair.

2.2.5.7 Day to Day Supervision

Test Managers, Test Directors and Chief Pilots provide day to day oversight of safe conduct of the test activity. Program Test Conductors and participants are selected to ensure that the appropriate competency of the test team for the activity.

2.2.6 Facilities and Tools

2.2.6.1 Test Planning, Execution and Reporting Tool (TPERT)

TPERT is the standard Test Planning, Execution, and Reporting Tool, designed for use across BT&E. TPERT aligns with the PTLC, guidance and processes. It includes client software that works with Microsoft Office suite of tools to communicate with an Oracle database. TPERT allows users to create detailed test plans and stores the test plan data on the Oracle database. Users are able to arrange and sequence test conditions and in some areas InfoPath create and deploys electronic forms and Test Cards to gather information. TPERT provides configuration control of the detailed Test Plans for the conduct of test activities. In addition, TPERT allows the test progress to be closely monitored by the test team for onward communication with program leaders.

2.2.6.2 Briefing Checklists

Briefing Checklists are used to guide the test crew to ensure that all relevant regulatory and procedural requirements are complied with. This gives the test briefing a well-known structure and focus on the task of the day, including Test Hazard mitigations. Equally debriefing follows a structured format after the flight with the first element flight safety points followed by key test results.

2.2.6.3 Operational Risk Management

Boeing uses an Operation Risk Assessment for each flight to separately determine the risk associated with the conduct of the test on the day. Factors that include:

- Show time;
- Planned duty day;

- Planned take-off and duration;
- Non-standard shift patterns;
- Flight planning time;
- Complexity/Test Risk;
- Crew composition;
- Crew qualification and training;
- Recency;
- Operating area;
- Departure/Arrival weather;
- Type of flying, i.e., VFR, VMC, IFR, IMC; and
- Intangible considerations.

The scores assigned to these are factored and the total is used to identify the level of authorisation required for the flight test.

2.2.6.4 Risk Register

The UK MAA regulations require aircraft operators to have and maintain a Risk Register. The rationale for the Risk Register is to ensure that the Risk to Life in operations of an air system are demonstrably tolerable and ALARP. Boeing Operations in the UK have been mainly based at established military aerodromes with aviation activities and operational commitments. To comply with MAA regulations, Boeing Operations in the UK developed a generic risk register that caters for all risks outside of the testing environment and includes site specific risks, which are derived from Airfield Operating Hazard Logs (AOHLs). All generic and test risks are sentenced using both the Boeing and MAA Risk Matrices and are reviewed periodically dependent on the level at which they are held. A Safety Panel is held approximately every 6 months, in addition to specific test reviews, to allow the AM(MF) to review and accept the risks associated with the Boeing Flight Operation of UK military regulated aircraft. This allows military Duty Holders to understand Boeing operating Risks in a recognisable format.

2.2.6.5 Bow Tie Diagrams

In support of understanding the risks in the Boeing Operations in the UK, our Air Safety Team also utilise Bow Tie diagrams to identify barriers or mitigations to potential incidents and accidents. This is more aligned to routine operations but can also provide useful information in test hazard analysis to support test planning and approval. This tool is widely used by the UK Military and aligns Boeing Operations with the UK Air Safety policy.

2.2.6.6 Occurrence Reporting Systems

Boeing uses companywide IT systems to report occurrence and hazardous observations. These are managed by the UK safety team who may use trained Investigators to determine the root causes and corrective actions across the business operation. In the UK Boeing also replicates reporting in the UK MoD Air Safety Information Management System to allow easy access for all relevant UK military and civilian partners to safety information. The close interaction of the Boeing and front line operation of aircraft requires Air Safety Teams in Boeing and the MoD to work together to support investigations and allows Boeing to take an active role in UK Air Safety.

2.2.6.7 Communications

A key element to safe test conduct is constant positive reinforcement that all employees play a vital role in Air Safety. This is achieved through a number of routes in BT&E including:

- Leadership webcasts;
- Safety Stand downs / commitments aligned to the Company go4zero initiative;
- Regular Flight Operations meetings globally and locally;
- Recognition of open and honest reporting of occurrences and potential hazards; and
- Regular global e-mail communications from the BT&E Flight Safety Team.
- Test Participants are reminded in pre-test briefings that they always have a 'no vote' through the Safety Andon Practice (encouraging anyone to stop an activity if they see anything that might affect safety).

2.2.6.8 Air Safety Management System Maturity

The Safety Team use a number of measures around safety occurrences and reporting to assess the maturity of the safety culture in the organisation. Key elements to this are trends in Boeing and RAF reports, who is reporting (1st, 2nd or 3rd age reporting), normalised reporting rates and safety audits.

2.2.7 Discussion and Observations

2.2.7.1 Practices and Principles

Boeing uses a similar approach, in terms of practices and principles, for test risk management to that of the wider aerospace industry. For the approval by the UK MAA a key aspect was ensuring that the equivalency of these practices and principles against the UK regulations were articulated. Boeing continues to support risk management development and supports industry wide symposium and other events to share knowledge and support the development of process and tools to enhance flight test safety. A clearly demonstrable benefit to conducting a test activity from the verification and validation requirements is a key aspect for risk owners to determine whether a risk is Tolerable and ALARP. The Quality and Safety Management Systems of the organisation are therefore intrinsically linked.

2.2.7.2 Positive Air Safety Culture

While a strong culture of safety exists at Boeing, it requires continual reinforcement to persist and remain strong. The continuous commitment of senior business leaders that safety is the highest priority is essential to help people do the right thing and drive the highest standards in test safety. This includes engagement of the test team in the early stages of planning to achieve realistic program schedules for the test program. Even apparently simple things like organising office space to provide a test crew 'bubble' and removed distraction where practicable can help. The removal of day to day schedule pressures allows the team to focus on all aspects of the aircraft operation during the test. Most importantly of all is ensuring that all the test participants, and even those not directly involved in the operation of the aircraft, understand their impact, no matter how small, on the safety conduct of the test.

2.2.7.3 Understanding Terminology

Terminology across organisations, and indeed national boundaries, varies for aspects of safety management for testing and aircraft operation. Whether it is different names for similar documents or processes (Test Hazard Analysis opposed to Trials Risk Assessments) to subtle changes in how safety is viewed (Test Hazards rather than Test Risks). It is important to constantly verify that the test team understand the terms being commonly used in relation to safety management and risk mitigation. This ensures that the team have a consistent application of risk mitigation and safety management.

2.2.8 Conclusions and Recommendations

Overall, there is significant amount of common ground between different organisations on how T&E safety is organised, managed and approved. This includes how test risks are identified, mitigated and justified. As T&E conduct becomes more integrated across organisational and nation boundaries, the equivalence and understanding of how safety is managed is an important part of safe test conduct. In addition, ensuring that everyone involved knows that they are empowered to raise observations, through an effective reporting system, and if needed stop operations, supports the early identification of hazardous situations before they become an accident.

2.2.9 Appendix

N/A

2.3 CANADIAN FORCES AEROSPACE ENGINEERING TEST ESTABLISHMENT

2.3.1 Nature of Flight Test Activity

As the primary Flight Test Agent for the Canadian Forces (CF), the Aerospace Engineering Test Establishment (AETE) conducts a variety of flight and ground testing on fighters, multi-engine, and rotary wing aircraft and aircraft systems.

2.3.2 Background

Flight testing did not emerge in Canada until after the First World War, when Parliament created the Air Board to regulate air navigation. In 1920 an aerodrome in Rockcliffe, Ontario, was stood up and aerospace testing and evaluation began. Ground and aerial testing in support of Canada's aerospace program included projects such as oil dilution systems for engine starts in winter, fog landing equipment, fire resistant flight suits, parachutes, and even aerial photography for mapping the country.

Canada's flight test centre proved extremely valuable when the Second World War broke out in 1939. It carried out testing on electronics, gunnery, navigation, and other aeronautical elements. Due to the ever-growing demand and the skill and expertise of the small but sophisticated flight test operations, the RCAF officially reorganized the group into the RCAF Test and Development Establishment in 1940.

Over the next several decades, various test and evaluation units were stood up, each playing an important role in the development of Canada's aerospace program. It wasn't until the consolidation of these units in 1971 that the Aerospace Engineering Test Establishment (AETE), located in Cold Lake, Alberta, became the premiere flight test agency for the Canadian Armed Forces (CF).

2.3.3 Regulatory Framework

N/A

2.3.4 Organisation and People

2.3.4.1 Command and Control Branch

The Command and Control Branch ensure the preservation of the operational unit culture, sovereign engineering flight test capability, and operational relevance. Within this branch are the Commanding Officer/Flight Test Authority, Senior Test Pilot/Officer Commanding Evaluation Branch, Senior Test Engineer/Officer Commanding Evaluation Support Branch, unit Safety Officer and Officer commanding Logistics.

2.3.4.1.1 Commanding Officer/Flight Test Authority (FTA)

The FTA is the designated individual responsible for ensuring that all DT&E and ET&E performed by or on behalf of Department of National Defence (DND) and the CF are conducted safely and by qualified and authorised personnel, such that Safety Of Flight (SOF) concerns based on the intended operational usage of aeronautical products are properly addressed prior to OT&E and operational service. The FTA is not an airworthiness authority, but the Technical Airworthiness Authority (TAA), Operational Airworthiness Authority (OAA) or Aircraft Investigative Authority (AIA) may assign the FTA authority for specific airworthiness related functions. The TAA, OAA and AIA shall consult with the FTA on airworthiness related flight test activities. The FTA is responsible for the safe conduct of DT&E and ET&E involving personnel from DND and the CF and oversight of DT&E and ET&E conducted by other organisations on behalf of DND and the CF. As the FTA, CO AETE is also assigned Operational Airworthiness (OA) responsibilities for AETE or supporting aircrew where flight test activities are required beyond other OAA delegation.

2.3.4.1.2 Logistics Support Branch

Lead by the Officer Commanding Logistics consists of the following services:

- Financial services and administration;
- Procurement and contract management; and
- Supply in support of flight test and maintenance activities.

2.3.4.1.3 Evaluation Branch

Lead by the Senior Test Pilot/Officer Commanding Evaluation Branch consists of the following sections;

a) Fixed Wing (FW) Evaluation is responsible for the evaluation of multi-engine, fighter and trainer aircraft, associated systems, and Unmanned Aerial Vehicle (UAV) projects;

b) Rotary Wing (RW) Evaluation is responsible for the evaluation of all helicopter and associated systems projects;

c) Avionics and Crew Systems Evaluation is responsible for the evaluation of avionics, crew systems, simulators, Electromagnetic Compatibility (EMC) and electromagnetic interference;

d) Operations is responsible for air operation planning and coordination, and the provision of weather-related support;

e) The Project Control Office (PCO) is responsible for project control, coordination, and the effective management of the overall flight T&E program; and

f) Quality System and Airworthiness section – Quality System personnel are responsible for the management of the unit's quality standard Air Force 9000 Plus, which is modelled after the International Organisation for Standardization 9000 Standards. The Staff Officer Airworthiness ensures all AETE flight test projects meet technical and operational airworthiness requirements.

2.3.4.1.4 Evaluation Support Branch

Lead by the Officer commanding Evaluation Support/Senior Test Engineer consists of the following sections:

a) Technical Support section – this section is responsible for data processing and engineering analysis including the analysis and presentation of Time Space Position Information (TSPI) obtained from tracking systems. The section is also responsible for specialized information systems support to flight test and support to test range infrastructure and equipment;

b) Data Acquisition and Processing section – a DTAES-accredited design organisation that is responsible for the design, certification, manufacture, installation, and maintenance of flight test items, prototypes, instrumentation, and data acquisition systems, including airborne photography and high speed on-board cameras; and

c) Aircraft Maintenance section – a DTAES-accredited maintenance organisation that delivers 1st and 2nd level maintenance of the nine aircraft assigned to AETE that are employed in flight T&E and proficiency flying.

2.3.5 Process and Procedure

2.3.5.1 Planning

The planning phase involves all activities following the project tasking until the approval of the Safety Review Board (SRB). Planning is essentially the creation of a specific sequence of events which will produce the data required to meet the project objectives. Planning is the most critical phase of a project, as the outputs from the planning phase will have a direct impact on subsequent phases and ultimately on the test results. Furthermore, and just as importantly, the assessment and mitigation of the risks inherent to a test program is conducted at the planning phase.

Figure 2-3.1 shows the steps of a typical planning phase. The paths associated with the potential need to return to a previous step, as well as lateral inputs, are not depicted and are considered to be implied. The planning phase can be sub-divided chronologically, from top to bottom, and between planning and reviewing activities (TRB, ARB, SRB). Not all projects will require data planning activities or an Experimental Flight Permit (EFP) and therefore, the applicability of some of the steps will vary by project. Additionally, projects could have multiple test plans and associated planning and reviewing steps.

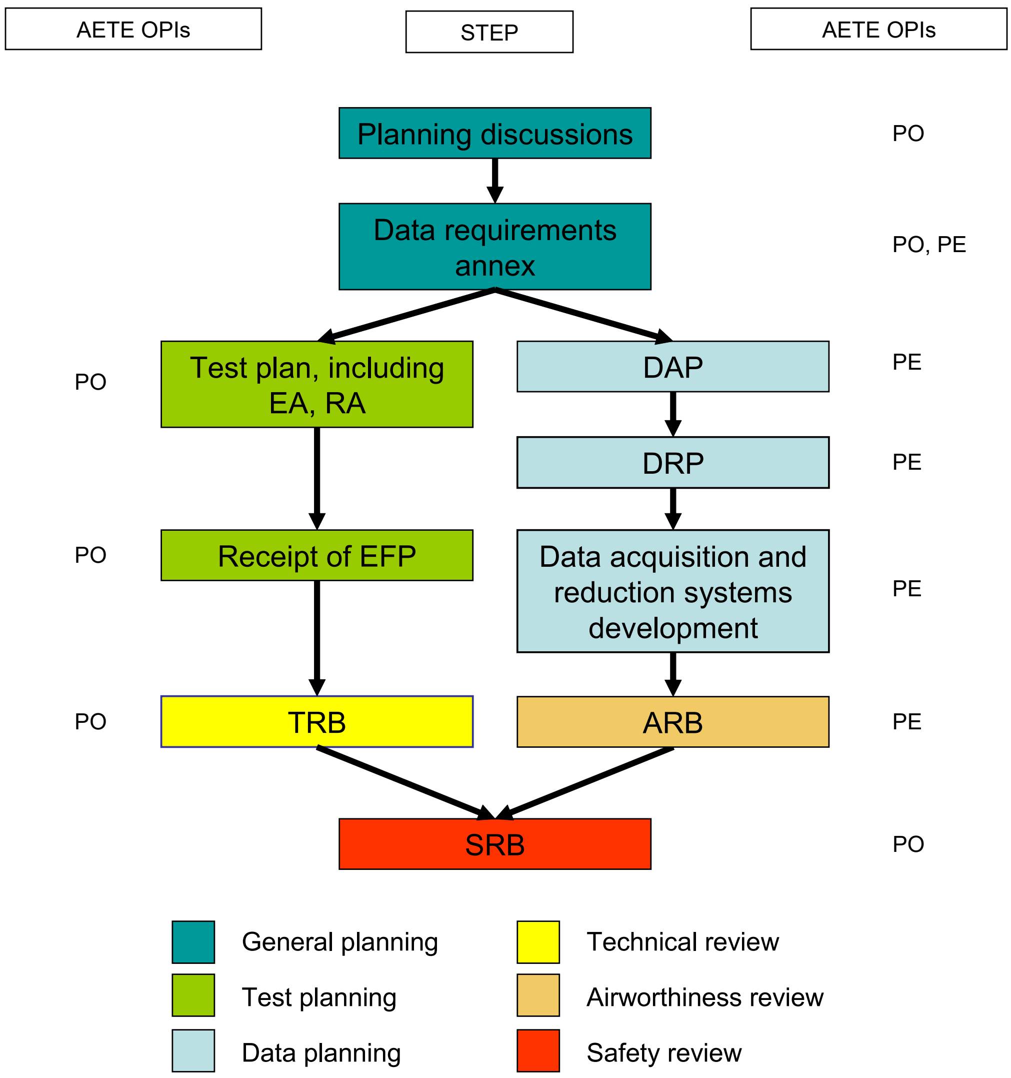


Figure 2-3.1: Planning Process.

2.3.5.1.1 Test Plan

The test plan is a comprehensive document which details the events and the sequence which will be executed to meet project objectives, including the limits and boundaries which must be followed by the test team. The approach taken by the test team will be tailored to each test program; however, the test methodology and sequence must minimise risk. A critical element of risk minimisation is the use of an incremental approach, such as by sequencing low workload test points prior to high workload test points and day flights before night flights, or by gradually reducing margins of safety until a targeted end point is reached. Do not delete headings or sections contained within the template. Conversely, test teams should ensure that test plans provide the necessary flexibility to maintain testing efficiency. For example, a control response test may initially be planned to use defined control input increments; however, a robust test plan could include the possibility of employing larger increments, up to a defined maximum, if the increments initially selected are inefficient. As another example, a test plan could include alternative test techniques to address technical risk.

2.3.5.1.2 Experimental Flight Permit (EFP)

As defined by the TAM, a flight permit is a flight authority granted to an aircraft which does not conform to the conditions for the granting of full or provisional flight authority. An EFP is used for any aircraft manufactured for, modified for, or engaged in, aeronautical research and development, or for showing compliance with airworthiness and environmental standards.

- EFPs are issued by the Technical Airworthiness Authority (TAA) or by authorised individuals such as the fleet Senior Design Engineer (SDE). Although the EFP is ultimately a sponsor responsibility, the PO must communicate requirements to the sponsor and to the individual authorising the EFP. In particular, the PO should ensure that the flight envelope permitted by the EFP provides sufficient buffer from the limits targeted in the test plan.
- If the EFP results in a technical risk level above the previously approved level of safety for the aircraft, the EFP must be accompanied by a Record of Airworthiness Risk Management or appropriate risk management documentation. Additionally, the EFP must not be contingent upon the completion of the AETE SRB. EFPs should be received, at least in draft form, prior to the TRB. The finalised and signed EFP must be received prior to the SRB.

2.3.5.1.3 Environmental Assessment (EA)

Most projects will qualify for an EA exclusion, in which case the only requirement is to complete an EA exclusion form and include it in annex to the test plan. However, POs are responsible to, seek advice from the AETE safety cell to ensure that an EA exclusion is warranted.

2.3.5.1.4 Data Acquisition Plan (DAP)

The DAP is a document that describes how data will be acquired during the test program. Production of the DAP is a Project Engineer (PE) responsibility; however, input from the Project Officer (PO) and the rest of the test team is crucial to determining acquisition requirements.

2.3.5.1.5 Data Reduction Plan (DRP)

The DRP is a document that describes how test data will be translated from raw data to a format required to meet data analysis needs. Production of the DRP is a PE responsibility; however, input from the PO and the rest of the test team is crucial to determining reduction requirements.

2.3.5.1.6 Data Acquisition and Reduction Systems Development

Following the production of the DAP and DRP, the PE will lead the development of data acquisition and data reduction systems (software and hardware), including, as required, system manufacture and installation.

2.3.5.1.7 Technical Review

The main purpose of technical review is to ensure that the test plan meets the project objectives. The Technical Review Board (TRB) is the forum for the technical approval of a test plan. The TRB is a section-level activity chaired by the test plan approving authority (normally the project lead SH) and facilitated by the PO; as such, the conduct of TRBs may vary slightly between sections. Concurrence from the lead SH must be obtained to waive/modify any portion of the TRB process with the exception of the requirement for the test plan approval authority to attend the TRB. For testing conducted under an ITT, personnel from the other organisations forming part of the ITT should attend the TRB as appropriate. This can be done through teleconference or video conference if it is not practical to do so in person. For testing involving contractors, appropriate personnel from the contractors should attend the TRB if appropriate.

2.3.5.1.8 TRB Approval

Once any corrections directed by the TRB have been incorporated in the test plan and associated documents, TRB approval requires a review and approval signature by AETE staff with the test plan review and test plan approval personnel authorisations respectively. The approval authority is normally the lead SH and the review authority is normally the section senior aircrew or senior engineer. The lead SH shall consult with the lead BH should exceptional circumstances arise where it was not possible for the test plan approval authority to attend the TRB.

2.3.5.1.9 Secretarial TRBs

TRBs can be conducted secretarially at the discretion of the lead SH. Secretarial TRBs should be reserved for simple projects, for projects which have significant commonality with previous test programs or minor amendments to test plans.

2.3.5.1.10 Airworthiness Review

An airworthiness review is conducted for every project; however, for projects that do not use FTI or use only baseline FTI, the process ends with AR1 sign-off. The ARB shall be completed prior to the SRB.

2.3.5.2 Flight Test Safety Review

The safety review process must be conducted for all testing conducted under the authority of the Flight Test Authority (FTA). It starts with the PO and test team creating a risk assessment of project specific risks. The SRB is the forum for the risk acceptance of a test plan. Although predominantly focused on risk management and test safety, the SRB also includes an overview of the project objectives and project schedule. It formally authorises the execution of the test plan. The SRB is chaired by the FTA but facilitated by the PO. Concurrence from the FTA is required to waive or modify any part of the SRB process.

2.3.5.2.1 Risk Acceptance

Risk acceptance is based upon a hazard's unmitigated risk level. In accordance with the Designation of FTA Letter, the FTA has been authorised to accept risk up to and including "High" while performing authorised flight test programs. The Chief of the Air Staff and the Assistant Deputy Minister (Materiel) have designated

CO AETE as the FTA. If necessary, acceptance of "Extremely High" risks lies with the Chief of the Air Staff (CAS) as the Airworthiness Authority (AA). It is important to distinguish the role of the FTA and CO AETE in the safety review process. In his absence, CO AETE may assign his FTA responsibilities separately from his CO AETE responsibilities. The individual assigned the FTA responsibilities is authorised to accept risk up to and including "High" for authorised flight test programs. Note that the acceptance authority is determined by the unmitigated risk level. Risk acceptance is based on three critical components, the unmitigated risk level, the minimising procedures and the residual risk (after applying the minimising procedures).

2.3.5.2.2 Risk Assessment

In conjunction with test plan preparation, the PO shall prepare a risk assessment that contains a complete list of test-specific hazards, causes, effects, probability of occurrence, mitigating procedures, corrective actions and risk levels. The Risk Assessment Template (PMM Template 7) outlines the content and format of the risk assessment. The purpose of the risk assessment is to:

- Identify test-unique hazards that could reasonably be expected to occur and to assign a level of risk to each hazard;
- Devise procedures to minimise the risk associated with each hazard;
- Assign a "risk level" based on the identified hazards and their associated risks, taking into account the anticipated effectiveness of the minimising procedures; and
- Provide senior management with a detailed assessment of the level of risk associated with a particular evaluation or phase of an evaluation using the test methods described in the test plan.

Utilising inputs from the test team and other available sources, the PO will compile a list of all test-unique hazards throughout the project planning phase. Once a hazard is identified, it must be analysed using the following techniques.

Hazard Description: Any real or potential condition that can cause a mishap, degradation, reduction of safety margins, injury, illness, death or damage to or loss of equipment or property. In describing a hazard, avoid the tendency to name the effect or outcome, e.g., electrocution, versus the real hazard, which may be an exposed, energised electrical panel.

Hazard Cause: Anything that could lead to the presence of the hazard (e.g., hard braking at excessive landing weight).

Hazard Effect: The injury or damage which is being prevented (e.g., major aircraft damage or serious injury). A methodical approach must be used in the determination of hazard effects requiring sound engineering and operational judgement. All factors must be considered in identifying credible hazards and effects. Sometimes multiple effects can result from a single hazard. Each hazard/effect must be listed and considered separately. The hazard severity and probability must be assigned for each effect. If the mitigating procedures or corrective actions are the same for some of the effects, they need only be stated for the first effect and then referenced in the subsequent hazard/effect identified in the risk assessment.

Hazard Severity: The hazard severity category corresponding to the unmitigated effect is assigned according to the following definitions provided Technical Airworthiness Manual (TAM):

Category A – CATASTROPHIC: Would prevent continued safe flight and landing. Could result in death of the aircrew, normally with loss of the aircraft.

Category B – HAZARDOUS: Would reasonably be expected to result in a large reduction in safety margins or functional capabilities, including higher aircrew workload or physical distress such that the aircrew may not be relied upon to perform tasks accurately or completely. Could result in death or major injury to aircraft occupants or major damage to an aircraft system. Could result in death or major injury to ground personnel or the general public.

Category C – MAJOR: Would reasonably be expected to result in a moderate reduction in safety margins or functional capabilities, including a moderate increase in aircrew workload or physical distress impairing crew efficiency. Possible physical distress, including injuries to occupants or minor damage to an aircraft system.

Category D – MINOR: Would not significantly reduce aircraft safety but would reasonably be expected to result in a slight reduction in safety margins or a slight increase in aircrew workload.

Category E – NEGLIGIBLE: No effect on safety. Negligible effect on safety margins. Hazards assessed as Category E do not need to be included in the risk assessment.

Hazard Probability: The probability of the unmitigated hazard occurring at the previously identified severity category is assessed according to the following qualitative definitions:

Level 1 – FREQUENT: Likely to occur frequently during the test.

Level 2 – PROBABLE: Expected to occur one or more times during the test.

Level 3 – REMOTE: Unlikely, but possible to occur during the test.

Level 4 – EXTREMELY REMOTE: Not expected to occur during the test.

Level 5 – EXTREMELY IMPROBABLE: So unlikely, it may be assumed that it will never occur during the test.

Unmitigated Risk Level: The risk level is used to determine the Risk Acceptance Authority and is assigned according to the Airworthiness Risk Index table provided in the TAM and presented herein as Table 2-3.1. The unmitigated risk level is based on the hazard severity category and hazard probability level.

Minimising Procedures: Detail ways to minimise the hazard (e.g., flight crew and the Flight Test Control Room (FTCR) will monitor the brake temperature real-time and fire-fighting vehicles will be positioned at the planned stop point).

Corrective Actions: Detail actions taken if the hazard occurs to lessen the severity of the mishap (e.g., flight crew will follow checklist procedures, local first aid personnel and equipment will be available and the fire department will extinguish the fire).

Residual Hazard Severity: The residual hazard severity category is assigned taking into account the effectiveness of the minimising procedures.

Residual Hazard Probability: The residual hazard probability is assigned taking into account the effectiveness of the minimising procedures.

Residual Risk Level: The residual risk level is assigned according to the Airworthiness Risk Index in Table 2-3.1 and is based on the residual hazard severity category and the residual hazard probability level.

Table 2-3.1: Airworthiness Risk Index.

Hazard			Category				
Probability \ Severity			A	B	C	D	E
			Catastrophic	Hazardous (Severe Major)	Major	Minor	Negligible
LEVEL	1	Frequent	A1 Extremely High	B1 Extremely High	C1 Medium	D1 Low	E1
LEVEL	2	Probable	A2 Extremely High	B2 High	C2 Low	D2	E2
LEVEL	3	Remote	A3 High	B3 Medium	C3	D3	E3
LEVEL	4	Extremely Remote	A4 Medium	B4	C4	D4	E4
LEVEL	5	Extremely Improbable	A5	B5	C5	D5	E5

Risk Threshold

Note: Risks below the risk Threshold are considered to be within the Acceptable Level of Safety for all approved missions and flying operations.

2.3.5.2.3 Safety Review Board Attendees

The following personnel are mandatory SRB attendees:

a) FTA (Chair);

b) Senior Test Pilot (STP);

c) Senior Test Engineer (STE)

d) Senior Design Engineer (SDE);

e) Unit Safety Officer (USO);

f) PO; and

g) At least one member of the flight test crew (if flight tests are part of the test plan).

If available and applicable, the SRB should also be attended by:

a) Test Plan Approval Authority;

b) Project Pilot (PP);

c) Test Director;

d) PE;

e) Experimental Aircraft Maintenance Engineering Officer (XAMEO) and aircraft technician representatives, if project safety issues impact aircraft maintenance, technical issues affect test safety or test procedures create new hazards to aircraft maintenance or servicing activities. If testing is to be conducted at a deployed location, a maintenance representative from the host unit should attend the SRB; and

f) Other advisors as determined by the FTA or PO (e.g., SOAW, FTCR, RSO).

g) For projects conducted under an ITT, appropriate personnel from the other organisations forming part of the ITT must attend the SRB. This can be done through teleconference or video conference if not practical to do so in person.

h) For testing involving contractors, appropriate contractor personnel should attend the SRB if appropriate, or at the very least be available to answer questions, usually by phone.

2.3.5.2.4 SRB Approval

Once any actions directed by the SRB have been completed (including incorporating corrections in the test plan and associated documents), the FTA will sign the SRB block on the Project Approval Form, or, if required, the risk assessment will be sent to the AA under FTA cover for risk acceptance. SRB approval denotes acceptance of the identified risks, minimising procedures, corrective actions and residual risk levels. SRB approval authorises the execution of the test plan and marks the end of the planning phase.

2.3.5.2.5 Post-SRB Approval

A minimum of 48 hours is required between SRB approval and the first test conduct activity, to ensure that the test team has reviewed and understood the risk assessment and that test preparation is not constrained by programmatic pressures. This requirement may be waived at the discretion of the FTA.

2.3.5.2.6 Secretarial SRBs

Subject to FTA approval, SRBs can be conducted secretarially if a test plan follows an established test method and carries minimal risk. Secretarial SRBs can only be used for test plans which carry unmitigated risks of "Medium" or lower and residual risks of "Low" or lower. Secretarial SRBs are completed as follows:

a) The PO requests SH concurrence to proceed with a secretarial SRB request.

b) The PO electronically distributes the SRB documents including the test plan executive summary, risk assessment, EFP and EA/EA exclusion to all formal SRB attendees, allowing at least two workdays for review. In the e-mail, the PO requests comments on the SRB documents and concurrence on proceeding with a secretarial SRB. The FTA is included on the distribution for awareness. Attendees can provide comments and concurrence via e-mail or verbally to the PO. If any of the attendees raise significant concerns or do not concur with proceeding with a secretarial SRB, the secretarial SRB shall cease and a formal SRB shall be held.

c) The PO incorporates any required changes to the SRB documents and test plan and presents a hardcopy of the Secretarial SRB Checklist, Project Approval Form, test plan executive summary, risk assessment, EFP and EA/EA exclusion to the FTA. The comments from the initial distribution to SRB attendees must also be presented and the PO must confirm the concurrence of each attendee.

d) Once any actions directed by the SRB have been completed (including incorporating corrections in the SRB documents and test plan), the FTA will sign the SRB block on the Project Approval Form. SRB approval authorises the execution of the test plan and marks the end of the planning phase.

2.3.5.2.7 Post-SRB Approval Activities

Post-SRB approval activities identified above apply. Though secretarial SRBs alleviate the need to formally gather the required individuals in a meeting, experience shows that this approach is rarely faster than formal SRBs. Formal SRBs are also typically more efficient because all SRB members can address any safety issues together during the time allotted for the SRB through discussion rather than through e-mail correspondence over a period of several days.

2.3.5.3 Test Plan Amendments

Test plans may require amendment throughout the life of a project, for example to address scope changes or in response to test findings. Three types of amendments exist:

1) Minor amendments with no effect on the risk assessment;
2) Minor amendments with an effect on the risk assessment; and
3) Major amendments.

A minor amendment is an amendment which has a negligible effect on the conduct of test. A major amendment is an amendment which has an effect on the conduct of test. The determination between a minor and a major amendment, and whether or not the amendment has an effect on the risk assessment, is made by the test team with concurrence from the Test Plan Approval Authority.

Requirements for instrumentation changes may require a new ARB. In particular, test plan amendments may have ARB implications even if no instrumentation changes are made. For example, changes in manoeuvring loads may reduce or eliminate structural margins of safety.

2.3.5.3.1 Minor Amendments – No Effect on Risk Assessment

Minor amendments which do not modify the risk assessment do not require a TRB or SRB. In this case, the amended test plan is signed off by a Test Plan Approval Authority and the ARB signature is obtained from an ARB Approval Authority. A test plan amendment summary sheet must be provided, and the amendments to the test plan must be clearly identified.

2.3.5.3.2 Minor Amendments – Effect on Risk Assessment

Minor amendments which modify the risk assessment require a new TRB and SRB. These can each either be formal or secretarial. The normal review procedures apply; however, the reviews will focus on the amendments, which must be clearly identified. Approval of a minor amendment which modifies the risk assessment can be conducted secretarially even for test plans which do not meet the risk level requirements, provided that the amendment does not increase the original risk level.

2.3.5.3.3 Major Amendments

Major amendments require a new TRB and a new SRB. If the original SRB was a formal SRB, the new SRB must also be a formal SRB. If the original SRB was a secretarial SRB, the new SRB can be secretarial if the requirements met.

2.3.6 Facilities and Tools

N/A

2.3.7 Discussion and Observations

N/A

2.3.8 Conclusions and Recommendations

N/A

2.3.9 Appendix

N/A

2.4 NASA ARMSTRONG FLIGHT RESEARCH CENTER

2.4.1 Nature of Flight Test Activity

NASA AFRC is a United States government entity that conducts the integration and operation of new and unproven technologies into proven flight vehicles as well as the flight test of one-of-a-kind experimental aircraft. AFRC also maintains and operates several platform aircraft that allow the integration of a wide range of sensors to conduct airborne remote sensing, science observations and airborne infrared astronomy. To support these types of operations AFRC has the organisation, facilities and tools to support the experimental flight test of unique vehicles and conduct airborne sensing/observing. The current aircraft fleet encompasses a wide range of aircraft, including remotely piloted and autonomous vehicles and consists of:

- F-18A/B;
- F-15B/D;
- T-34C;
- TG-14;
- G-III;
- B-200 (KingAir);
- DC-8;
- B-747SP;
- ER-2;
- RQ-4;
- MQ-9; and
- Wide range of small Unmanned Aircraft Systems (UAS).

2.4.2 Background

AFRC was originally established in 1946 as the High-Speed Flight Research Station. A contingent of engineers, pilots, maintainers and administrative support personnel were deployed to Muroc Army Air Base (now Edwards Air Force Base) from the National Advisory Committee for Aeronautics Langley Memorial Aeronautical Laboratory to support the first supersonic research flights of the X-1 rocket-powered aircraft. The organisation grew and expanded its capabilities over the years as it continued to support the development of, and research associated with aerospace research vehicles. The staff currently consists of 535 civil servants and approximately 600 contractor personnel. In 2006, AFRC established a long-term lease with Los Angeles World Airports for Building 703 located adjacent to USAF Plant 42 (Palmdale Airport). The majority of the airborne remote sensing and airborne astronomy is accomplished from this facility. Through agreements with the US Department Of Defense (DOD), AFRC maintains access to the airfields and airspace that allows the conduct of a full range of aeronautical flight research and test from both locations. Dryden Aeronautical Test Range (DATR) supplies a comprehensive set of resources for the control and monitoring of flight activities, real-time acquisition and reduction of research data, and effective communication of information to flight and ground crews.

2.4.3 Regulatory Framework

2.4.3.1 External

NASA has been granted the authority by US Federal legislation to provide airworthiness certification, outside of the Federal Aviation Administration (FAA) and DOD systems, for all aircraft and UAS operated under its purview. The NASA airworthiness certification process provides the opportunity to conduct flight operations both domestically and internationally.

It is a requirement of NASA Headquarters that the Center maintain a Quality Management System. AFRC's Quality Management System is certified through the AS9100 quality system requirements.

2.4.3.2 Internal

To provide airworthiness certifications and review of flight test activities, the Center has developed a robust airworthiness and flight safety review process. AFRC processes used to support flight test and safety activities satisfy the AS9100 requirements.

The overarching guidance document is AFG-7900.3-001, Airworthiness and Flight Safety Review, Independent Review, Technical Brief, and Mini-Tech Brief. The full procedure governing this and the supporting Airworthiness and Flight Safety Review and Tech Brief and Mini Tech Brief are referred to in Section 2.4.9.

2.4.3.2.1 Flight Test Policy

NASA policy, as codified in NPR7900.3 Aircraft Operations Management, states:

a) For each Center operating aircraft/UAS or procuring and/or acquiring aircraft/UAS services, the Center Director shall maintain a program-independent Flight Operations Office, the specific purpose of which will be to plan, organise, direct, and control the operations, maintenance, modification, safety, and support of all Center-assigned or -contracted aircraft.

b) The Center Director shall assign the Chief of the Flight Operations Office the authority and responsibility and provide the resources necessary to manage and conduct safe, effective, and efficient operations in accordance with NASA directives, guidance, and other applicable Federal regulations.

c) Center Directors shall be responsible for the airworthiness and flight safety of all Center-assigned aircraft and UAS, including commercial aircraft services.

2.4.3.4.2 Flight Test Safety Management System

AFRC has implemented this policy through a matrix management system of Project Managers, Engineering, and Flight Operations, with Safety and Mission Assurance providing an independent assessment and support to the project team. The Center Director has also established the position of Center Chief Engineer who is the independent authority for airworthiness, flight safety and mission success. Long established Center practice has demonstrated that safe flight research results from an effective leadership team consisting of a Project Manager, a Project Chief Engineer (typically from the Research Engineering Directorate) and an Operations Engineer from the Flight Operations Directorate. The focus of the Project Manager is leadership of the team and responsibility for schedule and financial resources. The Project Chief Engineer provides leadership for the engineering team and the focus on the research aspects. The Operations Engineer is responsible for aircraft airworthiness and is the interface with the hands-on workforce in the Flight Operations Directorate. In total, this team owns the responsibility for the assessment of risks, identification of mitigations, and implementation of these mitigations. The Safety and Mission Assurance Directorate is a partner in this process, but also functions as an independent authority. The risk/hazard evaluation process is described in Section 2.4.5. This team is also responsible for Mission Success. AFRC's Senior Leadership (Center Director and Directorate Chiefs) is engaged as described in Section 2.4.5. This implementation allows a small Center to manage and execute the broad portfolio of work described in Section 2.4.1.

2.4.4 Organisation and People

2.4.4.1 Research and Engineering Directorate

This organisation is responsible for performing the research and engineering tasks necessary to safely and successfully accomplish the Center's flight research and test mission. The Directorate is organised with seven Branches addressing key engineering disciplines: Systems Engineering and Integration, Aerodynamics and Propulsion, Dynamics and Control, Advanced Systems Development, Flight Instrumentation and Systems Integration, Aerostructures, and Research Engineering Operations.

2.4.4.2 Flight Operations Directorate

This organisation fabricates, maintains, modifies and instruments aircraft and flight test articles, ensures airworthiness/flight readiness and safely flies them in a precise manner to required test points in order to deliver highest quality data to the customer. The Branches in this organisation include: Flight Crew Branch, Operations Engineering Branch, Avionics and Instrumentation Branch, Fabrication Branch, Life Support Branch, Maintenance Branch, Aircraft Records Branch, and Engineering Support Branch.

2.4.4.3 Mission Operations Directorate

This Directorate provides effective and efficient Simulation, Range and IT solutions. The Dryden Aeronautical Test Range (DATR) supplies a comprehensive set of resources for the control and monitoring of flight activities, real-time acquisition and reduction of research data, and effective communication of information to flight and ground crews. The primary services provided for safety and risk management are the aircraft simulations and the services and capabilities of the Dryden Aeronautical Test Range.

2.4.4.4 Safety and Mission Assurance Directorate

The mission of this Directorate is to ensure safe operations and mission success while understanding and mitigating risks to the public, property and mission. In addition, S&MA ensures a safe and healthy work place for employees and visitors. The Branches in this organisation are: Quality Assurance Branch, Safety and Environmental Branch, Flight Research and Test Safety Branch.

2.4.4.5 Programs and Projects Directorate

This Directorate leads and manages Center Project and subproject activity, providing the Project Management and Program Planning and Control functions.

2.4.4.6 Mission Support Directorate

This Directorate provides the Facilities infrastructure support, Protective Services, and Procurement functions that enable all of the Center's flight test and operations activities.

2.4.5 Process and Procedure

2.4.5.1 Flight Test Safety Review Process

Over the past 70+ years AFRC has developed an airworthiness and flight safety review process that provides an efficient way to review and approve vehicle airworthiness while ensuring a high probability of safe operations for the flight test of unique aerospace technologies and vehicle configurations. This single process can be tailored to address the airworthiness and safety review of a wide variety of flight test activities, manned as well as unmanned. A risk and hazard management based approach is applied that promotes the safe and successful execution of high risk flight tests. It assesses, communicates and accepts the residual risks inherent in the operation and test of unique flight vehicles.

2.4.5.2 Airworthiness and Flight Safety Review Process

2.4.5.2.1 Review Boards

Flight test activities are reviewed and approved for flight by independent review boards.

a) **Airworthiness and Flight Safety Review Board**

The Airworthiness and Flight Safety Review Board (AFSRB) is a standing board of Armstrong senior leadership (Research and Engineering Director, Flight Operations Director, Mission Systems Director, Safety and Mission Assurance Director, Programs and Projects Director) chaired by the Center Chief Engineer who deliberate on the material presented and formulate a consensus based recommendation to the Center Director regarding the project's readiness for flight and the acceptability of residual risk. This Board is augmented by the Chief Test Pilot and the Aviation Safety Officer for piloted tests and the Range Safety Officer for UAS activities.

b) **Flight Readiness Review Board**

The Flight Readiness Review Board (FRRB) is an ad hoc group of subject matter experts fully independent of the project under review. The board is chartered by the Center Chief Engineer to conduct an independent review and assessment of the entire project and ensure that proper, adequate planning and preparation have been accomplished resulting in the project being conducted in an acceptable safe manner. The FFRB verifies that the System Safety Plan has been followed and that all analyses and results have been properly documented by the project team. They can also be charged with assessing the ability of the project to achieve mission success. They ensure that all identifiable risks have been documented, assessed, and are adequately controlled or properly identified as accepted risks. A key element of the review at this level is constant communication between the FRRB, the project team and Center management. In addition to maintaining awareness, this allows issues to be worked early at the correct level. The FFRB assesses the approach and implementation in regard to public, ground, flight, and range safety and examines the project generated hazard analyses in detail, verifying that proper mitigations have been implemented and that reasonable residual risk has been identified. If deemed necessary for their assessment the FRRB may conduct independent analysis or simulations to compare with project generated results. They present their findings and recommendations to the AFSRB.

c) **Technical Briefing Board**

A standing board of Armstrong senior managers chaired by the Center Chief Engineer who provide a final series of peer reviews of the project's plans and preparations through the execution of the project. The Technical Briefing, or Tech Brief, is one of the more important tools used by the Center to ensure the safe and efficient conduct of the flight test mission. Its major function is to continue the review process after the AFSRB has made its final recommendations and a program moves into the flight or test phase. There are two primary purposes for holding Tech Briefs. First, the individual Project Office is given the opportunity to present its goals and plans to a group of peers. These peers represent all the various disciplines at Center, with special emphasis on the particular areas of interest that are being explored during the proposed flight tests. A Project, in this way, receives the benefit of the experience and expertise of projects conducted previously. The peer review, using past experiences, is a proven way of bringing overlooked items to light. The second purpose of Tech Briefs is to present a current assessment of Project risks to the Center management team. It allows management to reconsider its understanding of the risks involved prior to each flight. This helps ensure that any risks that cannot be eliminated or reduced will be accepted at the appropriate level of authority and responsibility. The Tech Brief review should also address the data analysis results from previous flights of the aircraft with particular emphasis on envelope expansions or any unexpected results, and whether or not they are expected to present problems during future tests. These results should provide a smooth transition to the objectives of the proposed flight plan.

2.4.5.2.2 Level of Review

Early in a project's life cycle the chair of the AFRC Airworthiness and Flight Safety Review Board (AFSRB) works with the project team and Center management to determine the appropriate level of independent review required. The level of review is based upon factors such as complexity, criticality, visibility and level of residual risk. Four review levels are available:

a) **Chief Engineer Review**

For low risk, simple, non-critical tests the Center Chief Engineer, as AFSRB chair, may solely review the project team's plans and preparations for adequacy for performance of the proposed operation with the necessary level of safety and clear it for flight.

b) **Chief Engineer with Subject Matter Experts**

The next level of review is conducted by the Center Chief Engineer with a small team (2 – 4 people) of subject matter experts who review the project team's plans and preparations for adequacy with the necessary level of safety and clear it for flight with a Technical Briefing.

c) **Airworthiness and Flight Safety Board Review**

The next higher level of review is conducted by the full AFSRB. The project team presents their plans and preparations to the entire AFSRB who determine whether the project had integrated appropriate flight safety and adequately assessed the residual risk of conducting the test. The Board presents their recommendation as to the project's readiness to proceed to flight and the residual risk stance to the AFRC Director who either concurs or non-concurs with the AFSRBs recommendation for the project to flight. Final flight approval is provided through a Technical Briefing

d) **Flight Readiness Review Board Review**

The most rigorous level of review is conducted by a Flight Readiness Review Board who assesses the project's plans, preparations and residual risk position and whether they have adequately integrated flight safety. The FRRB presents their assessment, findings and recommendations to the AFSRB who determine whether the project should proceed to flight. The AFSRB presents their recommendation and the residual risk stance to the AFRC Director who either concurs or non-concurs with the AFSRBs recommendation for the project to flight. Final flight approval is provided through a Technical Briefing

2.4.5.2.3 Hazard Evaluation and Communications

Hazard Review: Hazard analysis and review is conducted throughout a project's life cycle. Hazard analysis and report generation are conducted by the project's system safety working group typically made up of the project's lead for safety, chief engineer, operations engineer, pilot, and project manager. Hazard reviews are conducted by each review board held for system engineering and airworthiness and flight safety reviews.

Residual Risk: Experimental flight often carries higher risk than operational flight. After all appropriate mitigations have been accomplished the residual safety and technical risks are documented, reviewed and communicated through the system engineering and airworthiness and flight safety reviews.

Hazard Matrix: There are two Center residual risk Hazard Action Matrices (HAMs) that serve as the primary means of communicating safety hazard management classification. The purpose of these templates is to relate human safety hazards, loss of high-dollar value assets, and/or loss of mission in terms of the hazard's severity and its probability in order to identify the associated overall hazard risk. The HAMs identify the level of management approval required for actual acceptance of risks (accepted risks) by the solid red and red cross-hatched areas on the HAMs. The HAM instructions reflect the accepted, Center wording for hazard probability and severity classifications of mishap occurrence. Projects will not change the substance of the HAM presentation if it is planned for use as part of the Center airworthiness process without an approved waiver. Final hazard classifications are determined after the project or program has exhausted all planned corrective and controlling actions utilising the Hazard Mitigation.

Hazard Probability: The probability categories are derived from NPR 8715.3, NASA General Safety Program Requirements. "Probability is the likelihood that an identified hazard will result in a mishap, based on an assessment of such factors as location, exposure in terms of cycles or hours of operation, and affected population." The probability is based on the scope and duration of the risk being assessed and presented to Center management. The probability is determined by quantification (analysis/calculated), or by qualitative means with appropriate justification (clear rationale) for the assessment. The Hazard Probability categories are:

- **Frequent –** Likely to occur immediately OR expected to occur often in the life of the project/item. Controls cannot be established to mitigate the risk.
- **Probable –** Probably will occur OR will occur several times in the life of a project/item. Controls have significant limitations or uncertainties.
- **Occasional –** May occur OR expected to occur sometime in the life of a project/item, but multiple occurrences are unlikely. Controls have moderate limitations or uncertainties.
- **Remote –** Unlikely but possible to occur OR unlikely to occur in the life of the project/item, but still possible. Controls have minor limitations or uncertainties.
- **Improbable –** Improbable to occur OR occurrence theoretically possible, but such an occurrence is far outside the operational envelope. Typically, robust hardware/software, operational safeguards, and/or strong controls are put in place with mitigation actions to reduce risk from a higher level to an improbable state.

Hazard Severity: Severity can be broken out into personal injury or loss of asset/mission. Personal injury can be broadened to include death, disability, illness, and several categorisations of injury (life-threatening, lost time, minor, etc.). Loss of asset/mission can be broadened to include loss of system, substantial system damage, minor system damage, property damage, and loss or compromise of mission (incomplete mission success).

The Human Safety Hazard Severity categories are:

CLASS I (CATASTROPHIC)	A condition that may cause death or permanently disabling/life-threatening injury.
CLASS II (CRITICAL)	A condition that may cause severe/lost time injury or occupational illness.
CLASS III (MODERATE)	A condition that may cause medical treatment for a minor injury or occupational illness (no lost time).
CLASS IV (NEGLIGIBLE)	A condition that could cause the need for minor first aid treatment (though would not adversely affect personal safety or health).

The Loss of Asset/Mission Hazard Severity Categories are:

CLASS I (CATASTROPHIC)	Total direct cost of mission failure and property damage of $2M or more, ***OR*** Crewed aircraft hull loss, ***OR*** Unexpected aircraft departure from controlled flight for all aircraft except when departure from controlled flight has been pre-briefed.

CLASS II (CRITICAL)	Total direct cost of mission failure and property damage of at least \$500k, but less than \$2M.
CLASS III (MODERATE)	Total direct cost of mission failure and property damage of at least \$50k, but less than \$500k.
CLASS IV (NEGLIGIBLE)	Total direct cost of mission failure and property damage of at least \$20k, but less than \$50k.

2.4.6 Facilities and Tools

2.4.6.1 Flight Loads Laboratory (FLL)

The FLL was constructed in 1964 as a unique national lab to support flight research and aircraft structures testing. FLL personnel conduct mechanical load and thermal test of structural components and complete flight vehicles in addition to performing calibration tests of vehicle instrumentation for real-time determination of flight loads. Mechanical loads and thermal conditions can be applied either separately or simultaneously to simulate combined thermal-mechanical load conditions. FLL personnel also conduct modal survey and structural mode interaction testing to support structures research and assess aircraft for flutter airworthiness.

The FLL staff has expertise in ground and flight test design and operations: load, stress, dynamic and thermal analysis; and instrumentation and measurement systems development. This expertise, coupled with a large array of capital equipment and advanced data acquisition and control systems, make the FLL and ideal laboratory for research and testing of aerospace vehicles and structures flying in the subsonic through hypersonic flight regimes.

2.4.6.2 Research Aircraft Integration Facility

AFRC maintains a simulation engineering capability that is focused on providing high fidelity fixed base aerospace vehicle simulations that support research from concept through flight test phases of activity. This capability consists of batch, pilot-in-the-loop and full hardware-in-the-loop simulations. Where necessary, ground assets may be extended to remotely piloted vehicles and distributed environments that have combinations of real and simulated vehicles or combinations of real and simulated components.

2.4.6.3 Experimental Fabrication and Repair Shop

The AFRC Experimental Fabrication Branch is a one-stop manufacturing, modification, and repair center that can assist a project from initial design through assembly and installation. The branch consists of five shops that provide machining, sheet metal, tubing, welding, and composite fabrication for aerospace and ground requirements. The engineering technicians in the branch are highly skilled fabricators and experienced master craftsmen. Pro-Engineering software is the primary CNC programming system used in the branch to produce complex or sophisticated parts. A production controller on staff will coordinate the outsourcing to offsite manufacturing facilities if the requirements exceed the capacity or competency of the branch.

2.4.6.4 Dryden Aeronautical Test Range

Dryden Aeronautical Test Range (DATR) supplies a comprehensive set of resources for the control and monitoring of flight activities, real-time acquisition and reduction of research data, and effective communication of information to flight and ground crews. Precision radar provides tracking and space positioning information on research vehicles and other targets, including satellites. Fixed and mobile telemetry antennas receive real-time data and video signals from the research vehicle and relay this data to telemetry processing areas. The processed data is displayed at the engineering stations in the mission control center and archived in a post-flight storage area. Audio communication networks support research operations in the DATR, covering a broad frequency spectrum for transmitting and receiving voice communications and flight termination signals for unmanned aerial vehicles. Video monitoring provides real-time and recorded data for the control and safety of flight test missions.

2.4.6.5 Subscale Flight Research Lab

The Subscale Flight Research Lab performs rapid prototyping, development, and testing of one-of-a kind subscale research and training aircraft that range from micro scale up to 330 lbs. The aircraft and associated support equipment may be manufactured entirely within the lab or may be either unmodified or highly modified Commercial Off-The-Shelf (COTS) equipment or a combination of the two. Unique aerodynamic configurations ranging from low speed testing of advanced hypersonic shapes to simple, proof-of-concept small Unmanned Aircraft Systems (sUAS) such as hand-launched gliders are often the focus. Operational concepts have varied from controlling the vehicles using conventional Radio Controlled (R/C) systems flown from the ground with visual feedback to conducting missions from within a ground control station using a traditional stick and rudder ground based cockpit with the control signals being telemetered up to, and down from, the research vehicle. The majority of the support tasks for Subscale Flight Research is comprised of design, fabrication, assembly, maintenance and R/C piloting of sUAS assets.

2.4.7 Discussion and Observations

NASA AFRC has honed this process over the course of 71 years of conducting flight test on a wide range of vehicle and experiments. There are several keys to the success of this process. The establishment of the Center Chief Engineer as the sole authority keeps the process focused while tailoring the level of review appropriately for the size and scope of the project. The nature of being a small Center with one primary mission focus (flight test) also helps maintain the focus. The use of independent co-workers in a process where the project and the review team share the mutual goals of safe flight and mission success is another key consideration.

2.4.8 Conclusions and Recommendations

N/A

2.4.9 Appendix

NASA Armstrong Flight Research Centre has released a number of complete procedures that provide detail that complements the preceding text. These are quite substantial and have been added as Annexes at the end of this AGARDograph:

Annex A: AFG-7900.3-001 "Airworthiness and Flight Safety Review, Independent Review, Technical Brief and Mini-Tech Brief."

This is a high level procedure that provides a process overview that describes what the Title Elements are and how they fit together within the overall process. It contains two very useful Appendices. Appendix A – covering a Completeness Checklist and Appendix B – covering an interesting list of Challenge Questions. Both are commended to the reader.

Annex B: AFOP-7900.3-023 "Airworthiness and Flight Safety Review Process."

This is a detailed procedure that flowcharts the Airworthiness and Flight Test Safety Review Process. To support this it includes a set of amplifying notes.

Annex C: AFOP-7900.3-022 "Tech Brief and Mini-Tech Brief."

This is a detailed procedure that flowcharts the Tech Brief and Mini-Tech Brief Process. To support this it includes a set of amplifying notes.

2.5 NLR – NETHERLANDS NATIONAL AEROSPACE CENTRE

2.5.1 Nature of Flight Test Activity

NLR Flight Operations performs Research Test Flights to meet basic and applied scientific research needs for a wide range of customers including regulators, aviation authorities, transportation safety boards, operators, manufacturers, supply industry and the research community. NLR presently operates a single (civil registered) modified Citation II aircraft, but occasionally leases other aircraft if required. Research topics include:

- Aerodynamics research;
- ATM concepts validation;
- Atmospheric research;
- Biofuel research;
- Micro-g research;
- System tests;
- Data gathering for rulemaking development;
- Technology development; and
- HMI development.

Research flight test typically is performed at low TRL levels, well before product development or certification flight test.

Besides Research Flight Test, the following Specialized Operations also fall inside the scope of NLR Flight Operations activities:

- NAVAid calibration and procedure validation services for ANSPs;
- Flight Mechanics Flying Classroom (performed by Delft University of Technology); and
- Airborne Remote Sensing.

Typical for Research Flight Test is a frequent, almost weekly, significant change of the aircraft configuration to prepare for the next mission by accommodating other sensors, displays and data acquisition systems. To support this, NLR has its own nationally (Dutch) approved Part 21 Design Organisation to develop and certify new or changed aircraft configurations, as well as EASA and Dutch approved Part M Continuing Airworthiness Management and Part 145 Maintenance Organisations to implement the required configuration changes and prepare the aircraft for the next mission.

2.5.2 Background

NLR has been operating dedicated research aircraft since its foundation. The first research aircraft was a Fokker F.II, operated between 1920 and 1936, subsequent research aircraft included a Fokker F.VII, a Siebel Si 204, a Fokker S.14, a Hawker Hunter, a Beechcraft Queen Air, a Fairchild Metro II and since 1991 a Cessna Citation II, operated in conjunction with Delft University of Technology, Faculty of Aerospace Engineering.

Also, NLR supports the RNLAF Flight Test wing, operating and maintaining the data acquisition system on the dedicated F-16 test aircraft.

NLR Flight Operations has a very close working relation with Delft University of Technology; it co-owns the Citation II research aircraft and the Flight Operations and Aircraft Maintenance departments are merged. For brevity "NLR Flight Operations" is used in lieu of "NLR/TUDelft Flight Operations."

The home base is Amsterdam Airport Schiphol, one of the busiest airports in Europe. Flights normally depart from a separate runway meaning that the advantages of operating at a large airport can be enjoyed (logistics, 24/7 accessibility and ATC support), without having to merge into the main commercial traffic operating at the airport. In addition, NLR Flight Operations has a second operational base at Rotterdam The Hague Airport Zestienhoven.

For airspace use, NLR has a close working relation with ATC. The Netherlands and Dutch Military Air Operations and is able to access civil and military restricted airspace and airfields if required.

NLR as a company has an ISO 9001:2000 Quality Management System, monitored through audits. Additionally, NLR has introduced an ICAO Annex 6 and 19 compliant Safety Management System (SMS) to cover Flight Operations. For maintenance, continuing airworthiness management and design national regulations apply, that either refer to or are similar to the EASA Part 145, Part M and Part 21 regulations.

2.5.3 Regulatory Framework

2.5.3.1 External

Although NLR's Citation II C550 aircraft originally has a type certificate against civil (FAA, JAA and EASA) Part 25 standards, because of its specific role and modification as Research Aircraft, it is operated with an ICAO Certificate of Airworthiness issued by CAA-NL and falls under the provisions of EASA Annex I to the Basic Regulation (EC).

Since NLR is a non-profit organisation, all flights are considered as non-commercial activities. Most flights are executed as part of scientific programs related to NLR or associated parties and organisations, other flights are either training flights or positioning flights.

NLR does not hold an Air Operator Certificate (AOC), prohibiting commercial air transport activities. Because the aircraft it operates is an Annex I aircraft, operations are governed by national (Dutch) legislation, and not by EASA Air Operations provisions. Dutch legislation requires operations with Annex I aircraft to adhere to ICAO Annex 6, Part II, hence that is the regulatory compliance basis. NLR Flight Operations has opted to fully comply with EASA Part-SPO provisions and by doing so complies with ICAO Annex 6 and Dutch Law.

NLR Flight Operations processes and procedures are described in the (EASA Part-SPO compliant) Operating Manual, consisting of the following parts:

- **Part A** – Basic Operations Manual;
- **Part B** – Aircraft Operations Manual;
- **Part C** – Route Manual;
- **Part D** – Training Manual; and
- **Part X** – Flight Test Operations Manual (FTOM). The FTOM describes the flight test preparation and operational standards and risk management procedures applicable to NLR test flights within a framework of a research or certification project. The FTOM is controlled by NLR Flight Operations, but also serves as the NLR Part 21 FTOM, complying with Dutch and EASA Part-21 legislation.

To comply with ICAO Annex 6 and Annex 19 and additional EASA and CAA-NL requirements or guidelines, NLR has developed an integrated Safety Management System (SMS), applicable to NLR Flight Operations, Aircraft Maintenance, Continuing Airworthiness Management and the Part-21 Aircraft Design Organisation.

2.5.3.2 Internal

NLR has opted to comply with EASA Air Operations provisions, including a management structure with an Accountable Manager and Postholders Flight Operations, Ground Operations and Flight Crew Training.

The FTOM further identifies the Project Pilot (PP) and Project Flight Test Engineer (P-FTE) as designated functions within the processes leading to an NLR test flight. For every test flight, or series of test flights, a Flight Test Plan (FTP) is developed under the responsibility of the designated Project Pilot. A Risk Assessment is part of the development of an FTP, depending on the outcome of this risk assessment the FTP is signed for release by:

- The Project Pilot for ROUTINE or LOW RISK flight tests.
- The Postholder Flight Operations for MEDIUM RISK flight tests.
- NLR has chosen in principle not to perform HIGH RISK flight tests, but if required the Accountable Manager in consultation with the NLR General Director and TU Delft Dean (representing the owners of the aircraft) will need to approve the FTP.

2.5.3.2.1 Flight Test Policy

Within NLR a Safety Policy is in force that is signed by the Accountable Managers of the Flight Operations, Continuing Airworthiness Management, Maintenance and Design Organisations, as well as by the Head of Delft University Control and Simulation Department (because Delft University is a co-owner of the aircraft). This statement (see Appendix 2.5.9) is physically visible, as framed copies are put up at several places in offices and workshops, and the policy is available on intranet portals. The statement emphasises that safety is never to be compromised and that all personnel have a responsibility to contribute to a safe operation, making safety everybody's concern. Furthermore, it stressed that a Just Culture is applied, in which no-punitive actions will be taken, except in case of established gross negligence, wilful violations and destructive acts.

Additionally, the individual organisations have a quality policy in force that is endorsed by the management and is recorded in the various management system handbooks.

2.5.3.2.2 Flight Test Safety Management System

NLR operates a Safety Management System (SMS) based on ICAO Annex 19 and following ICAO Doc 9859 guidelines.

Additionally, the SMS complies with EU regulations on occurrence reporting (Regulation (EU) No 376/2014 and Commission Implementing Regulation (EU) No 2015/1018), EASA Part ORO and Dutch regulations.

The SMS is an integral part of the NLR Management System(s) and is applicable to all personnel, management, activities and facilities of the NLR Flight Operations, Aircraft Maintenance, Continuing Airworthiness Management and Design Organisations (i.e., the Flight Test organisations).

2.5.3.2.3 Management Structure

The Accountable Manager is ultimately responsible for safety performance of the Flight Test organisations at the overall SMS level. This position is held by the Accountable Manager of the Flight Operations, Part-145 and CAMO organisations. To perform this role the Accountable Manager typically has to have some operational experience and knowledge of Safety and Quality management systems, the NLR SMS, applicable regulations and the application of Human Factors principles.

Due to the nature of the Flight Test organisations (being a subdivision of NLR) and Accountable Manager being an ancillary function of an NLR manager, a 'Delegated Accountable Manager' position has been defined to alleviate the Accountable Manager of certain tasks (however not of responsibilities).

The Accountable Manager together with the owner of the aircraft and the Chief Executive of the Part-21 organisation constitute the Safety Committee that is responsible for the effectiveness and safety performance of the SMS, the appropriate allocation of resources and to yearly review the overall safety objectives, set the yearly safety goals and promote the safety policy.

The postholders (nominated persons) have a role in the SMS as well. They are individually ultimately responsible for safety performance within their domain (Flight Operations, Ground Operations, Crew Training). Together they make up the Safety Action Group that has the responsibility to coordinate risk management activities (e.g., hazard identification and risk assessment, mitigating actions, and management of change) in case a safety issue covers more than one domain and to oversee safety promotion activities for the improvement of safety awareness.

A Safety Manager has been appointed, who in short has the overall responsibility to maintain the SMS system, collect occurrence reports, facilitate hazard identification and risk analysis, monitor mitigating measures and evaluate their results and provide periodic reports on the organisations safety performance.

2.5.3.2.4 Safety Policy

The NLR Safety Policy (see Section 2.5.3.2.1 and Appendix 2.5.9) is incorporated in the SMS manual.

2.5.3.2.5 Safety Reporting and Follow-Up

Safety (occurrence) reports enter the SMS from the Flight Test organisations who each have their own obligations towards mandatory and voluntary reporting, covered by one shared reporting system.

1) The follow-up of reported occurrences is done through the SMS processes, in which the Safety Manager has the responsibility to de-identify the recorded information, inform the postholders concerned and/or the Accountable Manager and to carry out or facilitate a hazard and risk assessment that if required leads to mitigating measures being defined.

2) The responsible postholder for the domain in which the occurrence took place is responsible to identify the root cause and set out any additional mitigating measures if deemed necessary. It is upon the discretion of the postholder that all required mitigating measures have been identified.

2.5.3.2.6 Hazard Identification and Risk Assessment

Hazards may originate from multiple sources. Most hazards will arise from safety assessments for Test Flights. Additionally, hazards will typically result from changes in the organisation (see Section 2.5.3.2.7), occurrences, brainstorms, safety information from external sources (e.g., accident/incident databases, flight test safety databases, Best Practices from relevant organisations such as SETP and SFTE) and feedback from training.

1) Flight Test related hazards are identified and processed according to the FTOM processes (see Section 2.5.5.1 and the related risks are accepted or mitigated (and then accepted or rejected) as required, in advance of or during the respective project.

2) All other hazards are processed alike, under the responsibility of either the Safety Manager (occurrences) or the postholder. Internal or external Subject Matter Experts are involved as seen fit. The source of the hazard is explored, taking safety nets that are assumingly/already in place into account, (any additional) hazards and scenarios are defined, and for each hazard the risk level is determined, based on the Flight

Test organisations risk matrix (severity x probability = risk level). For Flight Test related hazards (in the FTOM) this risk matrix is adapted to incorporate the duration of the project.

3) The responsible postholder classifies the risk of a hazard in terms of tolerability (intolerable, tolerable, acceptable) and may always upscale if deemed necessary. In case of intolerable risks, the Accountable Manager is involved. The accepted risk classification determines whether mitigating measures are required to be taken or not.

4) Mitigating measures are taken under responsibility of the postholder who in due time, when the results of the action taken should be apparent, checks its effectivity. He initiates additional actions as necessary.

All SMS related data (occurrences, hazards, mitigating measures), including those resulting from Flight Tests are recorded in a database system for review over time (are implemented measures still effective?) and as a knowledge base for future re-use.

2.5.3.2.7 Management of Change

Changes in the organisation typically comprise of significant expansion and contraction, changes to existing or the introduction of inherently new: systems, equipment, facilities, policies, processes and operations and major regulatory changes. Based upon considerations of criticality of systems and activities (potential consequences of safety risk), stability of systems and operational environments (frequency of changes occurring and whether the changes are under control of the organisation or unplanned) and past performance (as an indicator of future performance), the postholder determines whether a hazard identification and risk assessment (see Section 2.5.3.2.6) should be held.

2.5.3.2.8 Safety-Related Investigations

For incident and accident investigation a dedicated internal process is available that is additional to the occurrence reporting process and any external investigations. Main objective is to learn from what has happened and the prevention of accidents and incidents, not to apportion blame or liability.

1) An independent investigation team will be appointed by the Accountable Manager, the composition of which depends on the extent of the incident (e.g., nature, complexity, severity). Specific experience and training requirements apply for the (chairman) of the investigation team. NLR has served as an independent investigation body for over 25 years and has capable incident and accident investigators in-house available.

2) The investigation team is relieved from their other work to conduct the investigation and records its findings in an investigation report. In this process the Safety Manager is responsible to deliver all relevant (safety-related) documentation and data to the investigation team. Focus of the investigation is on finding the root cause, hazards and establishing safety recommendations to prevent similar occurrences in the future and to enhance safety of the operation. ICAO Annex 13 is used as guideline for the investigation. Any information related to the incident and/or obtained during the investigation is confidential and will not be used anywhere else. In communication or publication of information from the investigation by the investigation team to parties/persons external to the investigation team, information will be de-identified.

3) The Accountable Manager and Safety Action Group will base their decisions on actions to be taken on the recommendations in the final investigation report.

2.5.3.2.9 Safety Performance Monitoring

Overall safety performance is monitored based on pre-defined Safety Performance Indicators, – Alert levels and –Targets that are adapted to the safety (threat) profile of the Flight Test organisations. The 'areas to be observed' by the SPIs are:

- Risk related to Flight Test execution;
- Specific attention areas (e.g., relatively high number of specific occurrences reported);
- Utilisation of responsibilities and procedures; and
- Safety perception of personnel and risk related to change.

The SPI are measured by the Safety Manager by one or a combination of various means:

- Review meetings of Flight Tests or changes;
- Using the information in the database system;
- Surveys among personnel; using trend information from the reporting system; and
- And audit results.

The Safety Manager reports the safety performance to the Accountable Manager.

2.5.3.2.10 Safety Training and Communication

All personnel of the Flight Test organisations receive initial and two-yearly recurrent (in-house) Safety Management training, with focus on the organisations SMS and legislation in force.

All SMS related information is communicated through a common Flight Test organisations digital portal. Furthermore, safety flyers, minutes of meetings and workshops will be used as communication means as appropriate.

2.5.3.2.11 Continuous Improvement and Compliance Monitoring

The SMS system is continuously improved to ensure its suitability, adequacy and effectiveness. To this extent management meetings at Safety Committee and Safety Action Group level are held, functional area hazard brainstorms may be organised and safety information from external sources analysed. Furthermore, a compliance monitoring system is in place to ensure the SMS remains in compliance with the applicable regulatory requirements. Results of which are reported to the Accountable Manager in a yearly Quality Management review. The above mentioned meetings are combined for efficiency if possible and may be combined with the (quality) management reviews of the individual Flight Test organisations.

2.5.3.2.12 Emergency/Contingency Response Plan

An ERP is defined as part of the SMS.

2.5.4 Organisation and People

2.5.4.1 Flight Operations

NLR Flight Operations is responsible for the preparation and execution of all NLR (test) flights.

Because NLR does not hold an Aircraft Operator's Certificate, NLR Flight Operations are not supervised by EASA or National Authorities but operate under ICAO Annex 6 provisions. The internal NLR Quality System oversees Flight Operations compliance with legislation and Best Practices.

The Postholder Flight Operations reports to the Accountable Manager Flight Operations.

Test flights are always performed within the framework of a "project" within NLR, governed by ISO9001 quality standard. Each NLR project will be assigned a Project Manager. For those NLR projects that involve flight test, a Project Pilot is assigned who is responsible for drafting the Flight Test Plan (FTP). Because the Project Pilot may be required to engage in the scientific background of the project, NLR pilots are required to have a strong scientific or engineering background, typically a Masters Degree in Engineering. In addition, pilots will need to have a flight test background, although it is possible that this experience is gained on the job.

Certification test flights may have to be performed as part of a design change to the aircraft. As these are governed by EASA FTL rules, NLR pilots will typically also hold an EASA Category 1 or 2 Flight Test Rating.

2.5.5 Process and Procedure

NLR's own Quality System is compliant with ISO standards, but NLR research projects may have different working methods, or may adhere to different quality standards. This is partly because many projects are done in conjunction with worldwide partners, and within a project different partners will agree on a working method, reporting format, quality system and management structure. However, once an NLR project includes a flight test effort with an NLR aircraft, the NLR Flight Test Operations Manual (FTOM) applies.

2.5.5.1 Basic Flight Test Process

The basic Flight Test Process described in the FTOM comprises five stages with associated documentation.

1) **Initiation Phase:** An NLR flight test project starts with a Request For Test (RFT), a formal request by the NLR organisation to NLR Flight Operations to consider preparing and executing a test flight (or series of test flights). The RFT contains an indication of available budget and time constraints, as well as a preliminary safety assessment based on a simple flow chart. The RFT is filled in by the Project Manager or Proposal Manager, with the help of an NLR pilot, and submitted to the Postholder Flight Operations for approval. When the P-FO signs the RFT this means that, within the budget, schedule and time constraints, the initial work of drafting a test plan can commence. The preliminary risk assessment is more a conscience building exercise for the Project Manager, in the test plan the actual risk assessment is performed.

2) **Definition Phase:** In the definition phase the Project Pilot will take the lead in drafting a Flight Test Plan. Every test plan will be peer reviewed by another NLR test pilot. In the FTP also the Flight Test Safety Assessment is performed, leading to a risk classification of ROUTINE, LOW, MEDIUM or HIGH risk. It is NLR policy not to fly HIGH RISK test flights. For MEDIUM risk, or if the Project Pilot deems it necessary, a dedicated Safety Board is installed which has as primary objective to question the flight test safety assumptions, mitigations and methods. The Definition Phase ends when the FTP is approved.

3) **Preparation Phase:** During this phase, the research aircraft will be modified and instrumented, the flight and ground crew will undergo the necessary training, the ground station(s) will be set up, arrangements with airports, ATC or other parties will be finalised, etc. Also, the Test Cards are generated, The Preparation Phase results in the aircraft, equipment and crew ready for the test flight and Test Cards generated.

4) **Execution Phase:** This phase includes the pre-flight go-nogo decision, the pre-flight briefing, the test execution and the post-flight debriefing.

5) **Evaluation Phase:** After the flight test campaign has been finished, it will be evaluated in order for future projects to benefit from the experiences gained. Lessons learned will be identified for each phase of the project. Within the scope of the Safety Management System this may then result in updates of Operations Manuals and forms. Typically, after the flight test campaign a Flight Test Report will be produced. The Flight Test Report does not need to have a specific format as it may be a Project Document. This report will normally contain the Lessons Learned as outlined above, if this is not the case, or Lessons Learned can be drawn outside the scope of the Project.

2.5.5.2 Safety Assessment

The purpose of the Safety Assessment is threefold:

1) Identify safety hazards;
2) Formulate Effective Risk Reduction Measures; and
3) Classify The remaining risk category of a test flight.

2.5.5.2.1 Risk Categories

NLR categorises flight test risks in one of four categories ROUTINE, LOW-, MEDIUM- and HIGH RISK. The risk category raises overall awareness of safety issues that are related to the flight test program, determines the authority required to approve the FTP, and determines flight test crew selection (including possible minimum crew requirements) and flight crew training requirements.

2.5.5.2.2 Financial Risk

It is possible that as a direct result of executing a flight test damage is sustained to aircraft, aircraft systems or components, instrumentation equipment, third parties or environment. This can be either direct expenses to replace possibly damaged items, or indirect loss due to loss of warranty or voidance of insured events. In the initiation and preparation phases the financial risk as a result of flight testing are assessed, this assessment should be seen independently of the project (financial) risks.

2.5.5.2.3 Risk Assessment

The risk assessment is based on the concept that risk is a combination of severity and frequency. Hazards are collected from different sources (internal and external hazard databases, expert sessions, lessons learned, Best Practices from SETP and SFTE) and combined into scenarios. For every scenario risk control measures are identified. Risk control measures are measures that reduce the severity of the scenario and/or provide an additional safety barrier in preventing the occurrence of the hazard (avoidance) and its consequence (recovery). Besides the reduction in risk that can be achieved with the risk control measure, the costs and effects of the risk control measures on the operation are to be taken into account. Before selecting risk control measures it is necessary to re-assess the entire operation with the proposed risk control measures in place to assure that these measures do not introduce new hazards in the operation and do not increase the risk level of the identified hazards. The risk assessment then assesses the residual risk, with the selected risk control measures put into place.

2.5.5.2.4 Severity

Severity is expressed as a level based on effect on aeroplane, effect on crew and occupants, effect on test flight, and financial impact (which includes effects on third parties), and is categorised as Catastrophic, Hazardous, Major or Minor.

2.5.5.2.5 Frequency

When available, a frequency of occurrence will be established for the hazard under investigation. In-flight test it may prove difficult to determine the frequency of occurrence as by definition certain aspects cannot be assessed using previous exposure data. An alternative method to establish frequency may be used based on the effectiveness of the control measure, in fact the inverse of the frequency. For control measures that are deemed very effective, e.g., redundancy is available, normal flight crew intervention sufficient to mitigate the risk, the frequency of a specific hazard leading to an undesired outcome is lower. The effectiveness of a control measure is categorised as Effective, Limited, Minimal or Not Effective. So even without being able to qualitatively or quantitatively establish a frequency, with the effectiveness of the control measure it is possible to identify the risk of a scenario.

2.5.5.2.6 Risk Tolerability

The combination of Severity and Frequency, or alternatively the combination of Severity and Effectiveness of Control Measures, is plotted in the Risk Matrix for every scenario. The most restrictive outcome of all applicable scenarios defines the risk category of the flight.

2.5.6 Facilities and Tools

N/A

2.5.7 Discussion and Observations

In a research environment typical challenges apply: a very wide scope of flight test objectives is found, and aircraft configuration changes frequently.

NLR has opted to adapt an organisation based on EASA (Part-SPO) Regulations. Pillars of the flight test organisation are the Flight Operations, Part-145, CAMO and Part-21 organisations. Project Management is regulated through NLR ISO:9001 Quality Management standards.

Overarching the flight test organisation is an integrated SMS based on ICAO Annex 19 and following ICAO Doc 9859 guidelines. Typical challenges for a small flight test centre include little data from reporting systems, and little operational data. It is almost impossible to quantitatively apply data analysis, identify trends and measure performance on the scarce data available. A more qualitative approach is applied, reverting to e.g., awareness campaigns and training.

NLR is a relatively small organisation. As a result, persons may hold more than one responsibility in the organisation or may have more than one task in the preparation, execution or evaluation of a test flight. Attention must be given to adequately separate tasks and responsibilities, and always have a separate set of eyes available for each step along the way.

2.5.8 Conclusions and Recommendations

N/A

2.5.9 Appendix

Dedicated to Innovation in aerospace

TUDelft

SAFETY POLICY STATEMENT

Safety is a key element of the NLR/TUD flight test operations. The NLR/TUD Flight Test Organisations (FTO) commit themselves hereby to implementing, maintaining and constantly improving processes to ensure that all flight test activities take place at the highest level of safety performance possible and in compliance with national and ICAO standards, as well as EASA regulations – to the extent applicable for the FTO. The Accountable Manager is ultimately responsible to balance the allocation of organisational resources in such a way that these goals can be achieved, in an economically sensible way.

The FTO is committed to:

- Support the management of safety through the provision of appropriate resources that will result in an organisational culture that fosters safe practices, encourages effective reporting and communication.
- Clearly define for all staff, managers and employees their accountabilities and responsibilities in safety.
- Ensure that no punitive sanction will be taken against the reporter of or persons involved in a safety concern or occurrence, unless gross negligence, a wilful violation or destructive act has been established.
- Ensure that sufficient skilled and trained human resources are available to implement and maintain this SMS.
- Ensure that all staff is provided with relevant aviation safety information and training and are competent in safety matters.

The FTO has established the following principles:

- Any NLR/TUD or external personnel involved in FTO activities shall never compromise on safety while performing their work.
- The Accountable Manager is accountable for safe and secure operational practices and fundamentally responsible to lead the safety effort in a consistent way, establish relevant goals and create a working environment in which employees can perform their work safely, while complying to applicable regulations and international standards.
- All FTO employees have the responsibility to contribute to a safe operation, comply with laws, regulations and procedures and participate actively in training. FTO employees shall also identify and alert other employees and the management to potential unsafe situations, not only in their own environment but also in cross-functional relationships.
- All FTO employees are expected to challenge each other about safety when performing their work. When an FTO employee is convinced that the task assigned to him cannot be performed without compromising safety, he is expected not to perform this task. Solutions for such situations will be sought without punitive actions towards the employee(s) concerned.

Date: 16 Nov 2017	Date:	Date:
Ir. M.J. Eijkman Accountable Manager of Flight OPS, RATO and CAMO, and NLR Division Manager Aerospace Operations	Prof.dr.ir. M. Mulder Head of Department Control and Simulation Delft University of Technology	Ir. M.A.M. van Venrooij Chief Executive of NLR RADO and NLR Division Manager Aerospace Systems

Figure 2-5.1: NLR Safety Policy Statement.

2.6 SAAB AB

2.6.1 Nature of Flight Test Activity

Aeronautics is engaged in advanced development of military and civil aviation technology. It also conducts long-term future studies of manned and unmanned aircraft as preparation for new systems and further development of existing products. Aeronautics includes the following product categories: Gripen Fighter Systems, Advanced Pilot Training Systems, Airborne Solutions, Mission Support Systems, Avionics Systems, Simulation Systems, Support Solutions and Operational Contracts.

The Flight Test and Verification department is responsible for development test, verification and validation of experimental, prototypes, pre-production and production aerial vehicles systems through simulator, ground and flight testing. It also provides support to the marketing department with demonstrations, evaluations plus land and aerial displays linked to various marketing activities.

The Organisation has Flight Test Capabilities covering the following areas.

2.6.1.1 General Vehicle Systems

Hydraulic systems, landing gear and brake systems, fuel systems, propulsion, environmental control systems, escape system, secondary power system, and electrical/lighting system.

2.6.1.2 Flight Dynamics

Flying qualities, handling qualities, flight mechanics, aerodynamics, weight and inertia, flight control system, and performance.

2.6.1.3 Structural Dynamics

Flutter, loads, physical environment sustainability.

2.6.1.4 Tactical Systems

Complete system of systems, avionics, decision support, human-machine interface, communication, sensors, mission support, and maintenance systems.

2.6.1.5 Weapon Systems

Weapon integration, control and guidance.

2.6.2 Background

SAAB AB is a Swedish Aerospace and Defence Company founded in 1937. It is based at Linköping in Southern Sweden. Since the 1930s the company has produced a long line of mostly fighter aircraft. Notable are the Tunnan, Lansen, Draken, Viggen and Gripen. Production today is focused on the Gripen and its continuing development.

2.6.3 Regulatory Framework

2.6.3.1 External

SAAB AB holds approved certificates as a Design Organisation and Flight Operator to perform Flight Operations, including experimental flight test, for civil aircrafts from EASA and for military systems from the Swedish Military Aviation Authority.

2.6.3.2 Internal

2.6.3.2.1 Flight and Product Safety Policy

When developing/producing products and providing services affecting flight safety, the safety level of the product/service (hardware/software/human-machine interface) shall exceed or meet international standards/best practice in accordance with the expectations of the society, customers and authorities.

The following principles apply to all our activities:

- All employees shall understand their role and associated responsibilities.
- All employees have a common responsibility to maintain product-, flight- and system safety by following established working procedures, and not to take risks that is not accepted by the appointed accountable.
- Anyone who identifies a deficiency has the obligation and responsibility to report the finding to the appointed accountable according to established procedures and routines.
- To maintain safe products, effective systems for reporting, monitoring and analysis of events, trends and potential product-, flight- and system safety risks during the complete product life cycle shall be in place.
- Time and resources, according to judgement by appointed accountable, shall be allocated to identify and analyse potential product-, flight- and system safety risks that may result in accidents or serious incidents and to prevent these as far as possible. Training and information to affected personnel shall be provided.

2.6.3.2.2 Flight Test Safety Management Systems

The following sections outline the personnel and the processes that together make up the SAAB Flight Test Management System.

2.6.4 Organisation and People

2.6.4.1 Foundation/Training

2.6.4.1.1 Test Pilots

The Flight Test and Verification department runs an internal education program for test pilots. The education leads to formalized competence levels where the higher levels entails the test pilot to represent the pilot perspective on design decisions and perform testing on all systems including envelope expansion and hazardous testing.

Test pilots graduated from an international test pilot school will have many of the internal education program elements covered.

On top of the general test pilot training is type training requirements for specific aircraft types.

An important part of flight operations is supervision of flying duty and the command chain. All these roles have training requirements including flight safety aspects.

2.6.4.1.2 Test Engineers

The Flight Test and Verification department runs an internal education program for Test Engineers. This ensures that the test leader has the needed knowledge and experience to take responsibility of experimental and potential hazardous flight test activities.

The program consists of three certification levels Test Engineer, First Test Engineer and Senior Test Engineer (Figure 2-6.1).

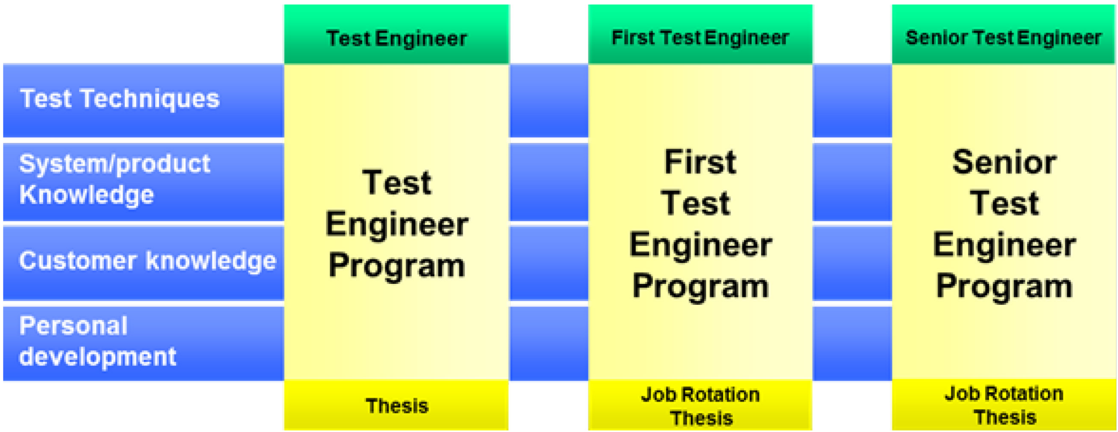


Figure 2-6.1: Internal Education Program for Test Aircraft Maintenance Personnel.

Two of the major goals are to achieve support fulfilment of authorities' request of formal education and achieve uniformed, efficient and, above all, safe working methods.

An important part of the program is On the Job Training working according to our Systems and Flight Test Process. Achieving higher authorisation levels is a prerequisite for leading hazardous flight test.

2.6.4.1.3 Test Aircraft Maintenance Personnel

The Flight Test and Verification department runs an internal education program for test aircraft maintenance personnel. This includes routines for modification of experimental aircraft configuration based on documentation provided by Test Engineers that are not in the current maintenance instructions. Special emphasis is put on the flight safety risks.

2.6.4.2 Flight Operations

2.6.4.2.1 Air Station

All flight operations are carried out by the Air Station Organisation. All responsibilities, roles and routines are regulated so that airworthiness is kept compliant for maintenance tasks, modifications performed on test aircrafts, and actual installed and loaded test configurations.

All test flights are carried out under an applicable Flight Test Permit given by the Airworthiness Authority. Based on Airworthiness Certificates and Operational Plans these Flight Test Permits can span long periods where the Air Station operates within those permits.

The focus on flight safety regulated in the Air Stations operational manuals and expositions are the most important foundation for these permits.

2.6.4.2.2 Flight Safety Officers

The Flight Safety Officers are responsible for the collection, analysis and reporting of flight safety information. This means that flight safety knowledge, lessons learned and recommendations for updates of operational manuals and expositions are handled with focus and continuously.

Flight Safety Officers covers flight, ground handling, maintenance and test methods.

2.6.5 Process and Procedure

2.6.5.1 Initial Planning

In the early planning stages the need for development test, verification and validation are converted to the need of test object, test stations and test environments.

An important part of the Flight Safety work is to early identify the need for and requirement on safety equipment and design for test functions.

2.6.5.2 Flight Test Plan

Flight Safety Assessment: The test team shall perform and document a Preliminary risk assessment within the test team that serves as a base for continued handling and formal Flight Safety Review including suggestions for actions to increase flight safety and personnel safety.

Envelope Expansion Routines: When the configuration to be tested have several new systems, functionalities and physical shapes a special frame test plan will govern the overarching configuration steps, envelope expansion steps as well as risk mitigation requirements. The ultimate example is of course a completely new aerial vehicle being flown for the first time. The underlying flight test plans will still be assessed regarding their own risks.

2.6.5.3 Flight Safety Review

All Flight Test Plans will go through a Flight Safety Review. This review is performed on the already approved Flight Test Plan and is the last step before it is authorised.

This task is performed by a group of experienced personnel from most involved flight test disciplines, including maintenance.

The aim of the review is to ensure that the collected experience has been used in order to accomplish the test with all consideration taken to flight safety.

2.6.5.3.1 Events

Dangerous events, which could be conceived as possible during the test flight, are to be identified. Only events related to the test are to be dealt with. General risks that are always associated with flight activity (e.g., ice accumulation, collisions and similar) should not be a part of this assessment unless the test itself leads to an increased probability for these risks.

During the assessment special attention must be paid to:

- What is new in the test?
- Is there any earlier experience?
- Are other systems affected?
- Is the envelope expanded?
- Difficult flight conditions/manoeuvres;
- Deviations from flight operations manual / line maintenance instruction;
- Can the test endanger (above what can be considered normal for the concerned duties) personnel safety, affect mental health or invade personal integrity?
- Can the third party be affected?

2.6.5.3.2 Cause

The cause of the event is identified. Here, whatever it is that causes the event (condition, function, pilot actions) is stated. Not the event, the risk or the consequence.

Consequence

Here, an assessment is made of the consequence of the event in question. The consequence is graded according to:

CATASTROPHE	Malfunction/condition that seriously reduces the aircraft's function, handling qualities and/or the pilot's capability to such a degree that continued safe flight and landing is not possible, with total loss of material, death and serious damage to the environment as a result.
CRITICAL	Malfunction/condition that reduces aircraft function, handling qualities and/or pilot capability to such a degree that serious personal injury, severe damage to material or great environmental damage can result.
MARGINAL	Malfunction/condition that degrades aircraft function and handling qualities in a way that is familiar, and at a level that the pilot can handle, but can lead to minor personal injury, minor damage to material, minor damage to the environment.
NEGLIGIBLE	Malfunction/condition that does not degrade aircraft function and handling qualities or does not noticeably increase the workload on the pilot.

2.6.5.3.3 Probability

A subjective estimate of the probability of an event actually happening is done.

The probability is rated according to:

OFTEN Happens every test sortie.

SOMETIMES Count on it happening several times; however, not in every sortie.

SELDOM Maybe it won't happen, but it cannot be totally ignored.

VERY SELDOM It is very probable that it won't happen; seldom if we do not expose ourselves too much.

IMPROBABLE We are certain it won't happen, and we are probably right.

2.6.5.3.4 Risk Index

For each identified event a risk index from 1 – 24 must be given. The risk index is a combination of the probability of an event actually happening and the consequences of the event. The relation between consequence, probability and risk index is shown in Table 2-6.1.

Table 2-6.1: Risk Index.

	Often	Sometimes	Seldom	Very Seldom	Improbable
Catastrophe	24	20	16	12	8
Critical	18	15	12	9	6
Marginal	12	10	8	6	4
Negligible	6	5	4	3	2

2.6.5.3.5 Results/Actions

A final review is performed and the risk index set by considering the actions that have been taken to reduce risks (Table 2-6.2).

Table 2-6.2: Risk Index: Results/Actions.

Risk Index	Assessment	Requirement
16 – 24	High risk test	Doubtful whether testing can be conducted. Further reviews must be taken regarding additional mitigating risk reduction actions or altered test methods.
9 – 15	Medium risk test	No special requirements. The test is managed in accordance with normal routines with authorised personnel, telemetry and test pilots.
2 – 8	Low risk test	Can be conducted without telemetry, and with low formal requirements on the test plan, etc.

2.6.5.4 Test Conducting

Most test flights contain either envelope expansion, integration and usage of new or modified equipment and functionality, hazardous test cases or potentially a very high workload for the pilot if something unexpected occurs. These test flights are therefore guided and monitored by an applicable test team from a control room by means of telemetered data and radio communication.

The general roleplay when performing a test flight is that the Test Conductor oversees and guides the Test Pilot through the whole flight, from start-up to shut-down. The Test Leader focuses on initial conditions, performance of test cases and quick analysis of online data compared to expected results. Test Engineers monitors instrumentation data compared to expected behaviour and supports both the Test Conductor and Test Leader with advice on how to proceed with the test flight.

Generally, only the Test Conductor communicates with the crew on board the test aircraft.

A Safety Pilot will often be present for hazardous testing to help reduce pilot workload both for known procedures and in unexpected events.

Online data is nearly ever directly relied upon for flight safety, but still can help mitigate risks through being able to establish known and safe initial conditions before the test point are executed.

2.6.6 Facilities and Tools

N/A

2.6.7 Discussion and Observations

N/A

2.6.8 Conclusion and Recommendations

N/A

2.6.9 Appendix

N/A

2.7 TURKISH AIR FORCE FLIGHT TEST CENTER 401ST TEST SQUADRON

2.7.1 Nature of Flight Test Activity

The majority of 401st Test Squadron flight test activities are systems integration and aircraft-stores compatibility tests. Its current instrumented test A/C types consist of:

- F-4E/2020; and
- F-16 (Block 30TM F-16, Block 40, F-16 Block 40M, F-16 Block 50M).

The Organisation has Flight Test Capabilities covering:

- **Airframe** – Structural, Performance, Flying and Handling Qualities;
- **Systems Integration** – Avionic Systems and Weapon Systems; and
- **Stores Test** – Aircraft – Stores compatibility tests of Air to Air and Air to Ground Weapons, Pods, Adapters and Fuel Tanks, etc. Carriage, Jettison, Guided Release, Live Firings.

2.7.2 Background

Within TurAF, Flight Test Activities started with the establishment of Test and Evaluation Branch within Technology and Weapon Development Command (TWSDC) which is located in Eskişehir. The TWSDC has also Avionics and Aeronautical Branches which are capable of F-4 and F-16 avionics and weapon systems integration.

The T&E Branch initially had no dedicated Test Aircraft, Flight Test Engineers or Test Pilots. It only had the Flight Test Instrumentation (FTI) capability and coordination role. Early flight test programmes were accomplished with the support of operational pilots and maintenance people provided by combat bases and discipline engineers provided by either TWSDC or Contractor Company.

As the complexity and the number of the projects increased, the necessity of establishing a test squadron emerged. During transition period, T&E Branch was transformed into Developmental Test Detachment Command in 2013 and then into 401st Test Squadron in 2015. Following the reorganization of TurAF in 2016, 401st Test Squadron was tied to 1st Main Jet Base.

It is now the only Flight Test Centre performing jet aircraft-store compatibility tests within Turkish Air Force and Turkish Defence Industry.

Its history begins with the Turkish Precision Guided Munition (Hassas Güdüm Kiti – HGK) Programme in 2006 and since then over fifty different types of inertial aided munitions, cruise missiles, short range and medium range A-A missiles, reconnaissance pods, targeting pods, gunnery pods, EW Pods integration and certification tests were accomplished.

With the launch of Turkish National Fighter Aircraft (TFX) Programme, 401st Test Squadron is now being prepared to lead the flight test of TFX which is planned to be held on a joint basis with industry partners.

In the near future, it is planned to transform Eskişehir into a unique Test and Evaluation Base including Fixed Wing, Rotary Wing and UAS capabilities.

2.7.3 Regulatory Framework

2.7.3.1 External

Currently all airworthiness and flight test safety issues within TurAF are managed internally according to Air Force Regulations.

However, Turkish Ministry of Defence is working on the establishment of Turkish Military Airworthiness Authority. And by the law come into force, The Authority is expected to rearrange and control all airworthiness and flight test safety issues.

2.7.3.2 Internal

The main Air Force Regulation driving the 401st Test Squadron Flight Test and Evaluation activities is Turkish Air Force Instruction HKY 165-15 Flight Test and Evaluation. All Safety management and flight release process are described in HKY 165-15.

Within TurAF, the technical management responsibility of the aircrafts is shared by two Air Supply and Maintenance Centre (ASMC). The 1st ASMC, which is located in Eskişehir, is responsible for all Fixed Wing jet aircrafts, and the 2nd ASMC is responsible for all rotary and Fixed Wing propeller type aircrafts.

401st Squadron is located at the ASMC facilities. ASMC is responsible for all modifications and configuration control of the Aircrafts including FTI, the 401st Test Squadron is responsible for Flight Testing.

For the risk assessment and safety approval of each flight test campaign, a Flight Test Safety Review Board (Test Uçuşu Emniyet Kurulu – TUEK) is established. After TUEK approval, recommendation for flight release is submitted to TurAF.

2.7.3.2.1 Flight Test Policy

Within TurAF, conducting Flight Testing without hazarding any personnel, aircraft or property/facilities on the ground is very important. The policy of 401st Flight Test Squadron is to deliver flight campaign without any missing issues of:

- Safety;
- Functionality; and
- Mission Effectiveness and Suitability.

2.7.3.2.2 Flight Test Safety Management System

The deployed Flight Test Safety Management System brings together the technical responsibility (ASMC), the flight test responsibility (401st Squadron) and Contractor Company if involved in the test campaign.

Each Flight Test Project Team has its approved Flight Test Engineers and Test Pilots from 401st Test Squadron and Systems Engineers and Specialists from TWSDC and Contractor Company. TurAF Flight Test Safety Process has three stages.

1) Firstly, a Flight Test Technical Review Process is applied to review the flight test design, requirements and success criteria, test items, required tools, facilities, test ranges, test steps, sortie plans, safety and security criteria, and to identify and mitigate the risk levels. A specific Flight Test Technical Board (Test Uçuşu Teknik Kurulu – TUTEK) is established for technical review of every proposed Flight Test and Evaluation Plan. TUTEK is coordinated by Flight Test Engineering Command and chaired by the Commander of TWSDC. The organisational structure of the TUTEK is given in Figure 2-7.1

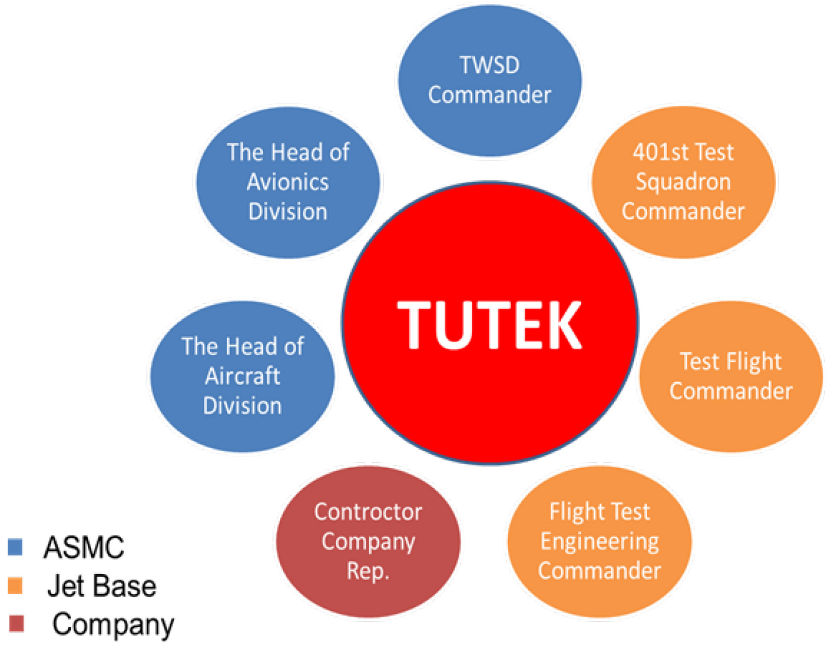


Figure 2-7.1: The Organisational Structure of TUTEK – Flight Test Technical Board.

2) Following TUTEK, the TUEK realizes the Flight Test Safety Review Process to review all safety of flight analyses and tests and to ensure that risk is identified and mitigated to acceptable levels and to approve safety of flight. TUEK is coordinated by Flight Test Engineering Command and Co-Chaired by The Commander of ASMC and The Commander of the 1st Main Jet Base. The organisational structure of the TUEK is given in Figure 2-7.2.

3) After the TUEK, recommendation of the flight tests is submitted to TurAF. The flight test is accepted and released by The Air Force Chief of Staff.

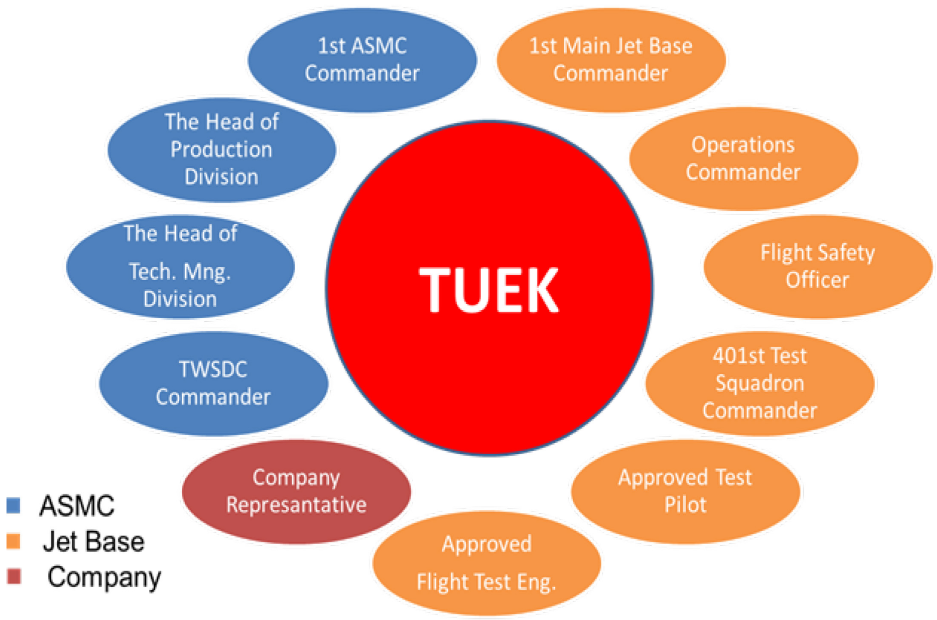


Figure 2-7.2: The Organisational Structure of TUEK – Flight Test Safety Review.

2.7.4 Organisation and People

401st Test Squadron consists of Flight Test Engineering Command, Flight Command, Test Support Command, Planning and Training Division.

2.7.4.1 Planning and Training Division

Planning and Training Division is responsible for:

1) Scheduling the Test Flights, Meetings, Trainings, etc.
2) Coordination of Test Area, Ranges, NOTAM, NOTMAR.
3) Coordination with Project and Quality Management.

2.7.4.2 Flight Test Engineering Command

Flight Test Engineering is responsible for:

1) Conducting all Flight Test Processes.
2) Interfacing and coordination among the Flight Test Team.
3) Coordination and reporting TUTEK and TUEK.
4) Data Processing and Reduction, Analysis, Reporting and Achieving.

2.7.4.3 Test Flight Command

Test Flight Command is composed of Test Pilots and Flight Planning Team. Main responsibility of this unit is planning, executing and reporting of Test Flights in conjunction with Flight Test Engineering. Additionally, they perform:

1) Operational/Technical assistance for Design Group;
2) Advising pilots/crew manuals;
3) Initial operational assessment of the prototype; and
4) Initial training for Operational Test Groups and/or users.

2.7.4.4 Test Support Command

Test Support Command is composed of FTI Engineering Coordinator, Maintenance Coordinator, special technicians including avionics, munitions, loadings, etc. Main responsibility of this unit is preparing Test Aircraft and Test Item. Additionally, they perform:

1) Operational/Technical assistance for Design Group;
2) Advising maintenance manuals;
3) Initial operational assessment of the prototype; and
4) Initial training for Operational Test Groups and/or users.

2.7.5 Process and Procedure

2.7.5.1 Common Procedure

Flight testing is a complex process and a great teamwork requiring different technical skills and good management. In order to achieve flight tests in a safely, efficiently and timely manner, to create a common language and to standardize all processes is very important. 401st Test Squadron has common flight test processes, tools and facilities across all projects. The Flight Test Engineering Command is responsible to manage the whole process and coordinate all test elements.

2.7.5.2 Flight Test Process

The basic Flight Test Process deployed within TurAF has three main phases with associated inputs, functions and outputs. These phases are outlined below.

2.7.5.2.1 Flight Test Design Phase

1) This phase commences as the project starts and continues till the execution phase. In order to deliver the flight test safely, efficiently and timely, it is critically important to establishing a Flight Test Programme and early integration of the flight test teams into the project. This will let to monitor the overall schedule, determine and control the risks in a timely manner and to establish an effective communication among the teams.

2) The contract based requirements and airworthiness requirements comprise the initial inputs of this phase. Definition and approval of the test methods, test procedures, the data and instrumentation requirements, tools, facilities, test ranges, limitations, safety and security requirements are the main functions of this phase.

3) Risk Assessment and Safety Management starts formally with flight test design phase.

4) At the end of the design phase, TUTEK and TUEK are accomplished, and submit the recommendation of the flight test to TurAF.

5) The final output of the design phase is the approval of Flight Test and Evaluation Plan and Flight Release.

2.7.5.2.2 Flight Test Execution Phase

1) The approved Flight Test and Evaluation Plan and the Flight Release are the principal inputs of the execution phase.

2) The Execution Phase is the part of the Flight Test Programme where the tests defined in the Test Plan are realized. The main functions of the execution phase consist of preparation the test cards, briefs, conduction of the test, debriefs and data processing. Test cards are produced by Flight Test Engineers in conjunction with Test Pilots.

3) A formal brief is done for each sortie by the relevant approved person with all involved parties. The brief is conducted by the assigned Flight Test Engineer and a Quality Engineer monitors to ensure the brief is fit for the approved Test Plan. At the conclusion of the brief the test card of the sortie is signed by the Aircrew, Flight Test Engineer and Quality Engineer.

4) Where sorties are supported by Telemetry the Team are present at the brief. The entire test is conducted by the assigned Flight Test Engineer.

5) Following the flight test briefing, test pilot conducts a separate flight briefing with his/her crew, chase and/or support A/C about inter-flight operations.

6) After each sortie a formal debrief is done. All test events are reviewed by the team and a post-flight report is prepared. All deficiencies are categorised into three groups. The first category deficiencies have the highest priority and unless solved the test is suspended. All safety critical issues are assessed as category one.

2.7.5.2.3 The Flight Test Conclusion Phase

1) The collected test data during the sorties and daily reports are the inputs of the conclusion phase. Analysing and assessing the test data are the main functions.

2) The data Analysis and Assessment is performed by the Flight Test Engineering in conjunction with the related Systems Engineering and Specialist.

3) The final outcome of the conclusion phase is the Test Report. Test Report covers all test activities, information and data. The report is released to Project Office. Interim reports can be released to identify and capture the safety-related issues, to determine the impact of the issue and to make recommendations for mitigating and controlling the risk.

2.7.5.3 Flight Test Safety Review Process

Within TurAF, conducting Flight Test without hazarding any personnel, aircraft or properties/facilities on the ground is the paramount objective.

Flight Test Safety Management Chart followed by 401st Test Squadron is shown in Figure 2-7.3.

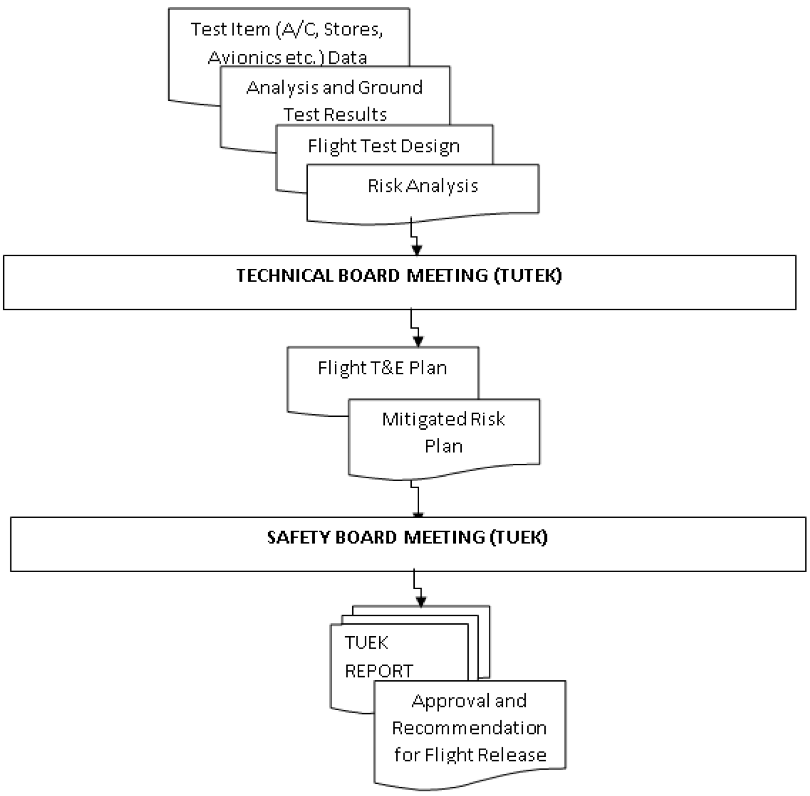


Figure 2-7.3: Flight Test Safety Management Chart.

2.7.5.4 Hazards/Risk Identification

Hazards are identified based on type of flight testing and mission requirements. Specific Flight Tests include specific hazards. A list of hazards associated with each phase of the operation is prepared.

To identify risk levels, the nature of the test, flight test profile/envelope, environmental issues and mission requirements are investigated. Controls and Actions for each risk are defined according to Risk Management Plan and a watch list is initiated for each risk.

2.7.5.5 Risk Assessment

Risk assessment is used to analyse hazards and minimise risks associated with flight testing. Analysis begins with a detailed study of critical risks that have been identified. The objective is to collect adequate information about the risks to judge the probability and severity of occurrence and the impact on the cost, schedule and the performance.

The assessments are based on the information comes from:

1) Similar tests conducted before,
2) Lessons learned from experience,
3) Results from ground testing,
4) Data from engineering analysis, (CFD, FEA, etc.)
5) Modelling and simulations, etc.

Ratings are indications of potential impacts of risks on a test program. They are a measure of the likelihood of a hazards/mishaps occurring and consequences of them.

Risk categories are expressed as High, Medium and Low. The final risk categorisation is reviewed and approved by TUEK.

The Risk Matrix used is derived from Air Force Risk Management Regulation.

Likelihood Criteria and the Risk Matrix are given in Table 2-7.1.

Table 2-7.1: Likelihood Criteria – Risk Occurrence Probability, Risk Severity and the Risk Matrix.

Likelihood Criteria		
Level	**Risk Occurrence Probability**	
1	Remote	Can assume will not occur **(Possible, but improbable).**
2	Unlikely	Possible to occur **(Remote chance of occurrence).**
3	Likely	Occurs sometime **(Sporadically).**
4	Highly Likely	Occurs several times **(Frequently).**
5	Nearly Certainly	Occurs often **(Continuously).**

Likelihood Criteria		
Level	**Risk Severity**	
E	Very Low	Less than minor mission degradation, injury, occupational illness, or minor system damage.
D	Low	Minor mission degradation, injury, minor occupational illness, or minor system damage.
C	Medium	Key mission degradation, injury, minor occupational illness, or minor system damage.
B	High	Major mission degradation, severe injury, occupational illness or major system damage.
A	Very High	Complete mission failure, death, or loss of system.

Risk Matrix					
SEVERITY/ OCCURANCE PROBABILITY	**E**	**D**	**C**	**B**	**A**
5	5E	5D	5C	5B	5A
4	4E	4D	4C	4B	4A
3	3E	3D	3C	3B	3A
2	2E	2D	2C	2B	2A
1	1E	1D	1C	1B	1A

The risk level is determined by entering the risk assessment chart with both the occurrence severity and probability, and seeing what risk category it fits into:

HIGH RISK – Test or activities which present a significant risk to personnel, equipment, or property, even after all precaution measures have been taken. This necessitates close oversight.

MEDIUM RISK – Test or activities which present a greater risk to personnel, equipment, or property than normal operations and require more than routine oversight.

LOW RISK – Test or activities which present no greater risk to personnel, equipment, or property than normal operations.

It is believed that Risk/Hazards/Mishaps can result from Human Factors, Environmental Factors, Logistic Factors, and Management factors. These factors are described below.

Human Factors: Answers to the following questions should be "yes" to minimise the flight testing risks:

- Flight Test Crews and Pilots are medically and professionally qualified?
- FTC and Pilots are trained in all relevant flight safety procedures, especially those specific to the test aircraft?

- Do they have enough knowledge about conducting test and test platform?
- Do Crew members' have enough previous experience?

Environmental Factors: Flight testing environment is one of the most important risk factors, Experienced Flight Test Crews should consider the weather condition on Flight Testing Day, NOTAM's, NOTMAR's FOD protections, Runway lighting Condition, etc.

Logistic Factors: The materials, arms, and other equipment used in flight testing should be controlled and it should be ensured to have no risk from that parts. Before Flight testing reliability analyses and maintenance documents should be carefully checked.

Maintenance Factors: All the Flight Test Crews should be aware of having the answers to following questions:

- Powers and Responsibilities are known at each level?
- Test plans, risk documentations and checklists are available and well prepared?
- Does TurAF FTC have Risk Emergency Plans for that test?

2.7.5.6 Risk Monitoring

The monitoring process systematically tracks and evaluates the effectiveness of risk handling actions of Flight Testing. Monitoring results may also be used to identify new risks and revise some aspects of risk planning.

2.7.5.7 Risk Handling

Risk Handling is an iterative process that culminates when the risk has been reduced to a level acceptable to the appropriate authority. Careful documentation of each step in the risk management process facilitates risk communication and the rational processes behind risk management decisions. Risk handling options include assumption, avoidance, control (also known as mitigation), and transfer.

1) **Risk Assumption:** is an acknowledgment of the existence of a particular risk situation and a conscious decision to accept the associated level of risk, without engaging in any special efforts to control it. It is most suited for those situations that have been classified as low risk.

2) **Risk Avoidance:** involves a change in the concept, requirements, specifications, and/or practices that reduce risk to an acceptable level. Eliminates the sources of high or possibly medium risk and replaces them with a lower risk solution. The risk avoidance is a decision process among the effected parties. The required measures should be defined during test design phase.

3) **Risk Control (Mitigation):** This is the process that identifies, evaluates, selects, and implements options in order to set risk at acceptable levels given program constraints and objectives. This includes what should be done, when it should be accomplished, who is responsible, and associated cost and schedule.

   Risk Control does not attempt to eliminate the source of the risk. It handles the risk in a manner that reduces the likelihood of its severity and/or occurrence.

4) **Risk Transfer:** is reallocating risk during the concept development and design processes from one part of the system to another.

2.7.5.8 Implementation of Risk Handling

All relevant personnel must be aware of the risk occurrence probability, risk severity, risk handling measurements, and residual risks after implementation of control actions.

Flight Test Personnel at every level must fulfil their respective roles in assuring controls. Final controls and reviews are made in pre-flight briefings.

Once controls are in place, the process must be periodically revaluated to ensure their effectiveness.

2.7.5.9 Risk Review

After assets are expended to control risks, then a cost benefit review must be accomplished to see if risk and cost are in balance.

- Was the flight test conducted in test limitations?
- What was the effect of the control measures on flight test performance?
- Was the established mission feedback system effective to take corrective or/and preventative actions?
- Were the controls effective to eliminate hazards or to reduce risks?

Feedback informs all parties about how the implementation process is working, and whether or not the controls were effective. Feedback can be in the form of briefings, lessons learned, risk documentations, test reports, etc.

2.7.6 Facilities and Tools

N/A

2.7.7 Discussion and Observations

N/A

2.7.8 Conclusion and Recommendations

N/A

2.7.9 Appendix

N/A

2.8 UNITED STATES NAVAL AVIATION

The content of the following is excerpts from and adapted from Naval Air Systems Command Instruction (NAVAIRINST) 3960.4C "Project Test Plan Policy for Testing Air Vehicles, Air Vehicle Weapons, and Air Vehicle Installed Systems", the "Test Planning Handbook", Naval Air Systems Command, Integrated Systems Evaluation Experimentation and Test, Version 1.3 of May 2015 and Naval Test Wing Atlantic Instruction (NAVTESTWINGLANTINST) 3710.7A "Standard Operating Procedures for Flight Operations" and by Mr. Jonathan R. Stevenson (USA).

2.8.1 Nature of Flight Test Activity

Naval Air Systems Command (NAVAIR) Flight Testing is carried out from a number of test locations by the Naval Air Warfare Center Aircraft Division (NAWCAD) and Naval Air Warfare Center Weapons Division (NAWCWD).

- NAWCAD: Patuxent River, Maryland and Lakehurst, New Jersey conduct primarily Aircraft Flight Test.
- NAWCWD China Lake, California and Point Mugu, California primarily conduct Weapons Systems Flight Test.

The extent of test capability is as follows:

- Military Flight Test Organization in support of US Navy and Marine Corps (Naval) aviation.
- Types of Flight Test – Primarily developmental flight test although significant partnering with industry in the conduct of experimental flight test.
- Areas of Expertise – Expertise in all aircraft areas, uniquely qualified to conduct shipboard flight test.
- Aircraft Types – Fixed Wing, Rotary Wing, Tilt Rotor, Lighter than Air, manned and unmanned, Fighter, Attack, Maritime, Training (all types in the USN/USMC inventory).

2.8.2 Background

NAVAIR is responsible to support the Naval aircraft acquisition for the US Navy and US Marine Corps. The Naval Air Warfare Centers in locations identified in Section 2.8.1, provide the ranges, facilities, infrastructure, personnel, operational and risk management oversight to support the acquisition process. The workforce is comprised of a mixture of uniformed military, government civil service, and contractors. Work to support external customers is also conducted using existing processes.

2.8.3 Regulatory Framework

2.8.3.1 External

US Department of Defense Instruction 5000 series governs the acquisition process for the US military. Some aircraft acquisitions are a combination of DOD and US Federal Aviation Administration policy.

2.8.3.2 Internal

Risk management and safety is integral for the Navy and Marine Corps, and NAVAIR follows that model. NAVAIR policy for flight test risk management is the purview of the Engineering Department. Naval Air Systems Command Instruction (NAVAIRINST) 3960.4C "Project Test Plan Policy for Testing Air Vehicles, Air Vehicle Weapons, and Installed Air Vehicle Systems" provides policy and process for the execution of testing for US Naval aviation.

Within NAVAIR there are two distinct parties in flight test:

1) The military squadron leadership, test pilots and aircrew; and
2) Government service flight test engineering.

A key component of flight testing at NAVAIR is the project officer project engineer team. The Project Officer / Test Pilot brings knowledge of how the fleet uses aircraft and the Flight Test Engineer brings detailed knowledge of how the systems work along with the system integration to form a very effective test team.

This teaming aspect is applied throughout the organization, up to and including senior leadership where the Commanding Officer (CO) or Chief Test Pilot (CTP), depending on risk, and Chief Test Engineer approve the test plans and ensure the spirt and intent of the test plan instruction is followed.

2.8.3.2.1 Flight Test Safety Policy

The Commanders of Naval Test Wing Atlantic and Naval Test Wing Pacific and their subordinate squadron commanding officers are directly responsible for the safe and efficient operation of test aircraft in support of Integrated Program Teams (IPTs), External Directed Teams (EDTs) and Integrated Test Teams (ITTs). The Commanders, Naval Air Warfare Center (NAWC) Aircraft Division and Commander, Naval Air Warfare Center Weapons Division are responsible for the safe and efficient operation of their laboratories, test facilities and ranges during the test execution. Risk acceptance is the responsibility Test Squadron COs for flight and ground tests of aircraft and the NAWC Commanders for tests in their laboratories, test facilities, targets, and ranges. Likewise, the Director, Flight Test Engineering is responsible for ensuring test teams are staffed with trained personnel qualified for developing plans to gather the required data safely and efficiently. These are serious responsibilities, and for this reason, the responsibility for test plan approval covered by NAVAIRINST 3960.4 rests with the Test Squadron CO; Chief Test Engineers; and NAWC Commanders for Ranges, Labs and Targets. However, there is also a responsibility for them to assess the risk of each test program and to delegate approval authority for the test plan in question to the lowest practical level in their chain of command, commensurate with the risk involved. Delegation of authority does not connote delegation of responsibility. Therefore, the responsible senior individuals have an obligation to ensure their subordinates receive the training, experience, and leadership to successfully exercise their increased authority.

2.8.3.2.2 Flight Test Safety Management System

NAVAIR flight test risk management is the ultimately the responsibility of the Test and Experimentation Coordination Team (TECT).

2.8.4 Organization and People

Flight test risk management occurs at two levels within each squadron. There is an aviation safety department and the Test and Experimentation Coordination Team (TECT) who are responsible for flight test and flight test risk management. Test squadron Safety Officers must ensure review of all test plans for ground and flight safety issues, verify key safety considerations are addressed in the overall test approach, and operating procedures are in compliance with safety instructions and standard operating procedures. The TECT is comprised of a Test Squadron Commanding Officers, Chief Test Pilot (CTP) assigned to the squadron, and a Chief Test Engineers assigned by the Directors of Flight Test Engineering. The TECT is responsible for the safe, effective and efficient conduct of flight test for the squadron and test plan approval.

2.8.5 Process and Procedure

NAVAIR test planning process governed by the NAVAIRINST 3960.4C is applied on several levels. The TECT approval on a test plan is the formal acceptance by the NAVAIR that the test risk is at an appropriate level and the appropriate risk mitigations are in place. There are three sections in NAVAIR test plans specifically addressing flight test safety risk, risk management, test hazard analysis, and the safety checklist. NAVAIR also uses the "No Vote" as a safety tool that is embraced throughout the organization. Additionally, Go-No-Go criteria are required in the test plan.

2.8.6 Facilities and Tools

2.8.6.1 NAVAIR Risk Management

The risk management section of a NAVAIR test plan is defined in NAVAIR Test Planning Handbook and is as follows.

2.8.6.1.1 Risk Management from NAVAIR Test Planning Handbook

Throughout the test plan, reference will be made to terms like safety, systems safety, hazards, risk, and risk management. The following provides definitions and clarification of these terms:

a) Safety is the practice of risk management and the avoidance of hazards, in accomplishing a task, in order to avoid injury, damage, or loss of resources or system availability.

b) Systems safety is the effort to make events as safe as practical by systematically using engineering and management tools to identify, analyze, and control hazards.

c) Hazards are conditions that are a prerequisite to a mishap.

d) Risk is an expression of possible loss in terms of hazard severity and hazard probability.

e) Risk management is the application of numerical ratings or value judgement to the weighing of risks against the controls necessary to minimize these risks.

f) Environmental analysis is the documentation process required to ensure the environment is considered in the planning process and life cycle of a program or project. Such analysis includes disclosure of potential environmental consequences of a proposed test project, evaluation of alternatives, and disclosure of practices implemented to offset any potential impacts.

g) The Range Safety Criteria for Unmanned Air Vehicles (UAV) Rational and Methodology Supplement, Range Commanders Council Document 323-99 will be utilized to minimize risk for all R&D UAV flights. Appendix B of this document provides "Range Safety Review questions for UAV projects" which must be answered to minimize risk and will help develop a level of confidence in order to grant authorization to fly the vehicle on a NAVAIR range.

2.8.6.1.2 Safety Checklist

The safety checklist presented in Section 2.8.8.3 will be included in all NAVAIR test plans. The checklist is designed to stimulate the thinking process of all test team members so that the risks associated with all types of test operations can be materially reduced. Additional questions should be added to this checklist to cover items that are not properly covered by the required questions. All questions on the safety checklist may be modified to accommodate unique ground testing requirements. The safety checklist is not applicable for simulator evaluations.

2.8.6.1.3 Test Hazard Analysis (THA)

Systems safety concepts and tools should be used to provide the systematic engineering and analysis necessary to identify, analyze, and control hazards. Preliminary hazard analysis, fault trees, and failure modes and effects analysis should be used where applicable. The THA, included as appendix, shall be prepared for any test which has equipment or procedures not detailed in the aircraft's current Naval Aviation Training Procedures

Standardization (NATOPS) or Naval Aviation Technical Information Products (NATIP). The THA shall address those hazards which are directly associated with the testing (test-specific). "Generic" hazards associated with normal operation of the aircraft or test equipment should not be included.

2.8.6.1.4 Firebreaks

Frequently, testing involves the actuation of weapons release controls either in a simulated launch condition or during actual releases. Firebreaks instruction or local ordnance instructions were developed to ensure an inadvertent release of the store under test or other loaded stores do not occur. These instructions are very specific about which weapons release actuations are allowed under which conditions. For all tests involving the actuation of weapons release controls, either during a simulated or actual release, a statement regarding adherence to the local Firebreaks instruction shall be made. Tests which do not adhere to Firebreaks requirements shall be specifically addressed with risk mitigation measures discussed.

2.8.6.1.5 Hazard Pattern

Describe the weapon footprint/hazard pattern, if applicable. Detailed hazard patterns may be included and list individuals and agencies that provided the analysis. Hazard patterns may be omitted from a test plan if planned to be formally reviewed as part of a firing readiness review established by the test plan. Describe any aircraft-specific hazard areas such as those associated with engine exhaust or RF emissions which could cause injury to personnel. Detailed diagrams or tables defining hazard areas should be included.

2.8.6.1.6 Environmental Analysis

The potential for environmental impact associated with test projects shall be considered during the early phase of test plan development.

2.8.6.1.7 Risk Category

State all risk categories, as determined by the Test Hazard Analysis to be encountered during testing and address how they are identified within the test plan. For example: "This test plan includes Cat A/B/C testing (defined in Table 2-8.2 below). Cat C testing will only be performed during the store separation work conducted with initial Mk 102 releases. Cat B testing will be conducted during live warhead weapon delivery accuracy testing, with all remaining tests to be Cat A. The test matrix identifies the associated risk category for each test event."

2.8.6.1.8 Real-Time Data Monitoring

Real-time data monitoring is a valuable tool that can improve flight test safety and efficiency, especially when proper coordination between the aircrew and personnel in the ground station is accomplished. For all SOF and SOT parameters identify who (by Name or Function) is assigned to monitor what (may be identified on the list of SOT/SOF/AC parameters). Describe data management techniques to detect adverse trends in these parameters. Describe what action will be taken, when and by whom, in order to stop adverse trends. Examples include:

- *"A cross plot of damping ratio versus airspeed will be utilised to detect an adverse trend in airplane response to control inputs during flutter tests. The result from each test point will be plotted to determine if the subsequent test point will follow predicted trends and remain within acceptable damping limits."*
- *"Manoeuvres will be terminated in the event of any Flight Control System (FCS) caution, loss of telemetry data or SOF parameter, loss of radio communications, or by the decision of the engineers at the ground station or pilot. If telemetry or radio communications cannot be reestablished, the test*

will be aborted, and the airplane will Return To Base (RTB) as soon as practical. Maneuver termination will be briefed." "For any non-emergency termination of manoeuvres, engineers at Real-Time Processing System (RTPS) will call "KNOCK IT OFF." This usually applies to loss of Telemetry (TM) or approaching test limits (Angle of Attack (AOA), Angle of Side Slip (AOSS), etc.). If emergency termination of the maneuver is required or if the airplane appears to be out of control, engineers at RTPS will call, "ABORT, ABORT, ABORT," and give altitude calls in 5,000 ft increments until 10,000 ft Mean Sea Level (MSL) and in 1,000 ft increments below 10,000 ft MSL."

2.8.6.1.9 Additional Special Precautions

List any additional special precautions or risk management requirements of the test team or test equipment. Include any specific RF spectrum use precautions or conflict mitigations. Additional RF spectrum use documentation such as detailed Frequency Use Plans should be attached.

2.8.6.2 Test Hazard Analysis (THA)

The NAVAIR THA process is defined in the NAVAIR Test Planning Handbook and included here.

2.8.6.2.1 Purpose

The Test Hazard Analysis (THA) is the primary tool for determining the risk associated with the conduct of a project. The THA process is designed to clearly identify and minimize existing and potential hazards inherent in the test planning and execution process.

2.8.6.2.2 Background

The THA is an essential part of the overall risk management process to identify and mitigate hazards unique to the planned test. Risk may be defined as "an expression of possible loss in terms of mishap severity and mishap probability." It is useful to expand somewhat on this definition of risk. Loss is measured in lives, dollars, equipment, and mission capability. Risk assessment, therefore, involves determining the hazard involved, predicting resulting frequency of occurrence, assessing severity or consequences, determining exposure, and identifying action to avoid or minimize the risk. The THA is required to discuss potentially hazardous conditions created by testing the item in question. When defining potential hazards, consideration should be given to the specific test item, the test maneuvers and flight conditions planned, and the environment in which the test will be conducted. Ensure that workload during critical flight maneuvers is taken into consideration when determining risk category.

2.8.6.2.3 Process

The following outline provides the desired information, which should be incorporated in the THA. The tabular presentation of the THA (example in the following pages) is the preferred format. Different formats are acceptable, with prior approval of the TECT, but all of the below elements must be included. Test teams shall use the THA as a risk management tool during the conduct of the test, to include reviewing the THA during pre-test briefings:

Step 1: Identify the hazards associated with the test. Some methods to identify potential hazards include test team discussions, conducting fault tree analysis, reviewing historical data, and reviewing hazard analysis and flight test lessons learned databases maintained by US Navy, US Air Force, and Society of Experimental Test Pilots.

Step 2: Identify the root cause(s) and their associated effect(s). The root cause is anything that could lead to the presence of the hazard identified in step 1. What is the root cause of the hazard? What is the effect of the hazard being uncontrolled? What aircraft system and subsystem failure modes can be identified?

Step 3: Identify precautionary measures available/required to eliminate or control the identified hazards. The precautionary measures attempt to break the chain of events linking the causes to the hazard. The precautionary measure should reference the specific cause being controlled. If the precautionary measure cannot be tied to a specific cause, it is possible that another cause needs to be identified. If the failure mode cannot be eliminated, what special precautions, emergencies and emergency procedures are anticipated? What can be done to reduce the probability of the hazard occurring, or the severity of the outcome?

Step 4: Identify corrective action. The corrective action attempts to break the chain of events linking the hazard to the mishap. This step is the list of actions to take to prevent a mishap if the hazard occurs. The list should cover the control room, ground personnel, flight crew and anyone else for with the situation calls. What agencies/personnel are available to assist in hazard control and mitigation, if applicable, both pre-flight and during the flight to minimize the impact of the hazard once encountered? Have assignments been made to ensure everyone understands their role during the test once a hazardous situation develops? Have appropriate individual qualifications been identified and assessed to ensure everyone can fulfil their roles and responsibilities? Are procedures in place to ensure personal qualifications?

Step 5: Classify residual hazard severity and probability. Considering the application of precautionary measures and assuming corrective action identified was appropriately applied during the test event, classify the residual hazard severity and probability following the Hazard Level Guide presented in Table 2-8.1 and Table 2-8.2.

Step 6: Determine risk category. After defining the hazard level, determine the risk category of the test event/flight profile following the classification in the Risk Category Matrix in Table 2-8.2.

Table 2-8.1: Test Hazard Level and Probability.

Hazard Severity		
Hazard Level	**Severity**	**Definition**
I	**Catastrophic**	May cause death or aircraft/system loss.
II	**Critical**	May cause severe injury or major aircraft/system damage.
III	**Marginal**	May cause injury or minor aircraft/system damage.
IV	**Negligible**	Will not result in injury or aircraft/system damage.
Hazard Probability		
Hazard	**Probability**	**Definition**
A	**Frequent**	Likely to occur immediately, or during an individual test event.
B	**Probable**	Probably will occur during this evaluation.
C	**Occasional**	May occur during this evaluation.
D	**Remote**	Unlikely to occur during this evaluation.

Note: Loss of a Group 1 – 3 UAV does not necessarily constitute a catastrophic event. Severity of loss of a Group 1 – 3 UAV shall be based on UAV cost and potential for injury.

Table 2-8.2: Risk Category Matrix.

Hazard Probability	**I**	**II**	**III**	**IV**
	Catastrophic	Critical	Marginal	Negligible
A – Frequent	UA3	UA3	Category C4	Category B5
B – Probable	UA3	Category C4	Category C4	Category A6
C – Occasional	Note 1	Category C4	Category B5	Category A6
D – Remote	Note 2	Note 2	Category A6	Category A6

Notes:

1) For test results with a residual risk assessment of I/C, discussions with the TECT will be required prior to proceeding with the test program under development.
2) For assessments that result in I/D or II/D, coordination with the TECT (prior to an ERB) will determine assignment of Category A, B, or C testing classification.
3) Unacceptable Risk (UA) means that the project is considered too high risk to proceed with testing.
4) Test Category C: Test or activities which present a significant risk to personnel, equipment, or property even after all precautionary measures and corrective actions would be taken.
5) Test Category B: Test or activities which present a greater risk to personnel, equipment, or property than normal operations.
6) Test Category A: Test or activities which present no greater risk than normal operations.

Step 7: Assign the test plan risk category(s). A description of risk categories, (Exhibit 1), examples of possible test risk categories (Exhibit 2) are presented on the following pages.

Exhibit 1: Description of Risk Categories

2.8.6.2.4 Project Risk Categories

The THA is the primary tool for determining the risk associated with the conduct of a project. The test hazards included in the THA are only those hazards that are specifically introduced by the nature of the testing. When a hazard is discussed, there is an associated severity and probability that defines the risk of a defined hazard. After precautionary measures and corrective actions are defined, there should be a level or risk that is less than the original risk. The risk which remains after all precautionary measures and corrective actions have been implemented is termed residual risk. Summarization of residual risk will be used to determine the category of the test plan. For example:

Category A – Low

Category B – Medium

Category C – High

The Risk Category Matrix shall be used to make the final assessment of the appropriate project risk category. Category D will encompass all ground and flight tests of prototype/pre-production aircraft and will not be determined by the Risk Category Matrix. Empowerment for test plan approval includes the responsibility for determining project category.

Exhibit 2 -Examples of Project Risk Categories

CATEGORY A: Ground tests or project flights not involving potential or known hazardous operations. This includes flights within the NATOPS flight envelope not involving testing of critical safety of flight components.

Examples include:

- Antenna patterns (specific category can be A/C dependent).
- Ordnance lot testing.
- Cruise performance tests.
- Pace flight at altitude with non-critical avionics.
- Generally, most ground and laboratory tests.
- Sensor evaluation (not including night vision devices).
- Inert Missile Functional Carriage Tests.
- Government Lot Acceptance Tests (GLAT).

CATEGORY B: Ground tests or project flights involving potentially hazardous operations.

Examples include:

- Automatic Carrier Landing Systems – Shipboard.
- Engine Stall Susceptibility.
- Stores Separation of non-standard or modified stores.
- Air Start Envelope Definition – Multi-engine.
- Accelerated Service Testing.
- Engine Component Improvement.
- Engine-Out Testing: One engine on three- or four-engine aircraft.
- Catapult and Arresting Gear Certification.
- Mission software not yet flown that could affect flight-related displays.
- Navigation/bombing accuracy.
- Tower fly-by tests.
- Air Combat Maneuvering (ACM).
- Night Bombing Test.
- Captive carry of live stores.
- Engine performance.
- Countermeasures towing of untested stores.
- Decoy Flare Lot Acceptance flight tests.
- Initial Instrument Meteorological Conditions (IMC).
- Safety of Flight (SOF) software checks.
- Lab tests that intentionally induce faults on power lines.

CATEGORY C: Ground test or project flights involving known hazardous operations.

Examples include:

- Flutter Testing.
- First flight of new/modified aircraft configuration.
- Aborted takeoffs.
- Ground and air minimum control speed determination.
- Spins.
- High Angle of Attack Evaluations.
- Air Start Envelope Definition – Single Engine.
- Minimum End-speed Catapult Shots.
- Carrier Suitability Structural Testing.
- Helicopter/Ship Dynamic Interface Testing.
- Envelope Expansion.
- Full Autorotation.
- Flight Control Software.
- Stores separation for envelope definition or expansion.
- Hazardous stores jettison tests.
- Missile gas ingestion engine tests.

CATEGORY D: Ground tests on, or all flights in, prototype aircraft including all pre-production aircraft and any other aircraft whose unique configuration or value warrants CATEGORY D designation by the Directors, Flight Test Engineering and Test Wing Commanders.

Note: AIRCREW QUALIFICATION: Due to the hazards involved with certain project flights and the increased level of aircrew experience required to safely conduct certain flight test projects, flights have been divided into categories. Aircrew minimum qualification and currency required for each category are defined in wing and squadron Standard Operating Procedures (SOP). TECT shall ensure, with the assistance of the squadron's operations officer, that the minimum aircrew qualifications specified are met for the type category of test to be conducted.

2.8.6.3 The NAVAIR Safety Checklist

The NAVAIR Test Planning Guide also includes a Safety Checklist which is required in all test plans.

2.8.6.3.1 Purpose

A Safety Checklist is required for all test plans. The purpose of the checklist is to stimulate thought in the area of safety and to ensure no critical aspects of test planning are omitted.

2.8.6.3.2 Background

Most of the questions in the Safety Checklist result from lessons learned from past mishaps in the RDT&E community. Flight test organizations external to NAVAIR that have their own safety assessment may submit them to TECT for review. If deemed adequate, the TECT may accept these documents in lieu of the NAVAIR Safety Checklist.

2.8.6.3.3 Scope

The Safety Checklist should be included as an appendix to the test plan, and the questions may be answered either in the checklist or in the test plan body. If the question is covered in the main body of the test plan, the applicable section or paragraph number should be placed in the "Response" column. If the question is answered in the Response column in the checklist, the answer should be brief and to the point, and may include a one-word response such as "no", as long as the question is comprehensibly answered. Questions requiring detailed answers should generally be included in the test plan body and only referenced in the checklist to ensure maximum clarity of the test plan. Do not be redundant by answering the question in both places. If the question does not apply, indicate in the "Response" column. There should not be any blank responses boxes in the completed checklist.

2.8.6.3.4 Contents

The Safety Checklist is broken out into five sections:

1) General;
2) Ground, EMC, and Anechoic Chamber Tests;
3) Ordnance, Stores, or Expendables Tests;
4) Airborne Tests; and
5) UAS Tests.

The general section addresses common concerns and must be included in all test plans. The remaining sections address specific types of testing. For test plans including "Ground, EMC, and Anechoic Chamber", "Ordnance, Stores, or Expendables", "Airborne" or "UAS" testing, only those applicable sections of the Safety Checklist must be included. Any changes to the Test Plan require a review of the Safety Checklist. The safety checklist is presented in Table 2-8.3.

Table 2-8.3: Safety Checklist.

No.	Question	Response
GENERAL		
1	Does this test have a high degree of residual risk which should be called to leadership attention through special notification?	
2	Has an offsite briefing/Letter of Instruction (LOI) for flight operations away from home base been generated?	
3	If any items under test are Contractor Furnished Equipment (CFE), has a pre-mishap plan been identified for these items?	
4	If a unique pre-mishap plan is required for non-NAVAIR agencies, who is responsible for executing it?	
5	Will any test maneuvers or test procedures require a waiver to NATOPS, FAA Regulations, local aircraft Standard Operating Procedures or maintenance procedures and have waivers been requested and approved?	
6	Have any external notification requirements, such as Notice to Airmen/Mariners, FAA, FCC coordination, etc. been identified and completed?	

No.	Question	Response
7	Are there any hazards to ground personnel (e.g., Hazard of Electromagnetic Radiation to Personnel/Ordnance (HERP/HERO)) or possible damage to equipment that require changes or special precautions to normal maintenance and/or ground handling procedures?	
8	If operating away from home base does your test or test article require any special notification or briefings of the host facility support? (e.g., unique crash and rescue procedures).	
9	What background material was reviewed? (e.g., contractor reports, previous T&E reports, or other agencies published reports on similar aircraft or equipment, discussion with contractor pilots, Naval Safety Center Data).	
10	What other agencies were contacted that have conducted similar tests, both military and civilian, so that benefit can be realized from consideration of their standard procedures and lessons learned?	
11	Are any additions to existing NATOPS emergency procedures required as a result of test modifications and/or possible malfunctions of test equipment and have they been identified?	
12	Were any special instrumentation or precaution notifications generated?	
13	Does removal/installation of project equipment constitute Functional Check Flight (FCF)/Safety of Flight Test (SOFT) criteria?	
14	Are any safety devices or interlocks bypassed or overridden during tests, and if so, what additional hazards are involved and what steps will be taken to reduce the risks?	
15	Do test instrumentation systems under any conditions prevent the normal operation of the aircraft systems (including UAV command uplink, downlink, autopilot or other critical systems)? Are instrumentation controls easily identified and conveniently placed?	
16	What ground, simulation or built-in tests are required to assess proper operation of project and/or emergency equipment unique to the test aircraft?	
17	What special additional aircrew, operator, engineer, or test team training is required and how will that training be achieved?	
18	Will any test maneuvers/test points require changes or adjustments to standard crew coordination, communication duties? Has training been conducted to address these changes?	
19	Under what circumstances will normal or emergency control transfers be required during test flights? Have test-specific control transfer criteria and any communication, switchology, operator actions which differ from standard procedures been outlined?	
20	What build-up is planned for high risk/pilot workload data points?	
21	Should project flight crewmembers and/or test team preview high risk/workload data points and compound emergency procedures in a flight simulator, laboratory environment or surrogate aircraft? (e.g., surrogate UAV or spin training aircraft).	
22	Has coordination with the local frequency coordination office been completed for any RF sources associated with this project?	

No.	Question	Response
23	Will testing involve the activation of any LASER equipment?	
	GROUND, EMC, AND ANECHOIC CHAMBER TESTS	
24	Will any peculiar support equipment or utilities be required (e.g., special cooling adapters, coolant oil, radar deflectors, power to pods, air data calibration systems, crypto equipment/keys, etc.) on the ground or inside the chamber?	
25	Will electrical aircraft systems be operated or energized during ground, EMC, or chamber testing?	
26	Will hydraulic aircraft systems be operated or energized during ground, EMC, or chamber testing?	
27	Will pneumatic aircraft systems be operated or energized during ground, EMC, or chamber testing?	
28	Will the aircraft be suspended from an overhead hoist or on jacks? If so, have slings and aircraft lift points been certified, has a stress analysis been completed, and have hard-points been inspected?	
29	Will any panels have to be removed during the time in the chamber that could impact EMC?	
30	Has a detailed stress analysis been completed if any stress panels are opened or removed while the aircraft is in the chamber and/or suspended?	
31	Will the transmitted power output exceed approved power density at any surface while in the chamber?	
32	Have permissible exposure limits been calculated and hazard zones (RF, jet wash, noise, heat, etc.) been established for both aircraft and test instrumentation systems?	
33	Will chamber test require simulated closed-loop and/or radiated test signals?	
34	Will the test require personnel and/or equipment to be positioned inside the test facility, ground test area and/or instrumentation pit?	
	ORDNANCE, STORES, OR EXPENDABLES TESTS	
35	Will any non-standard stores be required during ground, flight or anechoic chamber testing?	
36	Have range safety and explosive safety approvals, if required, been received?	
37	Do NAVAIR approved loading checklists exist for each store type? For non-NATOPS/NATIP loads, have stores loading checklists been developed by the project and approved by the appropriate authority?	
38	If stores are to be carried, will CADS be loaded? What procedures have been implemented to ensure the desired CAD configuration is loaded?	
39	Have stores with guidance systems been disabled as required?	
40	Are any special procedures required (other than normal loading or release checklist adherence) to guard against in-flight loss of ordnance or aircraft equipment? In the	

No.	Question	Response
	event of an inadvertent loss of the test equipment or item, are any special procedures or contingency plans required to safeguard personnel or property?	
41	If non-NATOPS/ NATIP stores loadings are to be carried, has an AIR-4.0P approved flight clearance been approved for those stores? Have the Aircraft Discrepancy Books (ADB) in Maintenance Control been placarded accordingly?	
42	Are special hung/unexpended ordnance procedures required?	
	AIRBORNE TESTS	
43	What airworthiness certification process was used?	
44	For local operations using non-resident aircrew, operators, will a course rules briefing be conducted?	
45	Does internal/external instrumentation change the aircraft operating envelope?	
46	Has a pre-maneuver checklist been generated for high Angle of Attack tests, blade stall tests, or flight within critical areas of the height-velocity diagram?	
47	If control of the vehicle is lost during the course of the test, what precautions have been taken to ensure that the vehicle does not cause injury to personnel or damage to property on the ground?	
48	If the air vehicle is equipped with a safety/recovery parachute or flight termination system, have control methods and criteria for actuation been completely described?	
49	For chase aircraft, have chase procedures/responsibilities been defined? Have chase danger/no fly areas been identified? (See Appendix 2.8.9).	
50	Have specific weather minimums including chase, that are consistent with test objectives, been established for both the terminal area and the operational area?	
	UAS TESTS	
51	In the case of air vehicle loss-of-link, what are the procedures to regain the link?	
52	In the case of air vehicle /GCS loss-of-link, what is the air vehicle programmed to do during the loss of link period? (e.g., if the air vehicle has a preprogrammed or “return home” function, what program/waypoints/holding point will be programmed?).	
53	What is the system response to loss of communication, navigation, and/or control (including loss of flight reference data)?	
54	What is the air vehicle response to loss of propulsion?	
55	Has a link analysis been conducted for both primary and back-up command and control transmitters?	
56	What is the system response when switching to back-up power or a failure of the GCS?	
57	Does the UAS system have a flight termination or recovery system? What are the activation criteria?	
58	How will the UAS system design and /or operational procedures / restrictions minimize the potential for mid-air collisions with other aircraft? (i.e., sense and avoid design features, exclusive use airspace required, etc.)	

No.	Question	Response
59	Do any test maneuvers/test points occur while the air vehicle is undergoing changes in state? If so, could latency in the sending or receipt of commands to the air vehicle result in those commands being executed in an undesired state?	

2.8.6.4 No Vote

If anyone with information, understanding or a belief that conditions exist that could lead to injury or equipment damage are obligated to exercise their "No Vote" at any point during test planning or test execution. Once leadership receives a "No Vote" they are obligated to respond with mitigation or information that addresses the "No Vote". In addition, there are four broad classes of issues or challenges within NAVAIR and who the responsible party for resolution is, depends on the context of the question being raised. These classes of challenges are discussed in the following paragraphs.

2.8.6.4.1 Issues with System Under Test (SUT)

Issues that arise with a system that is undergoing test should be promptly communicated up to the Government Flight Test Director (GFTD) and Lead Test Engineer (LTE). On the technical side, the appropriate TECT should be informed if SUT issues impact or inhibit the flow of testing that has been agreed to in the test plan. The appropriate Flight Test Divisions should be informed of technical issues as they arise.

2.8.6.4.2 Issues with Aircraft Operations

Issues with aircraft operation should be promptly communicated up the squadron chain of command to the Chief Test Pilot (CTP) and Commanding Officer (CO) since this is clearly a command responsibility. The CTE should be kept informed of these issues and the Assistant Program Manager for Test and Evaluation (APM (T&E)) should be informed if issues impact the planned pace of testing.

2.8.6.4.3 Issues with Test Tempo and Build-up

Issues with test tempo and build-up should be communicated up through the appropriate TECT, LTE, and GFTD. The pace of test and flight test engineering judgement are the purview of the TECT as the responsible parties for test plan approval and execution. Note that invoking the TECT implies both technical competency and squadron components.

2.8.6.4.4 Issues with Test Team Composition and Staffing

Issues with flight test engineers, flight test aircrew, test team composition, or staffing levels should be communicated up through the respective Branch/Division Head or Squadron leadership as appropriate. The TECT should be informed if staffing is not aligned with the Test Planning Introduction Document (TPID) or Project Planning Memorandum (PPM).

2.8.6.5 Go-NoGo Criteria

"Go-NoGo" for Test Evolutions. These are preplanned tripwires that terminate the evolution when met. "Go-NoGo" criteria are not flexible and should be identified during the risk analysis planning portion for any test where there is a significant hazard of damaging personnel or property.

2.8.6.6 Training

The flight testers at NAVAIR are trained several ways that provide a focus on flight test safety. The test pilots are training at a recognized military test pilot school, most commonly, the US Naval Test Pilot School (USNTPS) at Patuxent River, Maryland, USA. The Flight Test Engineers receive training through the College of Test and Evaluation (part of NAVAIR University), USNTPS, and on the job training.

2.8.7 Discussion and Observations

Higher risk test category (B and C) test plans are vetted through an Executive Review Board (ERB) process. The ERB is chaired by the TECT and offers a venue to assess if the test plan is ready for approval. Senior FTEs, test team leadership, first level supervisors, and squadron safety along with project officer (test pilot) and project engineer (FTE) attend the ERB. Concurrence from the senior FTEs, test team leadership, and the first level FTE supervisor is required before the ERB is held. The ERB is a page-by-page walk through of the test plan to make sure the approvers understand the test.

2.8.8 Conclusion and Recommendations

NAVAIR's flight test safety is process driven and relies on teaming between test pilots and flight test engineers at all levels. Test plan approval is managed at the test squadron level through the TECT. This construct means the test plan approvers detailed knowledge of the test aircraft and test techniques added to safe, effective, and efficient test.

2.8.9 Appendix

2.8.9.1 Use of Chase Aircraft for US Naval Aviation Flight Test

For manned aircraft, safety chase aircraft are required for all high risk test flights, prototype aircraft flight test flights and medium risk single engine test flights conducted in distant offshore areas. Regarding waivers to these requirements, consideration is given to relevant aircraft modifications, the nature of the test, prior policies for similar flight operations, and the redundancy of chase advantages with the use of available real-time telemetry coverage. Waivers by appropriate authority are permitted based on an operational risk analysis of all pertinent factors such as, shipboard testing with organic SAR assets or weapons separation testing with ground based camera coverage.

Chase aircraft requirement for Unmanned Aerial Systems (UAS) is determined by an appropriate authority in consideration of, but not limited to, the following:

- UAS maturity and reliability,
- UAS operator situational awareness, and
- UAS capability to integrate into the see and avoid environment including the visual detection of the air vehicle from other aircraft.

A chase aircraft provides essential risk mitigation for high risk test missions as an additional cockpit resource enhancing the test pilot's situational awareness (SA). High risk test points are often very high workload maneuvers that saturate the test pilot's ability to maintain SA outside of his aircraft. Additionally, many test aircraft used to conduct high risk test points are prototype or pre-production aircraft with limited mission systems (e.g., radar, position displays) available to the test pilot for SA. The safety chase pilot enhances the test pilot's SA in the following areas:

- Traffic deconfliction
- Airspace management
- Monitoring test aircraft flight parameters

Test safety increases during tanker operations by pre-checking the tanker's refueling system prior to engagement by the test aircraft. Test aircraft are often configured with a flight test noseboom that significantly increases the risk of in-flight refueling. Ensuring the proper operation of the drogue by the chase aircraft minimizes the risk of damage to a potentially one-of-a-kind test asset.

A chase aircraft in close proximity to the test aircraft permits real-time monitoring of test aircraft parameters during dynamic testing. The chase aircraft relays radio transmissions from the control room that are missed by the test aircraft antenna positioning during dynamic maneuvers. An immediate call to abort the test can make the difference between a mishap and simply having to repeat a test point. Should a mishap occur, the chase pilot is immediately on-station to initiate a rapid search and rescue response.

In addition to the safety enhancements provided by a chase aircraft, test efficiency improves as well. A visual inspection by the chase aircraft provides information not obtainable by the test pilot or the control room through any other means, allowing the test team to make sound risk decisions to continue testing or return to base. During a previous major test program, an estimated 10 – 15 % of all high risk test sorties required a safety chase visual inspection during the flight. Examples include:

- Detection of deformed or missing panels.
- Detection of missing telemetry antennas and towed decoys.
- Detection of missing weapons fins and loose arming wires.

In order for the safety chase to provide the maximum effectiveness, it must be able to maintain close proximity to the test aircraft and have sensors to increase SA. High-performance chase aircraft provide the following advantages:

- Provides the optimum balance of performance and maneuverability characteristics to enable precision and accuracy during demanding chase missions across the envelope of nearly all tactical aircraft operating regions (for example, low speed to supersonic, low to high altitude, and less than zero-g up to high normal acceleration (Nz)).
- Allows extended on-station time to improve efficiency through in-flight refueling and external fuel tanks configurations.
- On-board sensor capability allows range clearance, airspace monitoring, and other test- unique target requirements through organic on-board sensors.
- Provides the capability to carry a variety of external stores such as the airborne refueling store, Telemetry (TM) and Time Space and Position Information (TSPI) relay pods, and unique test measurement equipment such as capability for in-flight infrared measurement.
- Provides the necessary performance and maneuverability to permit close aboard collection of photogrammetric data for myriad test points such, weapons carriage and release, airflow visualization, and in-flight vibrations.

Using organic test pilots to chase test flights brings the collective capability of the test team to a level that would likely be unachievable with external chase assets. Chase pilot qualification in the test aircraft is the ideal situation, but not required. Familiarity with the test aircraft provides enhanced SA and improves the chase pilot's ability to assist the test pilot. Additionally, the experience gained as a chase pilot augments that pilot's competence during subsequent missions as the test pilot. Finally, chase missions provide a necessary means to keep pilot's aviation skills sharp.

Chapter 3 – OBSERVATIONS AND DISCUSSION

3.1 HIGHER LEVEL REQUIREMENTS

3.1.1 Overview

Every Flight Test Quality Management System must not only satisfy the internal requirements of the Host Organisation and the Specific Project but also the external requirements placed by International/National Standards and International/National Regulatory Requirements. For any Aerospace Organisation there are many standards and requirements that must be satisfied in order to certify and qualify a product and to trade successfully.

In the area of Flight Test Safety, the Case Studies give examples of the specific practices adopted by the contributing organisations. There is no standard model and each organisation has put in place a system that satisfies the requirements of the local regulatory regime. Anyone endeavouring to put in place a new system must therefore carefully study their local requirements and establish the system in conjunction with the Regulator. It is the Regulator who will grant the final approval.

Special care must be taken on International Projects where the requirements of several different National Regulatory Regimes may need to be satisfied.

3.1.2 International

There are no internationally recognised standards that universally govern flight test safety. Neither are there any prospects of there being any.

In the Civil Domain both FAA and EASA are recognised certifying authorities representing the US and Europe respectively and offer codes that are widely used across The World. Both codes are utilised internationally and do have elements governing the safe flight testing of the product. A number of the Case Studies describe compliance with both FAA and EASA requirements.

In the Military Domain there are no similar internationally recognised codes. There is a move for a common Military Airworthiness Approach in Europe which would cover flight test in a similar manner to EASA but at the time of writing, 2019, this is regarded as some way off.

There are internationally recognised standards that apply to Quality Management Systems and Safety Management, e.g., ISO 9000, that will drive how the associated Quality Management System is put together and for Health and Safety Management ISO 45001 but these are more about quality system content, development and assurance. Flight Test Safety becomes an element covered but is not specifically identified. All of the Case Studies describe ISO 9000 compliant systems.

3.1.3 National

The majority of the Case Studies describe Safety Management Systems that have been designed to be compliant with National Military Requirements, the exceptions being the Research Establishments, NASA and NLR. Again, there is no universally recognised approach but there are significant similarities in the responses described in the Case Studies.

So, whilst there is no common requirement there appears to be a shared generic approach across the organisations represented. Hence in developing a new system there is practice which can inform the system developer of elements that be incorporated to satisfy the Local Regulator. For the US MIL Standard 882 the US DoD Standard Practice for System Safety describes the generic approach to be taken.

3.1.4 Safety Policy

The starting point for the design of a Safety Management System that satisfies these higher level requirements is a Statement of Safety Policy. This describes the safety commitments of the organisation in simple terms such that all members of the organisation understand how safety will be achieved. It is the umbrella under which Procedures, Practices, Facilities, Tools, Staff Development and Approval are undertaken.

The Case Studies identify a number of different approaches. That offered by NLR is judged to be particularly complete and is recommended.

- It is a standalone document that can easily be placed where it can be seen.
- It is signed and endorsed by Senior Management.
- It declares in simple terms:
    - NLR's higher level key safety statement;
    - The responsibility of the Accountable Manager; and
    - The Organisation's commitments and principles in relation to delivering Flight Test Safety.

3.1.5 Internal

Each of the Case Studies describes a Flight Test Safety Management System that has been designed to satisfy the specific Higher Level Requirements and the Safety Policy pertinent to that organisation and produced in accordance with the Quality Management Standards of the organisation. Each is therefore bespoke and specific to the particular organisation. Despite this there is significant commonality at the higher level in the systems described despite their diverse national and domain origins. Each differs in detail but the basic approaches appear consistent.

3.1.6 Project

None of the Case Studies refer to Project Specific approaches. Indeed, a number go so far as to state that a common approach will be adopted across all projects in order to enhance safety through the use of the same processes, tools and facilities. This is highly recommended.

3.2 PEOPLE

3.2.1 Introduction

The most significant elements in any Flight Test Activity are the individuals who deliver the programme and ensure that the flight testing is planned and executed in a safe and effective way. Each of the Case Studies to a greater or lesser degree recognises this and provides detail of the specific approaches of the various organisations. A number of themes emerge as do different approaches to satisfying resulting emergent requirements. Above all things it is the way in which these individuals operate within the organisation and against its processes that establishes the approach to safety through the organisation's Safety Culture. Without an embedded high level Safety Culture which survives under adverse pressures and influences safe flight testing is highly likely to be seriously compromised. If there are any doubts about this a study of many flight test accidents will clearly demonstrate what can happen when Safety Cultures fail.

3.2.2 Management Responsibility

Management have a responsibility to put in place systems of work supported by competent staff that not only deliver effective flight testing but also safe flight testing. They must balance the demands of progressing the flight test programme to achieve its objectives with the need to deliver the flight testing safely. They, above all others in the team, have the responsibility for resisting those programme pressures that demand too much and begin to compromise safety.

3.2.3 Organisation

The Case Studies all provide an overview of the organisational approaches taken to satisfy the requirement to deliver safe and effective flight testing. They describe the elements of the organisation and the ways in which they come together and interact. For most organisations the elements described comprise:

- Management – Usually led by the Accountable Person.
- Flight Operations – Test Pilots, Aircrew, Airfield Management and Air Traffic Control.
- Flight Test Engineering – Detailed test planning, analysis and reporting.
- Flight Test Instrumentation – Instrumentation design, installation and support.
- Flight Test Data Processing – Real Time and Post Flight data replay and analysis.
- Maintenance Organisation – Aircraft Maintenance and Servicing.

There is not a common model but there are common themes.

Principal amongst these in relation to Flight Test Safety is the way in which the organisation addresses the interactions which are necessary to manage the general flight test process and the test safety management process. Here the elements must naturally work together in a co-operative way with the major interface being between Management, Flight Operations and Flight Test Engineering. All of the Case Studies describe how this is done within the subject organisations.

A number of the Case Studies refer to documents that describe the organisation and how it works, its composition and what roles they undertake. This is recommended, especially in large organisations, as a means of clearly identifying accountability chains and chains of command.

The Flight Test Organisation should have a level of independence from the project that leaves it free to raise safety issues without project interference.

3.2.4 Resourcing

It is the role of Management to ensure that adequate numbers of trained and competent staff are available to deliver the flight test programme. Failure to do this will result in an organisation that is stretched in its ability to deliver. Against this pressure the focus is generally one which concentrates on delivery and the attention drifts away from safety. During estimating and the planning of the resource, safety management requirements must be an embedded element of the calculations. It needs to be planned in at the start to ensure adequate resource. It must never be an afterthought.

3.2.5 Roles and Responsibilities

The Case Studies describe organisations where individuals have clearly identified Job Roles and Responsibilities. Each individual understands where they fit, what they are supposed to do and what their contribution is expected to be. One would expect each role to have a job description which clearly identifies what the job requirements are and this is the basis of competency assessment. Such job descriptions should clearly identify what aspects of the flight test safety process the jobholder is expected to undertake.

3.2.6 Accountable Manager

In recent years, the role of the Accountable Manager has become much more formalised and one expects any deployed Flight Test Safety Management System to clearly identify who the Accountable Manager is for managing Flight Test Safety. This is the individual who has been identified by an appropriate Authority and who is potentially legally responsible in the event of a mishap. Usually it is a Senior Member of the management team. The Case Studies describe the approaches taken which are always driven by the controlling Regulatory Authority and are external to the Flight Test Organisation.

Within the Military Organisations this is generally captured in the Chain of Command and Approvals are granted by the relevant National Military Authority.

For Civil Organisations Approvals are more likely to come from the governing National Airworthiness Authority. FAA, EASA, etc.

3.2.7 Authorised Persons and Approvals

Whilst the appointment of the Accountable Manager is an external issue the appointment of individuals locally to fulfil roles within the Flight Test Organisation is an internal one. Historically this was performed using a judgement by peers approach and was often not captured formally. In recent years this has become much more formalised with a growing requirement to demonstrate that individuals are appropriately qualified and experienced, generally referred to as SQEP, Suitably Qualified and Experienced Persons.

This covers both the operational requirements of the job and the safety involved requirements of the job. These requirements should be clearly described in the job description topped up where necessary with a formal statement of additional specific requirements relating to a particular task.

Management are responsible for ensuring a system is in place that not only captures the requirements of the job but also demonstrates that individuals are competent to satisfy those requirements. This acts as a prompt for training for those undergoing development and as a tool for demonstrating that and individual can be regarded as SQEP. A number of the Case Studies describe the approaches taken.

Supported by this evidence the Accountable Manager is able to grant Approvals to staff who hold significant Safety Responsibilities that are traceable and relate to accepted standards.

3.2.8 Competency

Competency is a measure of someone's ability to perform a task and in the field of flight testing it is essential that the activity is only conducted by competent people who are able to deliver not only effective testing but also safe testing. Within a Flight Test Organisation, you will need people at differing competency levels to deliver the business. It is the role of management to ensure that adequate numbers of staff are available with the right skills.

For the purpose of this assessment we shall use the following. Competency in any field is the summation of:

- Aptitude – an individual's natural ability to do something;
- Education – in a technical subject relevant to the field and at an appropriate level;
- Training – in the specifics of the subject domain on and off the job;
- Experience – of working in the subject domain gaining practical exposure to all its fields; and
- Currency – Exercising the skill set regularly so that it is second nature.

It is generally accepted that it takes 10000 hours to become expert in any field of endeavour. Assuming 1600 effective hours per year on the job this equates to some six years from starting a flight test career to being judged truly competent in one's technical specialism. Management experience typically comes later and is additional to this. Intensive training can accelerate this but that means time away from the workplace gaining experience and flight test is a field where experience counts a great deal. It is in truth a skill which is largely acquired through experience.

In relation to the initial judgement of aptitude this is an outcome of the recruitment process where the interviewer makes a judgement based on perception. The true assessment of aptitude comes on the job and judgement by peers normally suffices to identify those with special aptitude who are likely to develop to higher levels of competency.

Similarly, initial education to technician, engineer or piloting skill level is identified as part of the recruitment process and is a matter of record.

Training is an area where different organisations have varied approaches to developing skills and the responses identify some differences. SAAB is judged unique in establishing an internal training scheme for both pilots and engineers that leads to a recognised qualification level within the company. Other organisations have tended towards training on the job by giving exposure at increasingly more complex levels as the career progresses. This approach is only possible in an organisation which can provide such exposure. With the reduction in the number of active programmes this approach is becoming more difficult as opportunities become fewer. This has caused a number of organisations to challenge this historic approach and to engage in more structured training akin to the SAAB Model. Clearly the ultimate solution could be Test Pilot School training but this can only be a solution for the few because of the costs and therefore is likely to be targeted at candidates who are displaying high levels of aptitude. With the regulatory shift towards qualification routes based on Test Pilot School training as a measure of competence, especially in Europe, this will prove a challenge. There is a view that such training doesn't necessarily make you better but gets you to the end point faster.

Experience comes with time on the job and structured exposure to the different parts of the flight test process. It is the classical way of developing flight test competency. The management team should carefully consider the staff and ensure that they gain appropriate experience targeting this, if necessary, at those with the greatest aptitude who are likely to rise to positions of responsibility.

Currency must be maintained if one is to be effective and especially so if one is to test safely. Where an organisation does not maintain its currency and that of its staff it must seriously consider how it approaches the flight test task. Recognising and accepting a currency gap is becoming an issue in some organisations where workloads are falling and where new products are not passing through the system. In these instances, requalification of the team and the individuals is required when a tasking that has not been performed recently arises. Revalidation of currency may be achieved via a number of routes, through targeted formal training, cross project working, planned flying work-up or synthetic trials exercises (i.e., simulator linked to flight test telemetry). Regardless of the method consideration should be given to 'team requalification' as well as individuals, in order to maximise benefit.

These criteria give a framework against which individual competencies can be judged in determining who are Suitably Qualified and Experienced People, SQEP. These can then be used to support Role Approvals and applications for Accountable Persons using formally recorded levels of experience and competence.

3.2.9 Personal Responsibility and THE NO VOTE

Each individual in the organisation must recognise that they have a personal duty and commitment to constantly and continually challenge any instance where they believe that flight test safety could be affected and to bring this to the attention of the management stream. To support this management must create an environment where team members have no fear of sanction when they raise such issues and must be seen to act effectively when such issues are raised.

In the extreme, where there is judged to be a safety issue which is imminently likely to prove hazardous, any team member should feel empowered to exercise **THE NO VOTE** and call a stop to testing. In doing this they must not feel the threat of censure and must believe they will be supported by their management. The NAVAIR Case Study has a representative list of circumstances where an individual should feel entitled to exercise their **NO VOTE** and is recommended.

3.3 PROCESS

3.3.1 Overview

The Case Studies generally concentrate on this aspect of Flight Test Safety Management and provide a great deal of individual detail. The approaches taken within the Case Studies are, at the higher level, broadly similar across the organisations irrespective of their nationality or domain. This substantiates the originally held view that there was similarity of practice.

3.3.2 Safety is Fundamental

The Case Studies describe the approaches taken by the contributors and their organisations. They describe the Flight Test Safety Management System deployed by the organisations and the ways in which these are structured. It is widely recognised that Flight Testing has the potential to become very hazardous with attendant risk to life and of causing serious physical damage. The organisations therefore accept the management of test safety as a fundamental driver in everything they do and that is one of the foundation stones of the Quality Management System. The deployed systems address all aspects of the organisation Policy, People, Process, Procedures, Facilities and Tools when managing safety.

3.3.3 Common Process

All of the Case Studies universally describe a Common Process that is deployed across all projects within the organisation when managing Flight Testing and Test Safety. This enhances both efficiency and test safety as the staff only have to learn one system and then operate within it. None of the organisations describe Project Specific Flight Test Management Systems and some clearly record they are avoided.

3.3.4 Generic Flight Test Process

As is practice all of the contributors follow a common generic approach to Flight Test of:

- Plan – Generally split into a long term campaign planning phase and a near term detailed test programme planning phase.
- Execute – Management of the Flight Test Phase inclusive of flying and sortie management.
- Analyse – Real Time, Post Flight, Priority Analysis and Full Analysis.
- Report – Flight Reports, Progress Reports and Full Reports.

These are conducted in accordance with standard procedures and processes, using common facilities and tools and managed and delivered by trained and approved competent staff.

3.3.5 Flight Test Safety Process

All of the Case Studies provide details of the approaches that are taken to manage Flight Test Safety and there is a great deal of similarity. Risk is universally regarded as the product of hazard severity and its probability of occurrence. The processes described aim to reduce or control the impact of a hazard and/or reduce its probability of occurrence to levels that are judged acceptable.

The respondees typically describe a Generic Flight Test Safety Management Process which is run in parallel with a Specific Flight Test Safety Control Process.

The **Generic Process** is applied to all trials and describes the process that is used to manage the Risk Management Activity. This is very much about how the activity is assessed and monitored at a **higher level**.

Operating within this is a **Specific Flight Test Safety Control Process** that is applied to individual trials which analyses the trial in detail and is much more involved with what is being undertaken and how it is being controlled at the **operational level**.

A number of the respondees emphasise that the overall process is continuous starting at the design phase and following the trial through to its completion. Constant supervision and revision is a feature of an effective safety management process.

Throughout the overall process the responses reiterate the need for developed Safety Cultures and the application of the **NO VOTE** without censure

Both of these processes map onto the phases of the Flight Test Lifecycle. The list below endeavours to capture at, a high level, the activities contained in the Case Studies.

3.3.5.1 Long Term Test Planning

- Safety planning starts at the concept phase and the bigger the programme the more needs to be done upfront to ensure that the Safety Plan is developed effectively.
- Alternative concepts for the test programme must be investigated and assessed. The easiest answer might not be the best answer. Is there a better way?
- Long lead time critical mitigation measures must be developed and deployed in time for the programme. e.g., Loss of Control Recovery Systems, Real Time Analysis Systems, Escape Systems. Have you captured all of them and do they have a programme that delivers at the right time?
- Having established the concept, perform an initial risk categorisation of its elements to identify the areas of focus and the emergent hazards. Typically, this is performed between the Flight Test Team and a Peer Review Board of experienced independent senior experts. Involve junior staff; they need to learn.
- Environmental impact as well as test risks should be addressed.

3.3.5.2 Detailed Test Planning

- From the earlier work an initial risk categorisation should be available – Typically High – Medium – Low. This dictates how the Generic Process should be applied. Higher risk trials require deeper treatment.
- Identify and capture the detailed hazards. Checklists can help. The NAVAIR Case Study lists some useful checklist examples. Establish at a detailed level the High – Medium – Low risk hazards. Involve junior staff: they need to learn.

- Perform hazard analysis and establish the possible mitigations. Are these practical?
- Post mitigation establish the residual risk. What else can be done? Is this the final position? Is this ALARP and Tolerable?
- Present the evidence to a Review Board. Support with evidence and present Risk Matrices. The risk matrices presented in the Case Studies are of different formats. Notwithstanding this they all do exactly the same thing and allow a residual risk level (High – Medium – Low) to be ascribed based on assessment of severity and probability.
- Board membership must be appropriate to the perceived risk. Higher risk assessments need increasingly more senior and experienced attendees. Involve junior staff; they need to learn.
- Approval is granted from the Board. For higher risk activities the Board Recommendation may well need higher level approval within the organisation.
- The Approved Flight Test Plan must reflect the outcome of the Board and have sections clearly capturing the safety related findings, notably risks and mitigations.
- Ensure a mishap plan is in place and has been exercised and advertised before conducting the trial.

3.3.5.3 Execution

- The Test Cards must only contain tests from an Approved Flight Test Plan.
- Safety advice must be included against the relevant test points.
- Every Test Flight should have a Briefing involving all of the participants. It is recognised that for large multi-platform trials this may not be possible and that it may have to be a representative population.
- All participants must understand the purpose and conduct of the flight and their role in supporting it.
- At least one person present at the brief must be someone who is not part of the flight crew performing the duty.
- The Brief should be formally assessed for effectiveness by an independent witness who judges whether the brief has been complete and thorough and that there are no uncertainties. If the witness is not satisfied with the quality of the brief they have the authority to suspend the sortie.
- The Brief must consider the conditions of the day. Are they acceptable?
- The Brief may make minor changes to the Test Cards in response to operational circumstances e.g., weather. This can only be done by approved people in accordance with an approved procedure. **No Freelancing, no unapproved test points.**
- Safety of the test flight can be enhanced by appropriate support measures:
    - Team workup using Ground Environments. e.g., Simulator connected to Telemetry.
    - Rehearsal.
    - Real Time Monitoring.
    - Real Time Analysis.
    - Work up to critical conditions and demonstrations.
    - Chase Aircraft – The NAVAIR Case Study has an appendix discussing the use of chase aircraft (see Appendix 2-8.9).

- Every flight will be formally debriefed and recorded.
- Safety related arisings and issues will take priority and will be resolved before continuing testing.

3.3.5.4 Analyse

- Initial analysis must prioritise safety related assessments.
- Where a safety related issue exists analysis must be satisfactorily completed before further testing is performed.
- Post-Trial review the activity and capture lessons learned.

3.3.5.5 Report

- Safety reporting will take priority at all times.
- A system must be in place that escalates safety issues to the appropriate part of the organisation so that they can be managed and addressed.

3.3.5.6 Continuous Process

Throughout all of the activity participants must recognise that safety assessment is a rolling process.

- All must be vigilant and seek to identify emergent hazards not previously assessed.
- All must constantly review the programme to ensure that it is progressing as expected.
- Deviations should be identified and reported and assessed for impact.
- **Where doubts exist STOP. Take time out to consider before progressing.**
- Maintain records of the performance of the safety management system.
- Use these to drive improvement and to provide feedback to the team.

3.4 FACILITIES AND TOOLS

3.4.1 Overview

As originally envisioned this section was to capture those Facilities and Tools specifically developed and targeted at managing the Flight Test Safety Process. The Case Studies do not identify any systems of this type. They do describe generic tools e.g., Bow Tie, Hazard Analysis but do not identify special tools.

3.4.2 Common Facilities and Tools

What they do is almost universally declare that the use of common facilities and tools is an enabler to flight test safety as it reduces the need for learning and introduces a common workplace irrespective of project. It also results in a significant reduction in development costs which is a safety argument that is useful in presenting investment cases.

Chapter 4 – CONCLUSIONS

4.1 OVERVIEW

This AGARDograph originated from the interest that the STO Flight Test Technical Team (FT3) had in Flight Test Safety and Risk Management and the practices deployed by the NATO Nations. They wished to substantiate a view that, despite the disparate origins of the NATO Nation's Flight Test Organisations, there was largely common practice in relation to the approached deployed.

It is judged from the Case Studies provided that this view is, in the main, substantiated, and that Practice is Common.

No diversions from this common practice have been identified that indicate that there is any alternative approach that could be judged to be a better way.

Whilst there are detailed differences the Case Studies demonstrate high levels of commonality.

4.1.1 Higher Level Requirements

There is no universally accepted International Military Regulation in this area. The civil world is more harmonised and FAA and EASA dominate, but the military world and hence NATO falls back on National Practices. The approaches taken against these national frameworks are broadly similar but differ in detail. In developing a compliant management system, the developer must engage with their National Authority and comply with National Regulatory Rules.

4.1.2 People

It is recognised that the staff who deliver the Flight Test Product are the most important single element in the overall system.

- There must be adequate numbers of trained and competent staff with clearly defined roles and responsibilities who can deliver the product. Key is the ability to demonstrate that staff are SQEP Suitably Qualified and Experienced People and can fulfil their roles effectively.
- They must operate in a defined organisation which has clear chains of delivery responsibility and accountability in relation to safety.
- It is a management responsibility led by the Accountable Person to ensure that these criteria are satisfied.

4.1.3 Process

The processes described in the Case Studies are broadly similar at high and intermediate level. They deviate at the detailed level something that is to be expected. The studies provide example of practice that will inform those who wish to challenge an existing system or develop a new one.

4.1.4 Facilities and Tools

The key message is use common facilities and tools. Through familiarity this enhances safety as the staff only need to know one system. For management this enhances the arguments for investment through shared costs and enhanced safety.

4.1.5 Safety Culture

Regardless of the systems employed the development and maintenance of a mature and natural Safety Culture is elemental to Flight Test Safety and Risk Management. It will help overcome weaknesses in the rest of the deployed system and continually lead to healthy challenge and improvement. This is the single most important task falling at the feet of the management.

4.2 A FINAL THOUGHT

If you think Flight Test Safety and Risk Management is a tedious, expensive and time consuming overhead why not try having an accident instead!

An accident is traumatic and brings human, programme, financial and reputational costs that dwarf those associated with effective flight test safety and risk management practices.

Annex A – AFG-7900.3-001 "AIRWORTHINESS AND FLIGHT SAFETY REVIEW, INDEPENDENT REVIEW, TECHNICAL BRIEF AND MINI-TECH BRIEF"

Note: This Annex appears in its original format.

SUBJECT:

Airworthiness and Flight Safety Review, Independent Review, Technical Brief, and Mini-Tech Brief

RESPONSIBLE OFFICE:

Office of the Director

CONTENTS

1.0 PURPOSE & OBJECTIVES

This document presents the information needed to maximize the effectiveness of the airworthiness and flight safety review processes as practiced at the Dryden Flight Research Center.

- Responsibilities of the Airworthiness and Flight Safety Review Board (AFSRB), the AFSRB Chairperson, and the Dryden Flight Readiness Review (DFRR) Committee when one is formed.
- A sample DFRR outline as a guide for the DFRR Chairperson's consideration during the review process.
- Items that should be covered in the DFRR Committee report to the AFSRB.
- Technical Brief and Mini-Tech Brief guidelines.

2.0 SCOPE & APPLICABILITY

Scope: This process applies to all flight activities and hazardous ground tests involving aircraft, critical flight systems, and/or experimental facilities for which Dryden Flight Research Center (DFRC) has any airworthiness, ground, flight or range safety responsibility or that involve DFRC personnel utilizing non-NASA assets.

Applicability: This guidance applies to all Dryden organizations involved in the conduct of flight or ground test projects.

3.0 AIRWORTHINESS & FLIGHT SAFETY REVIEW

The AFSRB is tasked with performing certain review processes in order to ensure the flight safety of all projects conducted at Dryden Flight Research Center. The Dryden Organizational Manual (DOM) provides the authority for carrying out this task.

The DFRC Center Director appoints the chairperson and the members of the AFSRB. The AFSRB members are the line organizational Directors, Associate Director for Programs, the Chief Pilot, the Chief of Safety and Mission Assurance, and ex-Officio members. Other U.S. Government personnel may be appointed to the AFSRB as necessary to provide a thorough review.

In order to implement the assigned task, the AFSRB is given the authority and responsibility to perform reviews. The AFSRB Chairperson, in consultation with the AFSRB members and the Project under consideration, determine the appropriate level of review to be performed. There are four levels of review that will vary depending upon the complexity and the criticality of the project.

3.1. Airworthiness & Flight Safety Review Board

The first, though least extensive, level of the AFSRB review is that conducted solely by the AFSRB Chairperson. The chairperson is responsible for determining whether a specific project need be reviewed in any further depth or by any committee. If project plans and preparations are adequate for performance of their proposed operation with the necessary level of safety, the chairperson has the authority to cease reviews at that point. This will be documented in an approved-to-proceed memo.

The second level of review is one step beyond the sole review of the AFSRB Chairperson. If the chairperson decides that a specific project needs further review but does not require the full airworthiness board review, the chairperson may convene a small team of Dryden experts, independent of the project, to assist in determining whether the proposed project is cleared for flight. If the chairperson and the small team agree that the project should be cleared for flight, this will be documented in an approved-to-proceed memo.

The third level of review is to have the plans and proposed conduct of the project presented to the entire AFSRB for review. In this case, the entire board will make a judgment as to whether a particular project has adequately considered and integrated flight safety into its proposed plans. This determination will be based upon a presentation to the AFSRB by the project. The recommendation of the board to the Center Director will be based upon the general agreement of the members, with each major objection addressed and resolved or a minority report included with the recommendation. A quorum consists of the chairperson and representatives of Codes M, O, R, S, and XP.

The fourth level of review is to have the plans and proposed conduct of the project presented to the AFSRB by a team of experts, independent of the project, to determine whether the proposed project is cleared for flight. This team is called a Dryden Flight Readiness Review (DFRR) Committee. The entire committee will render a judgment as to whether a particular project has adequately considered and integrated flight safety into its proposed plans. The findings and recommendations of the DFRR team are typically presented to the AFSRB by the DFRR chairperson. The recommendation of the AFSRB to the Center Director will be based on the general agreement of the members, with each major objection addressed and resolved or a minority report included with the recommendation. A quorum consists of the chairperson and representatives of Codes M, O, R, S, and XP.

In any of the four review types, the AFSRB Chairperson has the authority to obtain assistance from any part of Dryden or any outside help that may be necessary to ensure that the project will be conducted in the safest manner possible. This assistance can take many forms, such as the hiring of a consultant, using the aircraft manufacturer's expertise, using experts in various fields, or forming ad hoc committees to assess any or all parts of the proposed program.

3.2. Dryden Flight Readiness Review (DFRR)

The AFSRB Chairperson may establish a formal DFRR Board (DFRRB) to assist in evaluating whether a specific project is adequately prepared to proceed with its proposed program. Typically, a DFRR will be convened if any of the following criteria are present:

A. Any new program or operation that can reasonably be assumed to contain significant risk to personnel or property

B. A phased program that is ready to enter a second or succeeding phase beyond that already approved by the AFSRB

C. A program that is preparing to exceed some limit previously approved by the AFSRB

D. A program that will require a major modification to the aircraft

The DFRRB will be established at a time when credible review and assessment can be made without delaying the operational schedule of the project, but in all cases, before the first flight or major operation of the project. DFRRs are normally limited in scope to addressing safety as the main subject of review but may also include a review of the project's potential for mission success when included in its charter.

A DFRR Board is charged with:

1) Conducting an independent review and assessment of the entire program or operation and ensure that proper, adequate planning and preparation have been accomplished, resulting in the project being conducted in an acceptable, safe manner. This review should include, where applicable, the design, fabrication, performance, and documentation of all software and hardware associated with the project as well as ground and flight operational procedures. It should also include any substantiating wind tunnel, computational fluid dynamics, ground, and/or simulation testing that has been performed.

2) Verifying that the approved System Safety Plan has been followed and that all analyses and results have been properly integrated into the project's planning and tracking documentation.
3) Ensuring that all identifiable risks have been identified, assessed, and either adequately controlled or presented to the Center Management as risks that must be accepted in order to conduct the program.
4) Providing engineering and technical recommendations to program personnel throughout the life of the DFRR, while recognizing that it is not a function of the DFRR to direct actual work effort.
5) Maintaining ongoing communication among DFRR members, program personnel, DFRC management, and the AFSRB Chairperson.
6) Submitting a final report on Board activity, findings, and recommendations to the AFSRB Chairperson.

The membership of the DFRR Board is selected by the AFSRB chair in consultation with the single letter codes to represent specific functions and disciplines necessary for an objective review and assessment of a project and its proposed plans. Broad experience and expertise are desirable among board members in order to ensure recognition of potential problems in a wide range of areas. Members will not be associated with the program being reviewed in any manner such that their activities or recommendations may be influenced through such causes as an over familiarity with the project. The chairperson of the DFRR board, a DFRC civil servant, is a senior engineer with extensive experience and expertise in the project's primary discipline. Other members may be drawn from NASA field centers and from the private sector as long as they are independent from the project under review.

The members of this board may go to their respective supervisors and/or the Safety and Mission Assurance Office for help or advice in interpretation of the board's charter. It is extremely important, however, that the individual member remain completely independent from line management biases while operating as a board member. The line management has the responsibility to ensure that individuals working under them are given the time and priority necessary to do a thorough job as a board member.

The board should take advantage of other advisors and consultants to assist them in fully reviewing the project. If an outside consultant must be hired, the project should provide funding. Decisions and recommendations are the sole responsibility of the board and its chairperson.

One purpose of the DFRR review is to expose individual or board concerns to higher management and the project while there is still time to avert a mishap. Therefore, project team members are encouraged to reveal information freely, cooperate with the review team(s), and be completely open in all exchanges, including those detailing any doubts or uneasiness experienced by the project team. Inviting the DFRR Board members to attend pertinent project meetings wherever applicable can emphasize this. The Project Team and the DFRR Board have a common goal and often the DFRR Board can help the project in attaining this goal. Briefings by the project team should be presented by qualified personnel to familiarize the board with overall efforts and specifics of all areas under evaluation. It is the responsibility of project personnel to ensure that all information presented is current, complete, and accurate, that all hardware, software, and equipment submitted for evaluation is properly prepared and represents actual configuration and functional characteristics intended for use, and all known or suspected anomalies, deficiencies, or areas of concern are identified.

Constant communication between the DFRR Board and the project team can provide benefits in both directions. A concern or recommendation voiced to the project team in a timely manner may allow the project to take action without delaying the project. Likewise, the proposed action of the project team, communicated to the DFRR Board in a timely manner, may expose areas of confusion or misunderstanding on the part of either the board or the project that could lead to unnecessary expenditure of valuable time and/or resources.

Upon completion of the board's review, the DFRR chairperson prepares a report to the AFSRB chairperson. This report should be presented in writing to the AFSRB chairperson. This report should include the board's recommendations, any unsatisfactory or marginal areas or conditions, any restrictions or limitations that should be imposed before the proposed operation may take place, and a discussion of any hazards that must be presented to the Center Director for acceptance. Ordinarily, the report should be signed by all DFRR Board members, but the chairperson may sign in an individual's absence if he states that the absent member either concurred in the majority report or has filed a minority report. Any member not concurring with the majority report should submit a minority report stating any areas of nonconcurrence or additional claims or recommendations as appropriate. Typically, the DFRR chairperson will present an oral briefing to the AFSRB. The written report should be delivered to the AFSRB and the Project Manager at least 48 hours prior to the AFSRB meeting.

The DFRR oral briefing to the AFSRB should include the material presented in the written report. Typically, the DFRR chairperson and DFRR board members will present the briefing. Project team members should be present to answer very specific questions that may arise. Hard copies of the oral presentation should be prepared and presented to the Project Manager and AFSRB members 24 hours prior to the AFSRB meeting.

Along with the presentation of the DFRR Board's final report, the Project Manager of the affected project will submit a report to the AFSRB chairperson addressing any open action items or recommendations that may have been in the DFRR report that require action before the first flight or significant project operation. Following these two report submissions, the AFSRB will make final recommendations as to whether the project should be allowed to continue on the planned course or should undergo some plan modification before continuing.

In order to allow sufficient time for the AFSRB to arrive at a decision without undue pressure, the final DFRR briefing to the AFSRB must precede the Project's Technical Briefing by a minimum of three workdays. It is also important to note that the Technical Briefing should precede the first flight/operation by a minimum of two working days. The DFRR Board should be present at the Technical Briefing in order to concur on closures of any issues that were deferred to the Tech Brief. For smaller projects less broad in scope, the above times may be compressed.

3.2.1 DFRR Outline

The outline in Appendix A is offered for the DFRR chairperson's consideration when conducting a DFRR of an assigned project. The board's primary concern is to investigate all matters that affect public, flight, range, and ground safety. Any items noted that may affect mission success may be reported, but unless specifically chartered are not the primary concern of the board.

3.3. Technical Briefs & Mini-Tech Briefs

The Technical Briefing, or Tech Brief, is one of the more important tools used by Dryden to ensure the safe and efficient conduct of the flight test mission. Its major function is to continue the review process after the AFSRB has made its final recommendations and a program moves into the flight or test phase.

There are two primary purposes for holding Tech Briefs. First, the individual Project Office is given the opportunity to present its goals and plans to a group of peers. These peers represent all the various disciplines at Dryden, with special emphasis on the particular areas of interest that are being explored during the proposed flight tests. A Project, in this way, receives the benefit of the experience and expertise of projects conducted previously. The peer review, using past experiences, is a proven way of bringing overlooked items to light.

The second purpose of Tech Briefs is to present a current assessment of Project risks to the Dryden management team. It allows management to reconsider its understanding of the risks involved prior to each flight. This helps ensure that any risks that cannot be eliminated or reduced will be accepted at the appropriate level of authority and responsibility.

Holding a Tech Brief prior to each flight of a research aircraft allows an adequate amount of time to process and thoroughly review data received from the previous flight. This forces a more comfortable and safe pace without project participants feeling they are being rushed into proceeding with a flight program after only a cursory look at available data.

A Tech Brief may be held for a block of flights of a research aircraft. This is typically allowed for more well-established research projects if the flights being conducted contain similar maneuvers and are deemed to be low risk by the Project and Chief Engineer. This can allow the project to proceed through the flight test plan more efficiently and present a more complete picture of the flight test results. A Tech Brief may be called for mid-block if unexpected results encountered or flight test plan changes are proposed.

The Project Manager is responsible for both scheduling and presenting the Tech Brief. The presentation should include, where applicable, the following:

A. Review of past flight(s)
   This review should address the data analysis results from previous flights of the aircraft with particular emphasis on envelope expansions or any unexpected results, whether or not they are expected to present a problem. These results should provide a smooth transition to the objectives of the proposed flight plan. Pilot comments from past flights should be addressed, particularly where the flying qualities of the aircraft are unexpected or not as good as have been expected. Significant anomalies or failures from previous flights must be reviewed.

B. Objectives of the proposed flight(s)
   The objectives of the flight or block of flights should be presented in light of the results of previous flight(s) and as part of overall program

objectives. Rationale and justification for the proposed flight should be shown based on an orderly progression from data points already obtained.

C. Flight Plan
The planned approach to obtaining the data maneuvers should be explained with emphasis on the technique and rationale for using it. Any risks, limits, or constraints on the aircraft or maneuvering should be presented and clearly explained with no assumptions made as to understanding of these critical areas. Preplanned alternatives should be presented to allow for unforeseen contingencies that may occur during flight. This plan should cover the entire flight period from takeoff to landing and give a clear and concise understanding of the pilot's duties at all times. If there is to be a period of pilot familiarization during flight, that should be briefed at the Tech Brief. This is not meant to limit the pilot's freedom, but to constrain all research aircraft flying to activity that has been preplanned and briefed.

D. Configuration Changes
A brief review should be made of the configuration that the aircraft will be in for flight. This is particularly important where there has been a change made to the aircraft between flights, no matter how small or seemingly unimportant. The status of the configuration documentation and waivers should be briefed to verify the completion of the changes or to identify any incomplete work and its effect on the proposed flight test. Additional risks perceived to have been incurred because of the changes are to be briefed in the Tech Brief.

E. Control Room Operations
For those Projects requiring a control room, the presentation of the Control Room procedures should include the room layout, the required people involved in the flight and minimum staffing levels, data they will be looking at and for, and instrumentation requirements. Any changes to the room or its functions should be explained. The communication network, both with the aircraft and in the Control Room, should be briefed. Any required control room training accomplished prior to flight should be presented.

F. Accepted Risk List
Every Tech Brief must present a list of any risks that are being taken knowingly by the Project. These risks may have arisen through various analyses such as a Hazard Analysis or may have shown up on previous flights or tests as discrepancies and processed through the normal Discrepancy Reporting system. In either case, the level of the associated risks and rationale for accepting them must be clearly

explained and justified. This list often takes the form of a Hazard Action Matrix that shows risk to human safety and risk to assets supported with a table of risk title, category and probability, causes, and mitigations.

G. Mandatory Requirements
Every flight of a research aircraft will have a specific set of conditions, personnel, instrumentation, and equipment required in order to conduct the flight as planned. These lists must be presented at the Tech Brief along with the action to be taken in the event a condition is not met or a person or item is not present or not operating. These could include cancellation, flight abort, or deletion of a specific maneuver or series of tests, but the goal is that all possibilities will be given detailed consideration in advance of the mission and precise alternatives planned and prepared for. These lists often take the form of the following:

1) Mission Rules – Required facilities, test systems, and their constraints
2) Aircraft Operating Limitations – Test specific aircraft system or maneuver limits
3) Weather Constraints – Test specific weather related limits or constraints
4) Go/No-Go Instrumentation – Safety or Mission critical instrumentation required to conduct the mission or specific portions of the mission
5) Required Documentation – Specific documentation, checklists, or procedures for the mission
6) Required Personnel – In addition to control room and flight crew, any ground crew required to conduct the operation.

H. Open Items
Occasionally, items may represent a major problem area and the Project is delayed until the items can be closed out satisfactorily. More often, the items are less severe and simply lack the necessary information at the time of the Tech Brief. These may normally be carried forward and closed out with the DFRC Chief Engineer or at the Crew Brief before the Project is cleared to proceed.

Technical Briefings are to be scheduled a minimum of two working days, preferably five, in advance of the proposed flight date. If not, it is the responsibility of the Project Manager to personally contact each of the mandatory attendees and notify them of the upcoming briefing. Actual scheduling is done through the Project's Administrative Office but remains the responsibility of the Project Manager. The keeper of the Dryden Center Calendar should be notified as soon as a date and time has been established so that no conflicting meetings will be scheduled. Dryden management has given the Tech Brief the highest priority.

The presence of the following individuals or designated representative is considered mandatory before a Tech Brief may be conducted. In the event any individual or a designated representative is not present, the Project Manager will cancel the Tech Brief and reschedule it.

- DFRC Chief Engineer (Tech Brief Committee Chair)
- Director, Research and Engineering
- Mission Director, Aeronautics, Exploration, Science, or Code Z as appropriate
- Director, Flight Operations
- Chief, Safety and Mission Assurance
- Director, Information and Test Systems
- Chief Pilot
- Project Manager
- Project Chief Engineer
- Project Operations Engineer
- Project Pilot

The presence of the following individuals or designated representative is considered highly desirable at the Tech Brief.

- Principal Investigator
- Designated technical monitor(s) (for each project) from Research Engineering

It is desirable for DFRR Board members to attend the first Tech Brief after their report to the AFSRB to ensure that actions directed by the AFSRB have been complied with by the Project. It is the responsibility of the person chairing the DFRR to notify the members regarding the Tech Brief.

Directorate management must ensure that designated representatives report issues and results to the directorate management to ensure continuity of directorate technical and safety monitoring.

It is the responsibility of each individual on the Mandatory Attendance list to maintain a current list of designated representatives who may attend Tech Briefs in his/her absence. A copy of the proposed flight request/mission plan will be made available in each of the Directorate Offices at least one day prior to the scheduled Tech Brief. It has been customary to circulate a draft of the proposed plan to all the interested parties a few days in advance of the Tech Brief. This is a desirable policy and should be exercised whenever possible. It provides the attendees with the benefit of being fully prepared at the Tech Brief as well as giving the Project Team the benefit of potential feedback at a much earlier point in the planning process. It also will allow each of the mandatory attendees enough time to ensure that they or their representatives can attend the actual briefing. Following the Tech Brief, the Directorate Directors (Operations, Projects or Airborne Science, Research Engineering, and Research Facilities) will approve and sign form D-WK 129-7, Flight Request. The Chief Engineer will sign the Flight Request Form to indicate approval to conduct the operation.

Any of these rules may be altered to fit a special case through negotiation with the Chief Engineer's Office. One example of a rule change that is permitted is the "Block Tech Brief," where a series of flights is briefed collectively. This would also include aerial refueling of a research aircraft where "one" flight is, in effect, two or three normal ones.

Although block briefing is often allowed, there is good reason and benefit from having the Project take the necessary time between flights to analyze data before proceeding with the flight program. This is especially true where an envelope is being expanded and data maneuvers proposed for a flight are highly dependent upon results from a previous flight. The usual technique is to expand the envelope on the first flight of a series and then use the remaining flights to fill in data points, or to expand an envelope in a different disciplinary area. A Tech Brief is then conducted before further expansion takes place.

A "Mini-Tech" covers only a limited new agenda aimed at a few items requiring clarification before continuing with a flight series. It is not a substitute for a Technical Briefing. Approved agenda items are prior flight results, relatively minor changes in configuration, prior flight anomaly explanation and analysis, minor changes to the Tech Briefed flight plan, and closeout items from Project reviews. Items covered at the Tech Brief must be readdressed, but may be covered by a statement such as "F. Accepted Risk List: No changes from the Tech Brief".

The "two day before flight" requirement is relaxed with Mini-Techs to facilitate a safe but rapid conduct of the mission. A Mini-Tech may be held immediately prior to the Crew Brief for most block-briefed flights, after the first flight.

The signatures of the appropriate entities on the previously briefed Tech Brief Flight Request must be reaffirmed by initials and dated. The initials show approval of the flight as briefed at the Tech and Mini-Tech briefings.

The final decision on what will or will not be allowed for any given project remains a decision to be made by the DFRC Chief Engineer, a decision based on what will facilitate the safest and most efficient flight test program possible.

APPENDIX A – Review Board Checklist

The purpose of a review is to provide DFRC management assurance that a satisfactory approach has been taken to achieving safe and productive flight operations. Reviews communicate an approach, demonstrate an ability to meet requirements, and establish status.

The objectives of a review are to establish that all interfaces are compatible and function as expected, confirm that the system and support elements are properly configured and ready for flight, and receive assurance that flight operations can proceed with acceptable risk.

This checklist provides a partial list of items to address for review team guidance when conducting an independent review. The team may select only those items that apply to the project reviewed. The list draws heavily from the Mars Climate Orbiter investigation.

1.0 Personnel

A. Leadership
   1) Emphasis on safety as the primary concern
   2) Experience level of personnel
   3) Clear line of authority to person in charge
   4) Examine team working and external interfaces
   5) Teamwork promotion
   6) Training opportunities provided
   7) Mentoring of new or inexperienced personnel

B. Organization and Staffing
   1) Sound organizational structure
   2) Staffing adequacy
   3) Customer representation
   4) S&MA representation

C. Communication
   1) Ranking of safety and mission success over cost and schedule
   2) Free exchange of information, opportunity to be heard
   3) Tracking of top ranked issues and their resolution to everyone's satisfaction

4) Problem reporting encouraged
5) Line organization and project communications

D. Project Team

1) Key positions filled and continuity encouraged
2) Experience level of team members
3) Adequacy of project team's reviews: PDR, CDR, Wind tunnel, test readiness, simulation
4) Customer involvement in decision-making and trade-offs
5) Team acceptance of external ideas
6) Team metrics relation to requirements

2.0 Process and Execution

A. Systems Engineering

1) Risk trade-off system used by the project
2) Risk management system used
3) Ground test versus flight test trade-off
4) Fault tree analysis used
5) Margin adequacy for parameters
6) Mission architecture provides data for failure analysis
7) Emphasis on mission success over cost and schedule
8) Formal review of past lessons learned
9) Rigorous configuration control process in place

B. Requirements

1) Mission success criteria established and baselined
2) Requirements level sufficiently detailed
3) Change process used and effective
4) Derived requirements flow from base requirements

C. Validation and Verification

1) Verification matrix structure and completeness
   - Vertical: Mission phase or hardware part or software

- Horizontal: Function, qualification method (analysis, test, similarity, none), results

2) Sound verification processes
3) Evidence that processes are used
4) Safety critical software identified and treated as such
5) Mission critical software identified and treated as such
6) System interface validation and data handoff
7) Simulation as a verification and validation tool
8) Other validation and verification facilities
9) IV&V (or iV&V) for software
10) Normal and off-nominal (contingency and emergency) testing
11) Test repeats after configuration changes
12) End-to-end testing results and configuration freeze

D. Cost and Schedule
1) Funding adequate to accommodate program
2) Bottom-up budget and schedule
3) Cost and schedule reserves
4) Mission success compromise for cost

E. Government and Contractor Roles and Responsibilities
1) Roles and responsibilities defined (written), workable, and followed
2) Experience level of contractor work force

F. Risk Management, Analysis, Test
1) Risk relationship to cost, schedule, and content of project
2) Risk analysis tools used: FMEA, FTA, PRA, etc.
3) Problem reporting procedures
4) Single point failures identified and remedied or accepted
5) Hardware and software reuse certification
6) Day-of-flight configuration testing
7) Potential failures identified, modeled, and overcome or accepted
8) Thoroughness of failure postulation

G. Independent Reviews

1) Review conducted by technical peers or experts
2) Sustained support for review members
3) Review independence from common management
4) Review results reported to top management

H. Operations

1) Contingency planning validated and tested (simulated)
2) Contingency training of personnel
3) Mission rules formulation and reasonableness
4) Telemetry and health monitoring during critical operations

I. Center Infrastructure

1) Senior management mechanisms for visibility into the project
2) Line organization accountability

J. Documentation

1) Documentation of design decisions and limitations
2) Decisions communicated to all concerned
3) Documentation process must be continuous
4) Electronic documentation distribution availability

K. Continuity and Handover

1) Transition plan for handover
2) Personnel transfer with handover
3) Recipient team training by development team
4) Training of recipients in procedures and databases
5) Continuity in key positions; overlap
6) New processes generated by the transition
7) Transition risks

L. Mission Assurance

1) Adequate mission assurance staffing
2) Mission success processes in place and followed

3.0 Technology

- Technology adequately matured
- Technology solutions alternatives considered
- Risk level of new technology
- New technology use and limitations

4.0 Technical Areas

View technical areas with the purpose, goals, and objectives of the Project in mind.

- Aerodynamics
  - Control surface effectiveness
  - External pylons, stores, protuberances, fixtures, mounts
- Alternate landing sites
- Aircrew
  - Aircrew evaluation of simulation results, aircraft readiness, problem areas
  - Guest aircrew in-briefing
  - Review of flight crew training, procedures, and qualifications
- Avionics
  - Redundancy, reliability
  - EMI testing
- Carrier aircraft (mothership)
  - Crew qualifications
  - Communications paths
  - Interfaces, launch panel
  - Pylon, hooks, sway braces
  - Separation analysis
  - Sling loads
- Computational fluid dynamics analysis
- Configuration control
  - Project requirements
  - Flight vehicle under configuration control
  - Hardware
  - Software
  - Hazard Reports
  - Waivers

- Control Room operations
  - Communications links and plans
  - Display and layout: monitoring and analysis
  - GRIM
  - Key personnel and replacements
  - Personnel training
  - Security
  - Uplink capability
- Data acquisition and transmission
- Documentation
- Experiment(s) description
- Flight envelope and expansion plans
- Flight controls
  - Flight controls computers and software functions
  - V&V, IV&V
  - Certification Standard (Level A: Flight Critical)
- Fuels and oxidizers: hypergolics, pyrophorics, oxygen
- Ground operations and servicing
- Ground support
  - Airfield facilities
  - Communications equipment
  - Ground support equipment
  - Maintenance facilities
  - Navigation, guidance, and landing aids
- Ground testing
  - Communications
  - Drag chute and deploy mechanism
  - Free taxi operation (disconnected from tow)
  - Ground track
  - Outside air temperature limit
  - Steering method
  - Support vehicles
  - Tow operations and tow connector link
  - Wind and crosswind limits

- Guidance, navigation, and control onboard
- Handling qualities
  - Predictions: simulation, analog
- Hazard analysis
  - Hazards identified, mitigated, tracked, and monitored through System Safety Working Group
  - Hazards configuration controlled
  - Severity and probability levels
  - Risk matrix
  - Accepted risks
- Human factors
  - Cockpit operations
  - UAV/RPV ground control station operations
  - Control room operations
- Hydraulics
  - Redundancy
- Inspection methods at contractor's location and at DFRC
- Instrumentation
  - Mishap reconstruction capable
  - System power requirements versus aircraft power available
  - Data Requirements (parameters, sensors, rates)
  - System component environmental qualifications
  - Research data acquisition systems
  - Telemetry
  - EMI
  - Go/No-Go List
  - Documentation
- Life support
  - Anti-G suit
  - Egress capability
  - Parachute characteristics, fit compatibility
  - Pressure suit
  - Sharp edge survey
- Mission rules
  - Limitations

    - Operational restrictions
- Operations
    - Checklists
    - Emergency procedures
    - Fact Sheet
    - Manuals
- Parachutes, vehicle
    - Construction
    - Pyrotechnics, mortar
- Pilot training (ground and flight)
- Project overview
    - Experiments planned
    - Facilities required
    - Hardware, software
    - Objectives
    - Procedures used
- Propulsion
    - Launch vehicle
    - Research vehicle
- Range requirements
- Range safety
    - Abort landing sites
    - Beacons
    - Command destruct system
    - Encryption
    - Expected casualty calculations
    - Flight termination system
    - Operating area
    - Trajectory
- Recommendations by the Review Board
    - Action Items
- Research vehicle
    - Vehicle purge
    - Landing gear
    - Mass properties

  - Pilot intervention for UAVs
  - Thermal protection
- Risk management
  - Assessment of residual risk
  - Accepted risk list
  - Risk/Hazard identification
  - Severity and probability matrix
  - Pre-mishap contingency plan
  - Pre-declared risk list
- Simulation
  - Certification: qualified for use
  - Configuration management
  - HIL, AIL
  - Nominal, off-nominal testing
  - Verification
  - Validation
- Software
  - Configuration control
  - IV&V
  - Simulation
  - Formal code reviews
- Stage separation
  - Aerodynamics
  - EMI
  - Ordnance
- Structures
  - Aeroelastic effects
  - GVT
  - SMI
  - Sideslip-dynamic pressure combination (ßqbar)
- Uncertainty analysis
  - Margins
  - Monte Carlo analysis
- Validation and Verification

  - Validation: System performs adequately to accomplish the mission: test, analysis, demonstration, similarity, inspection, simulation
  - Verification: System performs according to the specification: test, analysis, demonstration, similarity, inspection, simulation
  - All-up, end-to-end check: thermal, vibration, shock, pressures, etc., combined
- Vehicle health monitoring
- Waivers
- Wind tunnel predictions
- Wiring
- Work Breakdown Structure

APPENDIX B – Sample Questions For Review Board Members

MODIFICATIONS

1. Can the type and amount of power available support the electrical requirements of the installations?

2. Have operating procedures and an inspection checklist been developed for the installation?

3. Is cooling air adequate to properly cool avionics in flight and on the ground?

4. Have partial flight manuals and checklist been prepared and approved?

5. Have weight and balance figures been computed and are they within recommended limits?

6. Does the installation of test equipment in the aircraft interior keep aisles and emergency exits clear for evacuation?

7. Do installed racks and test equipment have projections (bolts, rivets, knobs, handles) that could cause injury to aircrew personnel?

8. Does instrumentation installed in the cockpit obstruct vision or egress or add discomfort and distraction to the aircrew?

9. Is the aircraft properly placarded and has the test instrumentation in the cockpit been properly identified and marked?

10. Do any external modifications affect the pitot-static system?

11. Have magnetic interference (EMI) ramifications been considered? Will flight day EMI be different from other days?

12. Have modifications been photographically documented on film or video?

13. Review fact sheet. Are all changes incorporated?

INSTRUMENTATION

1. Has the proposed and/or completed installation been inspected by the project test aircrew to ensure that it offers the safest possible installation? Has a cockpit safety design board approved the changes and documented approval?

2. Has a complete set of operating instructions been formulated and published?

3. Are the instrumentation appendages (nose boom pitot head, vanes, etc.) ahead of the engine checked regularly for structural integrity?

4. Has proper consideration been given to the separation of shielding of instrumentation and aircraft wiring, especially in the area of weapons system control circuits?

5. Have provisions been made for coordinating the data when more than one recording device is to be used?

6. Have adequate written procedures been developed for the maintenance, inspection, and calibration of the instrumentation?

7. Has a complete set of emergency or alternate procedures for test instrumentation failures been formulated in order that some part of a scheduled mission can be accomplished safely with certain instrumentation inoperative?

8. Are you reasonable certain that this test can be conducted safely?

9. Is it necessary or advisable to monitor internal black box temperatures monitored in flight, on the ground, and during build-up and maintenance?

10. Are black boxes instrumented to reveal elapsed operating hours? On/off cycles? Are hours and cycles frequently monitored and documented?

11. Are film/tape time limits on recorders and cameras understood? Speeds? Initiation and shutoff times?

12. Has the instrumentation installation been documented by photography/video prior to flight?

MAINTENANCE

1. Are there any special maintenance procedures that will be required to support the test? Are they published as a requirement?

2. Have inspection requirements been compiled into preflight, postflight, and phase documents?

3. Have the aircraft and, in particular, the modification areas, been thoroughly inspected for foreign objects?

4. Have closeout photos been taken of areas that are difficult to access or of all areas for vehicles that are to be unrecoverable post flight?

5. In the case of joint maintenance support, who is in charge?

6. Are you reasonably certain that the test can be conducted safely?

FLIGHT CONTROL ROOM – FLIGHT OPS

1. For each flight test maneuver or event:
    - Who are the key people monitoring the event? Are they properly trained? Are back-up personnel identified and trained?
    - What recorders, channels, and parameters are being monitored for critical and precautionary indications?
    - What are the critical and precautionary limits for the given event?
    - Is there any question concerning whom you notify, how you notify them, what phraseology to use, and with what urgency? Are there any questions concerning how you expect people to react when you notify them of a critical or precautionary indication?
    - Is the control room team familiar and proficient with emergency procedures?

2. Is there any question concerning the parameters monitored, type of sensor used, or the method of display?

3. Are you satisfied with the limits and accuracy of the monitored parameters? With interfaces with other monitored parameters?

4. Have you checked scaling and sensing (direction) of the parameters you are to monitor?

5. Are you satisfied with your communication network, procedures and equipment?

6. Are flight envelope limits clearly defined and understood before flight by necessary persons?

7. Will you be able to detect faulty instrumentation indications of critical flight parameters?

AERODYNAMICS

1. Have all aspects of new design or modification been considered for effect on
   - Aerodynamics/drag
   - Acoustics/vibration
   - Surface shielding/ineffectiveness due to boundary layer/wake shedding
   - Weight
   - CG
   - Inertia
   - Exterior Configuration
   - Shock interaction
   - Control surface movements
   - Pitot-static system
   - Other instrumentation (hot wires, pressure sensors/taps, hot films, etc.)
   - Etc.

2. Have effects of inflight unplanned alteration of appendages or flight surfaces (i.e., experiment breakup or impact on aircraft/fixture, etc.) been assessed?

3. Is the aero model satisfactory? Any undue or unaddressed concerns? How are you going to verify the aero model during envelope expansion flights?

4. Is simulation satisfactory? Have appropriate sensitivity changes been examined?

5. Is instrumentation and its calibration satisfactory? Does it tell you all you need to know for safety and mission accomplishment? What are the shortcomings?

6. Do you have any undue concerns about questions in the “Flight Control Room Flight Ops” section of this document?

7. Have all safety and mission concerns been adequately addressed?

8. Are you reasonably certain flight can be conducted safely?

AEROSTRUCTURES

1. Have all aspects of new design or modification been considered for effect on structure and vice versa?

2. Are ground load and ground vibration tests adequate? Any evidence of airframe vibration (flutter, buffet, acoustics)?

3. Is instrumentation satisfactory? Does it tell you all you need to know for safety and mission accomplishment? What are the shortcomings?

4. Do you have any undue concerns about questions in the “Flight Control Room Ops” section of this document?

5. Have all safety and mission concerns been adequately addressed? What factor of safety in design or test? What Margin of Safety?

6. Are you reasonably certain flight can be conducted safely?

CONTROLS (FLIGHT, ENGINE, ETC.)

1. Have all “fail to operate” and full hardover impacts been assessed?

2. Is the system implemented as intended by the designer? How is it ensured?

3. Have end-to-end tests been conducted on the full-up total system? Have all credible inputs been accomplished to observe system response?

4. Do all lights and indicators obtain intelligence from credible sources?

5. How does failure or erroneous signal in a light or indicator impact safety or mission accomplishment?

6. Is simulation satisfactory? Have appropriate sensitivity changes been examined?

7. Is there a “last resort” provision to switch back to a previously annunciated failed system in the event vehicle loss is imminent regardless? (i.e., the system may be healthy with the warning system malfunctioning.)

8. Have all prudent efforts been considered to continue operating system in a degraded “get home” condition in lieu of switching to a dormant or benign backup system whose health is not utterly known?

9. Has consideration been given to using parallel-active dual systems rather than primary-active, backup-benign systems?

10. In the event of a failure, will an impacted item be automatically positioned at an optimum setting (i.e., engine speed, flight control surface, etc.)?

11. Do you have any undue concerns about questions in the “Flight Control Ops” section of this document?

12. Have all safety and mission concerns been adequately addressed? Has a system safety assessment been accomplished?

13. Are you reasonably certain flight can be conducted safely?

MAN / MACHINE DYNAMICS

1. Have all aspects of new design or modification been considered for effect on
    - Dynamics and vice versa
    - Weight
    - CG
    - Inertia
    - Exterior configuration
    - Surface control movements
    - Pitot-static system
    - Other instrumentation
    - Etc.

2. Have effects of unplanned alteration of appendages or flight surfaces been assessed?

3. Is simulation satisfactory? Have appropriate sensitivity changes been examined?

4. Is instrumentation satisfactory? Does it tell you all you need know for safety and mission accomplishment? What are the shortcomings?

5. Do you have any undue concerns about questions in the “Flight Control Ops” section of this document?

6. Have all safety and mission concerns been adequately addressed?

7. Are you reasonably certain flight can be conducted safely?

PROPULSION

1. Are propulsion characteristics compatible with the
   - Intended flight envelope
   - Altitude
   - Speed
   - G-force
   - Angle of attack
   - Sideslip

2. Where is flameout or engine stall anticipated?

3. Are procedures adequate to avoid overtemp or other engine damage?

4. Are engine recovery procedures adequate?

5. Will testing be conducted in an area where emergency power-off landing can be safely performed?

6. Are flight control and electrical/hydraulic power adequate for power-off landing?

7. Is propulsion related instrumentation adequately installed and calibrated? Does it give the required information for safety monitoring and mission accomplishment?

PROJECT MANAGEMENT

1. Have all the policies of Dryden Management System Manual (DMSM) been addressed?

2. Have all project documents been completed at the appropriate life-cycle gates?

3. Has a review of all system safety documentation been accomplished?

4. What are your mission rules and accepted risks?

5. What configuration control process is utilized?

6. Has the Project utilized appropriate Lesson Learned databases?

APPENDIX C: Relevant Documents

Authority Documents

NPR 7900.3	Aircraft Operations Management
DCP-X-008	Tech Brief (T/B) & Mini Tech Brief (Mini T/B)
DCP-X-009	Airworthiness And Flight Safety Review Process

Forms

D-WK 129-7	Flight Request

APPENDIX D: Acronyms

AFSRB	Airworthiness and Flight Safety Review Board
AIL	Aircraft In the Loop
CDR	Critical Design Review
CG	Center of Gravity
DFRR	Dryden Flight Readiness Review
DFFRB	Dryden Flight Readiness Review Board
DMSM	Dryden Management System Manual
DOM	Dryden Organizational Manual
EMI	Electromagnetic Interference
FADS	Flush Air Data System
FMEA	Failure Mode and Effects Analysis
FTA	Fault Tolerance Analysis
GVT	Ground Vibration Test
HIL	Hardware In the Loop
HR	Hazard Report
IV&V	Independent Verification and Validation
MSR	Mission Success Review
PDR	Preliminary Design Review
PRA	Probabilistic Risk Analysis
RPV	Remotely Piloted Vehicle
SMI	Structural Mode Interaction
UAV	Uninhabited Aerial Vehicle
V&V	Verification & Validation

Document History Log
IPRP (limited distribution) Review Date: 09-23-10

This page is for informational purposes and does not have to be retained with the document.

Baseline, 10-15-10
- Replaces DHB-X-001

Admin Change Baseline-1, 11-17-10
- Corrected footer to show that document may be distributed outside of Dryden.

Admin Change Baseline-2, 08-16-11
- Corrected expiration date in header (pages 2-15).
- Fixed hyperlinks.

Admin Change Baseline-3, 02-07-13
- Updated to current template
- Updated ITAR labeling to show the document does not contain ITAR information.

Admin Change Baseline-4, 09-22-15
- Extended expiration date from 10-15-15 to 04-15-20.

Admin Change, Baseline 5, 03-23-16
- Corrected incorrect expiration date (2020 is incorrect above). Should have been 04-15-16.
- Extended expiration date from 04-15-16 to 10-01-16.

Admin Change, Baseline-6, 10-03-16
- Extended expiration date from 10-01-16 to 04-01-17

Admin Change, Baseline-7, 03-30-17
- Extended expiration date from 04-01-17 to 10-01-17.

Admin Change, Baseline-8, 09-25-17
- Extended expiration date from 10-01-17 to 04-01-18.
- Updated document number from G-7900.3-001 to AFG-7900.3-001.
- Updated owning branch code to name.

Admin Change, Baseline-9, 01-17-18
- Updated footer.

Annex B – AFOP-7900.3-023 "AIRWORTHINESS AND FLIGHT SAFETY REVIEW PROCESS"

Note: This Annex appears in its original format.

Compliance is mandatory.

SUBJECT:

Airworthiness & Flight Safety Review Process

RESPONSIBLE OFFICE:

Office of the Chief Engineer

CONTENTS

1.0 PURPOSE OF DOCUMENT

This document establishes the requirements for the Airworthiness and Flight Safety Review (AFSR) process used at the Armstrong Flight Research Center, henceforth referred to as the Center. Use AFG-7900.3-001, Airworthiness and Flight Safety Review, Independent Review, Technical Brief, and Mini-Tech Brief, in conjunction with this document.

2.0 SCOPE, APPLICABILITY, & WAIVER

2.1 Scope

This process applies to all flight activities and hazardous ground tests involving aircraft, critical flight systems, and/or experimental facilities for which the Center has any airworthiness, ground, flight or range safety responsibility or that involve Center personnel utilizing non-NASA assets.

2.2 Applicability

This procedure applies to all Center personnel involved in the airworthiness and flight safety review process.

2.3 Waiver

The requirements of this procedure may be waived per the process presented in AFPR-7123.2-001, Waivers and Deviations to Technical Requirements.

This procedure may be waived by the Center Director or the Center Chief Engineer for projects conducted jointly with organizations having a Center recognized safety review process (for example, other NASA Centers, the Air Force Flight Test Center, United States Navy test organizations, etc.) or where the safety review process is covered in a Memorandum of Agreement (MOA). Typically, the Center is represented in safety review processes conducted by other organizations for joint projects. An informational briefing may be requested by the Chief Engineer to inform Center management of the project content, test plan, and hazard analysis. The Center accepted risks must be approved by the Center Director or NASA HQ, as appropriate.

3.0 OBJECTIVES, TARGETS, METRICS, & TREND ANALYSIS

Objective: Ensure that research and airborne science projects (for which the Center has any responsibility for ground, flight and/or range safety and/or mission success) are airworthy, safe, and maximize mission success.
Target: Test and airborne science missions are well planned and residual risks are communicated to and accepted by the Center Director.
Metric: Approval to proceed to test or flight.

Objective: Ensure that test and airborne science research projects comply with Center policies and procedures.
Target: All Center policies and procedures followed.
Metric: Briefings in accordance with applicable policies and procedures.

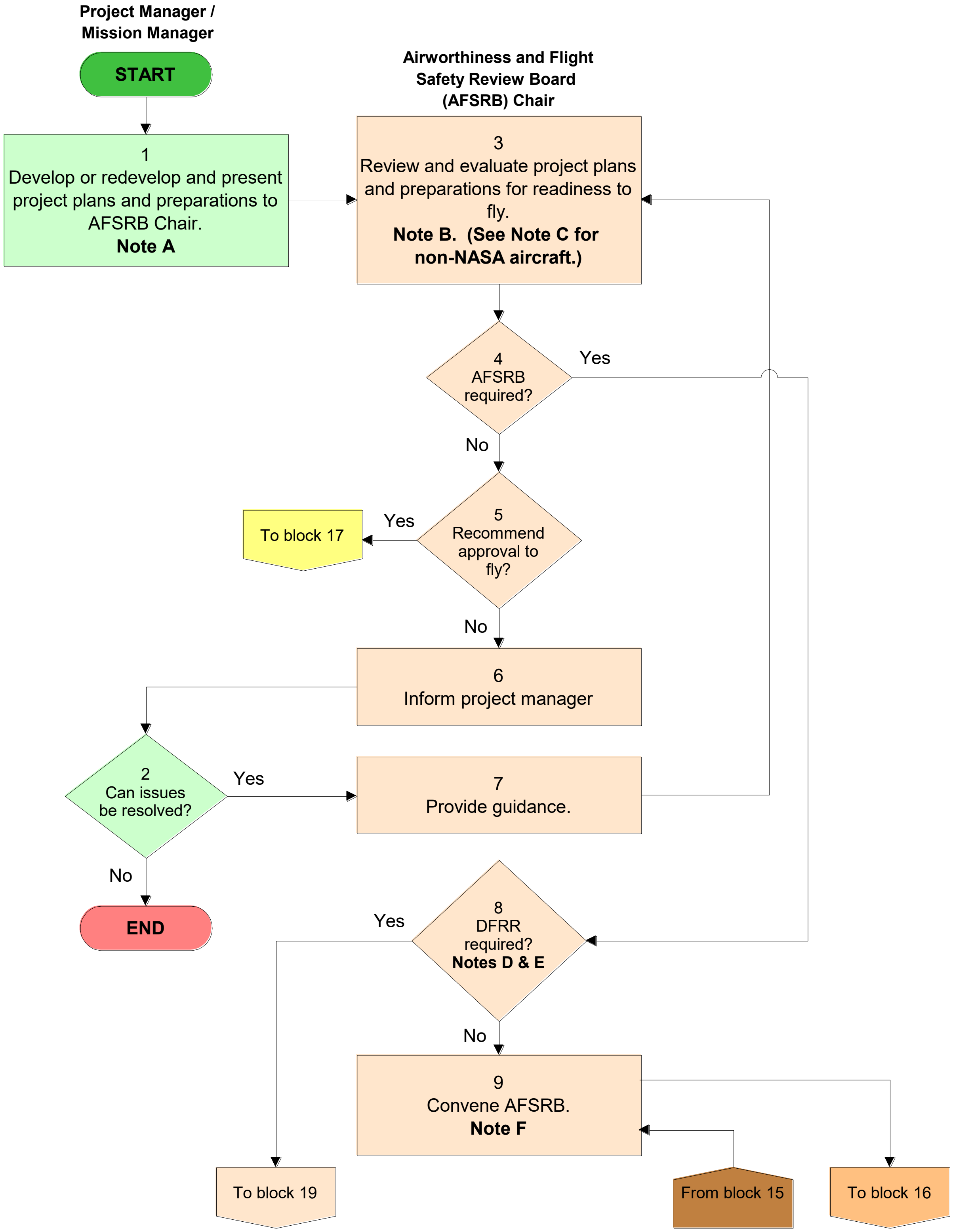
Objective: Allow the AFSRB to determine necessary additional procedures to ensure flight safety and to maximize mission success.
Target: Briefings provide required technical and safety information.
Metric: Briefings in accordance with applicable policies and procedures.

Objective: Review flight activities and tests involving all aircraft, critical flight systems, and experimental facilities.
Target: Provide required technical and safety information during briefings.
Metric: Briefings in accordance with applicable policies and procedures.

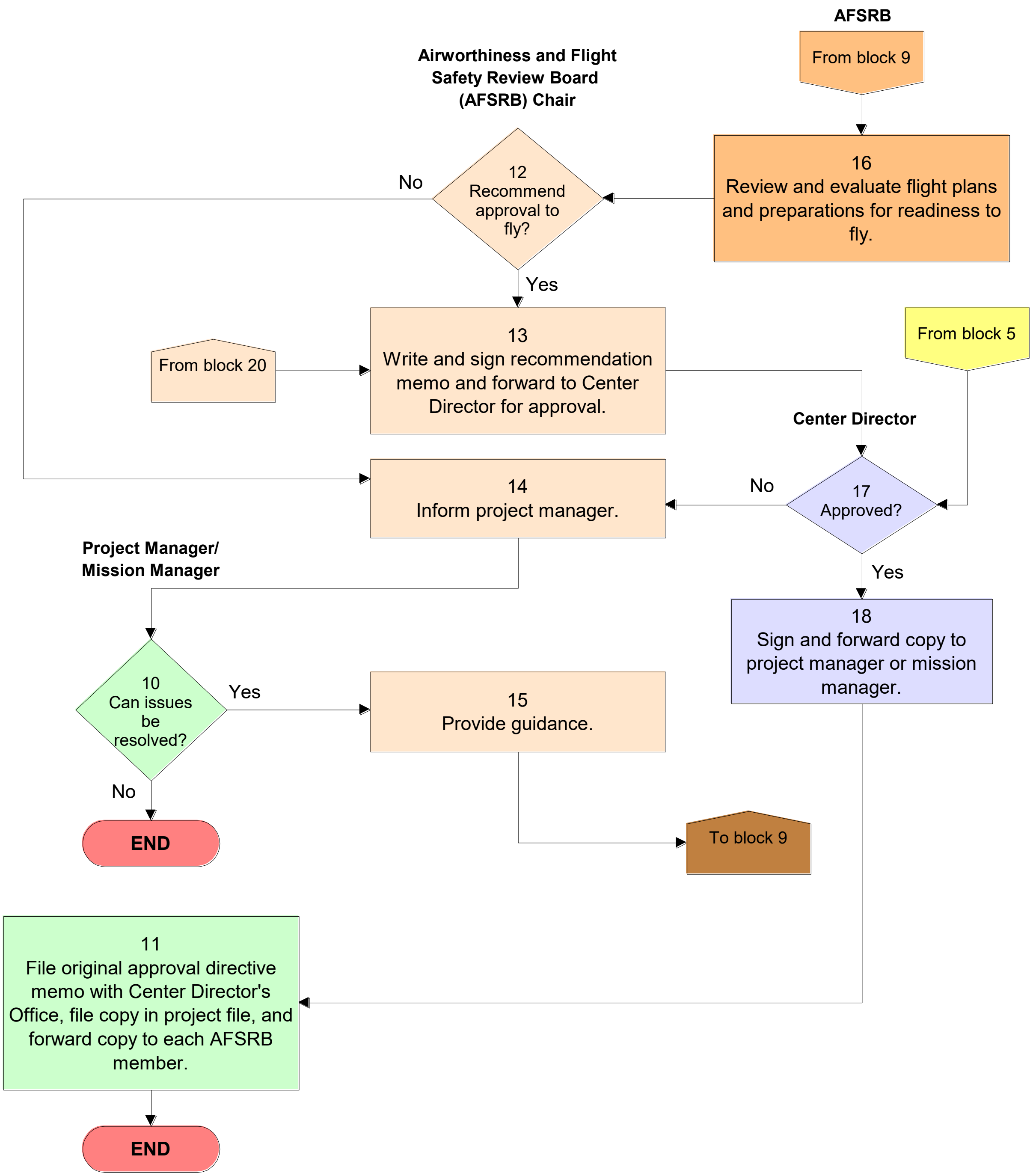
Trend analysis: Metrics will be analyzed to determine whether procedural objectives have been met.

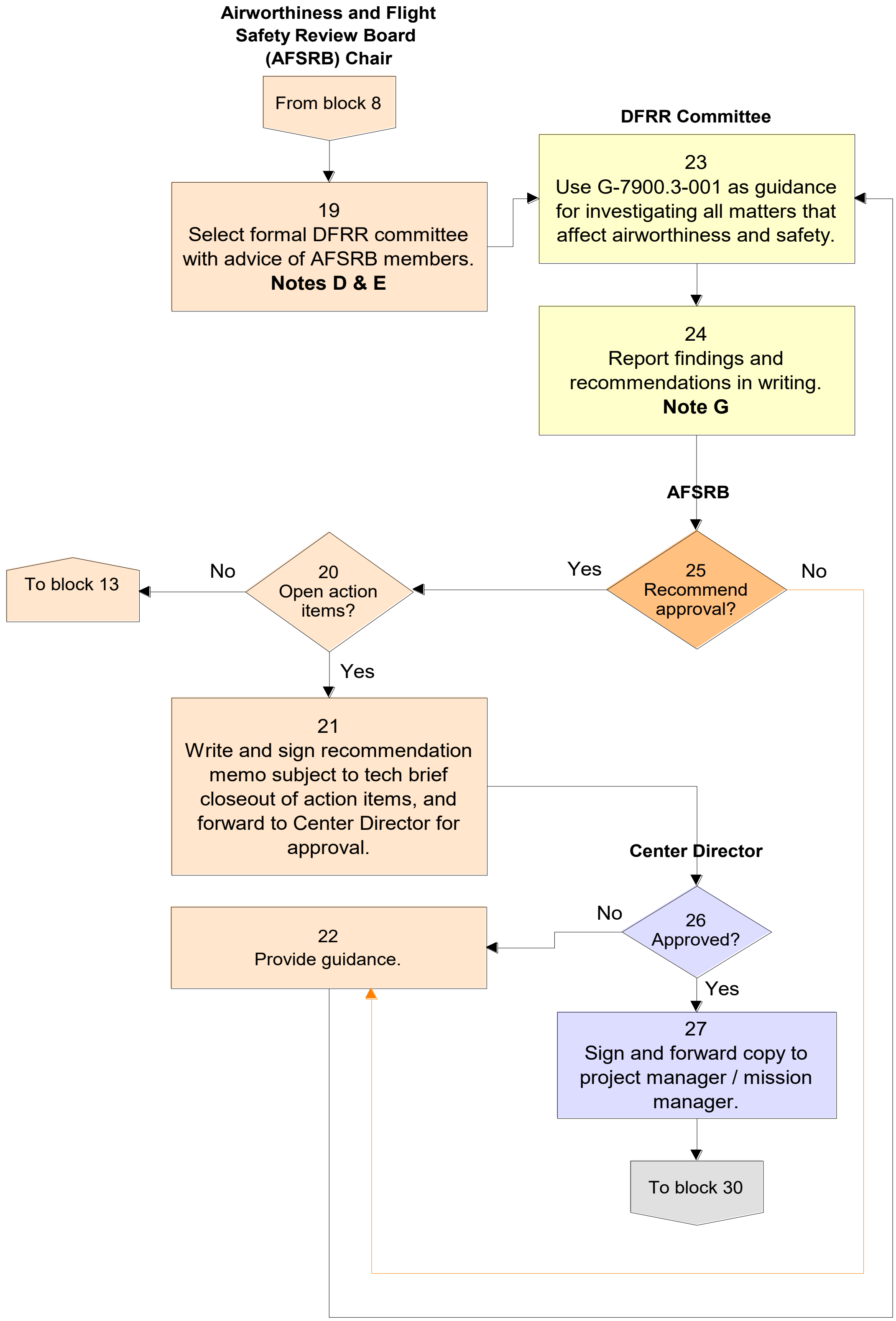
4.0 FLOWCHART

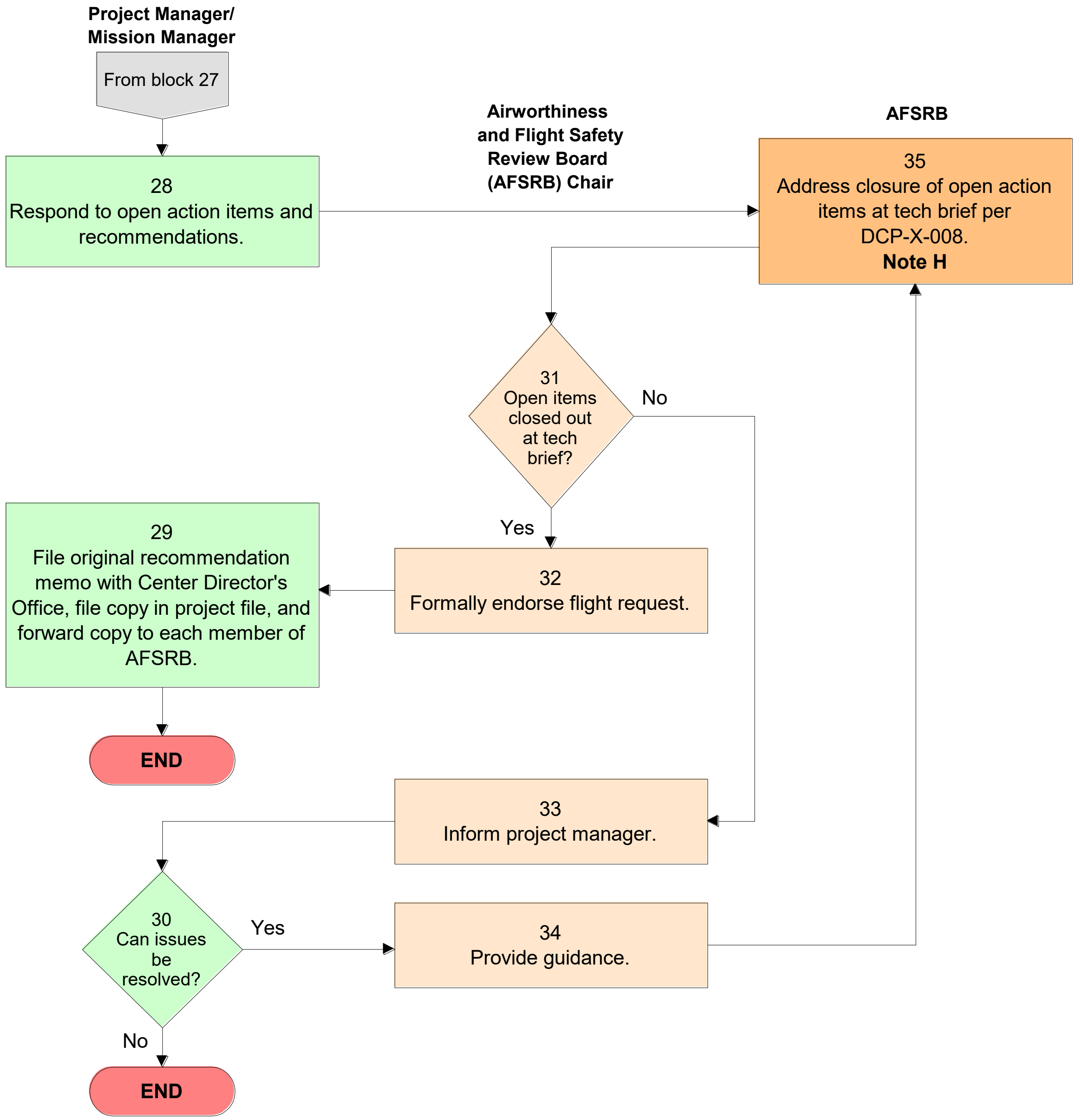
The AFRR can be required independent of the AFSRB, and is frequently done this way for less technically intensive projects such as the SBLT pylon on the F-15B. The AFRR will write a report to the Chief Engineer and attend the tech brief in lieu of the AFSRB to answer questions from the tech brief committee.



Before use, check the Master List to verify that this is the current version. For reference only when printed. This document does not contain export-controlled content and may be distributed outside the Center.


AFSRB
From block 9
Airworthiness and Flight Safety Review Board (AFSRB) Chair
16
Review and evaluate flight plans and preparations for readiness to fly.
No
12
Recommend approval to fly?
Yes
13
Write and sign recommendation memo and forward to Center Director for approval.
From block 20
From block 5
Center Director
14
Inform project manager.
No
17
Approved?
Yes
Project Manager/ Mission Manager
18
Sign and forward copy to project manager or mission manager.
10
Can issues be resolved?
Yes
15
Provide guidance.
No
END
To block 9
11
File original approval directive memo with Center Director's Office, file copy in project file, and forward copy to each AFSRB member.
END


Airworthiness and Flight Safety Review Board (AFSRB) Chair
From block 8
19
Select formal DFRR committee with advice of AFSRB members.
Notes D & E
DFRR Committee
23
Use G-7900.3-001 as guidance for investigating all matters that affect airworthiness and safety.
24
Report findings and recommendations in writing.
Note G
AFSRB
25
Recommend approval?
Yes
No
20
Open action items?
No
To block 13
Yes
21
Write and sign recommendation memo subject to tech brief closeout of action items, and forward to Center Director for approval.
Center Director
26
Approved?
No
22
Provide guidance.
Yes
27
Sign and forward copy to project manager / mission manager.
To block 30


Project Manager/
Mission Manager
From block 27
Airworthiness
and Flight Safety
Review Board
(AFSRB) Chair
AFSRB
28
Respond to open action items and recommendations.
35
Address closure of open action items at tech brief per DCP-X-008.
Note H
31
Open items closed out at tech brief?
No
Yes
29
File original recommendation memo with Center Director's Office, file copy in project file, and forward copy to each member of AFSRB.
32
Formally endorse flight request.
END
33
Inform project manager.
30
Can issues be resolved?
Yes
34
Provide guidance.
No
END

5.0 FLOWCHART NOTES

Note A
Plans and preparations will include the following:

1. project description
2. operations summary
3. aircraft/experiment development status/readiness
4. ground systems readiness
5. analyses/simulations
6. system safety analysis
7. schedule
8. Configuration Control Board (CCB) actions closed out
9. Waivers and status
10. issues/project requests

Note B
The Center Chief Engineer serves as the AFSRB Chair, and the Center Deputy Chief Engineer serves as the alternate chair.

In accordance with AFFTCI 91-105, the Chief Engineer will notify AFFTC/SET of any potentially high risk test activity or any test activity that will affect normal AFFTC operations prior to the start of testing. AFFTC/SET participation in the AFSRB accomplishes this requirement.

In accordance with AFFTC 91-105, joint projects that involve AFFTC assets (other than airspace, range, and airfield support of normal flight operations) require AFFTC review and approval. AFFTC/SET participation in the AFSRB may meet this requirement. The AFFTC Form 5028 cover sheet, as a minimum, is used by AFFTC/SET to document the process and gain approval for AFFTC participation. Projects may provide AFFTC/SET with the AFSRB briefing materials to attach to the AFFTC Form 5028 to provide additional information to the AFFTC approval chain of command. Projects should plan for the additional coordination time required for AFFTC approval.

Note C
Projects and tests that involve NASA assets (flight crew and/or high value equipment) and are flown on non-NASA aircraft will follow guidelines and policy set forth in NPD 7900.4, NASA Aircraft Operations Management, and NPR 7900.3. Additionally, the requirements of AFOP-7900.3-006, Chapter 10, Joint Flight Operations, will be followed when applicable.

Note D

Criteria for chartering Armstrong Flight Readiness Review (AFRR)

A. New project or operation with assumptions of risk
B. Phased project requiring approval to enter succeeding phase
C. Project exceeding limit previously approved by AFSRB - After major modification(s) to aircraft

Note E

AFRR composition depends upon vehicle, mission, and technologies involved.
AFRR chair is an expert senior technical person.

Note F

Membership of the AFSRB is appointed in by the Center Director and typically includes the following:

1. Chief Engineer (Chair)
2. Associate Center Director for Programs
3. Director for Flight Operations
4. Director for Research & Engineering
5. Project Mission Director
6. Chief, Safety and Mission Assurance
7. Director, Mission Information and Test Systems
8. Chief Pilot
9. Aviation Safety Officer

A quorum consists of the Chair and representatives from Codes M, O, R, S, and XP.

Note G

A. The written report will be delivered to the AFSRB and the project manager at least 48 hours prior to the AFSRB meeting.
B. Hard copies of the oral presentation will be made available to project manager and AFSRB members 24 hours prior to the AFSRB. Copies of slides may be made available using online resources available at the Center, such as email or computer servers accessible by the AFSRB membership. At least five hard copies are provided to the AFSRB Chair and membership at the briefing to facilitate documentation of discussion items.
C. The final AFRR briefing to the AFSRB must precede the project's technical briefing by a minimum of three workdays. This time may be compressed with the concurrence of the AFSRB Chair.

Note H
Representatives of the AFRR Board will be present at the technical briefing in order to concur on closures of any issues that were deferred to the tech brief.

6.0 MANAGEMENT RECORDS & RECORDS RETENTION

Destruction of any records, regardless of format, without an approved schedule is a violation of Federal law.

See the Code 100 record types and records plan for storage location, retention requirements, and ultimate disposition for the following management records associated with this procedure

Records of the required meetings are filed in the Center Chief Engineer's Office. An electronic version will be filed by the project on the MARS server in the Center's tech brief folder under the appropriate project.

Records of required meetings are retained for the duration of a project. They are further retained in the Center Chief Engineer's Office at the discretion of the Chief Engineer to provide guidance to future projects with similar technical or safety related challenges.

7.0 RELEVANT DOCUMENTS

AFRC documents may be found at https://odie.ndc.nasa.gov/SitePages/Home.aspx.

7.1 Authority Documents

NPD 7900.4	NASA Aircraft Operations Management
NPR 7900.3	Aircraft Operations Management
AFPR-7123.2-001	Waivers and Deviations to Technical Requirements

7.2 Referenced Documents

AFFTC 91-105	AFFTC Test Safety Review Process
AFOP-7900.3-022	Tech Brief (T/B) & Mini Tech Brief (Mini T/B)
AFOP-7900.3-006	Aircrew Flight Operations Manual
AFG-7900.3-001	Airworthiness And Flight Safety Review, Independent Review, Technical Brief And Mini-Tech Brief Guidelines

Document History Log
Review Date: 05-25-10

This page is for informational purposes and does not have to be retained with the document.

Baseline, 01-04-99

Revision A, 04-15-99

- Modified signature block from "Approved" to "Electronically Approved by"
- In all blocks containing the words "Approval Directive", the word "memo" was added
- Modified block 4 of the "Project Manager/Mission Manager" on page 1 and block 3 on page 2 Modified block 1 of "FRR Committee" on page 2

Revision B, 10-03-00

- Page 1 modified block 5 of "AFSRB Chair"and changed "Flight Readiness Review (FRR)" to "Dryden Independent Review (DIR)" in block 6, added 2nd block to "Center Director", and modified block 4 of "Project Manager/Mission Manager".
- Page 2 modified blocks 3 & 6 of "AFSRB Chair", added 2nd block to the "Center Director", and modified block 3 of "Project Manager/Mission Manager".
- Page 3 added block 1 for "Center Director", modified block 2 of "Project Manager/Mission Manager", and changed "FRR" to "DIR" in Notes 2 & 3.

Revision C, 01-27-03

- Replaced "Dryden Independent Review (DIR)" with "Dryden Flight Readiness Review (DFRR)" in all references.
- Changed "Approval Directive" to "recommendation" in all references, including column title p. 2.
- Moved Notes 1, 2 and 3 to within proximity of where each is referenced.
- Additional minor edits throughout.

Revision D, 11-26-03

- Note 3 that describes how the airworthiness process will apply to non-NSA aircraft

Admin Change, Revision D-1, 11-20-08

- Moved stand-alone flowchart to document template
- Extended expiration date

Revision E, 08-06-10

- Extended expiration date by 6 months.

Revision F, 01-01-11

- Updated format to current template.
- Added required paragraphs.
- Modified Section 3.0.
- Minor revisions of procedures.
- Moved flowchart notes to separate section.
- Rebuilt flowchart.

Admin Change, Revision F-1, 04-25-11

- Page 8: Note B, added paragraphs 2 and 3.

Admin Change, Revision F-2, 12-01-15

- Extended expiration date from 01-01-16 to 06-01-16

Admin Change, Revision F-3, 05-20-16

- Extended expiration date from 06-01-16 to 12-01-16.
- Updated format in some sections.
- Replaced reference to cancelled DOP-O-300 with replacement DCP-O-025.

Admin Change, Revision F-4, 11-30-16

- Extended expiration date from 12-01-16 to June 1, 2017

Admin Change, Revision F-5, 06-01-17

- Extended expiration date from 06-01-17 to 12-01-17.

Admin Change, Revision F-6, 11-09-17

- DCP-X-009 renumbered to AFOP-7900.3-023 in accordance with Center instruction.

Admin Change, Revision F-7, 11-30-17

- Extended expiration date from 12/01/17 to 06/01/18.

Admin Change, Revision F-8, 1-18-18

- Updated Footer.

Annex C – AFOP-7900.3-022 "TECH BRIEF AND MINI-TECH BRIEF"

Note: This Annex appears in its original format.

Armstrong Flight Research Center
Edwards, California 93523

AFOP-7900.3-022, Revision I-1
Expires March 1, 2021

Compliance is mandatory.

SUBJECT:

Tech Brief (T/B) & Mini Tech Brief (Mini T/B)

RESPONSIBLE OFFICE:

Office of the Chief Engineer

DCP-X-008, Tech Brief (T/B) & Mini Tech Brief (Mini T/B)

Concurrence Signatures

By signing this concurrence, I accept the requirements that apply to my organization.

Bradford Neal, Chief Engineer Chief Engineer, Code X	02 Mar 2016 Date
Bradley Flick, Director Research and Engineering, Code R	3/4/2016 Date
for Dennis Hines, Director Programs and Projects, Code XP	3/2/16 Date
Sean McMorrow, Director Mission Information and Test Systems, Code M	3-2-2016 Date
James Smolka, Director Safety and Mission Assurance, Code S	3-2-2016 Date
Dana Purifoy, Director Flight Operations, Code O	2 MAR 2016 Date
David McBride, Center Director	4 Mar 2016 Date

CONTENTS

1.0 PURPOSE OF DOCUMENT

This procedure describes requirements for technical briefings (T/Bs) for senior level management review of Armstrong Flight Research Center (AFRC) (hence forth referred to as the Center) flight research projects as part of the overall Center airworthiness and flight safety review process established in AFCP-X-009, Airworthiness and Flight Safety Review Process. Technical briefings are used to:

A. Continue safety and technical review processes after the AFSRB has made final recommendations and the flight program has moved into the flight phase;
B. Ensure project presents goals and plans for peer review;
C. Update current project goals, plans, and risks to the Center Management Team.

2.0 SCOPE, APPLICABILITY, & WAIVER

2.1. Scope

This procedure applies to all elevated risk ground tests and all flight research flown at the Center, whether resident or deployed. It also covers other flight research or test projects in which Center personnel participate or research aircraft or other high value assets are used.

2.1.1. Scope Exceptions

Typically, the Center is represented in safety review processes conducted by other organizations for joint projects. An informational briefing may be requested by the Chief Engineer to inform Center management of the project content, test plan, and hazard analysis. Center accepted risks will be approved by the Center Director or NASA HQ, as appropriate.

2.2. Applicability

This procedure applies to all project managers and T/B Board members.

2.3. Waiver

This procedure may be waived by the Center Director or the Center Chief Engineer for projects conducted jointly with organizations having a Center-recognized safety review process (for example, other National Aeronautics and Space Administration (NASA) Centers, the United States Air Force or United States Navy test organizations, etc.) or where the safety review process is covered in a Memorandum of Agreement (MOA).

The requirements of time between chart delivery and tech brief, and tech brief and flight, may be waived upon consultation with the Tech Brief Board Chair (Section 6.0, Remark A).

The requirements of this procedure may be waived per the process presented in AFPR-7123.2-001, Waivers and Deviations to Technical Requirements.

3.0 OBJECTIVES & METRICS

There are no metrics for this procedure.

4.0 ROLES & RESPONSIBILITIES

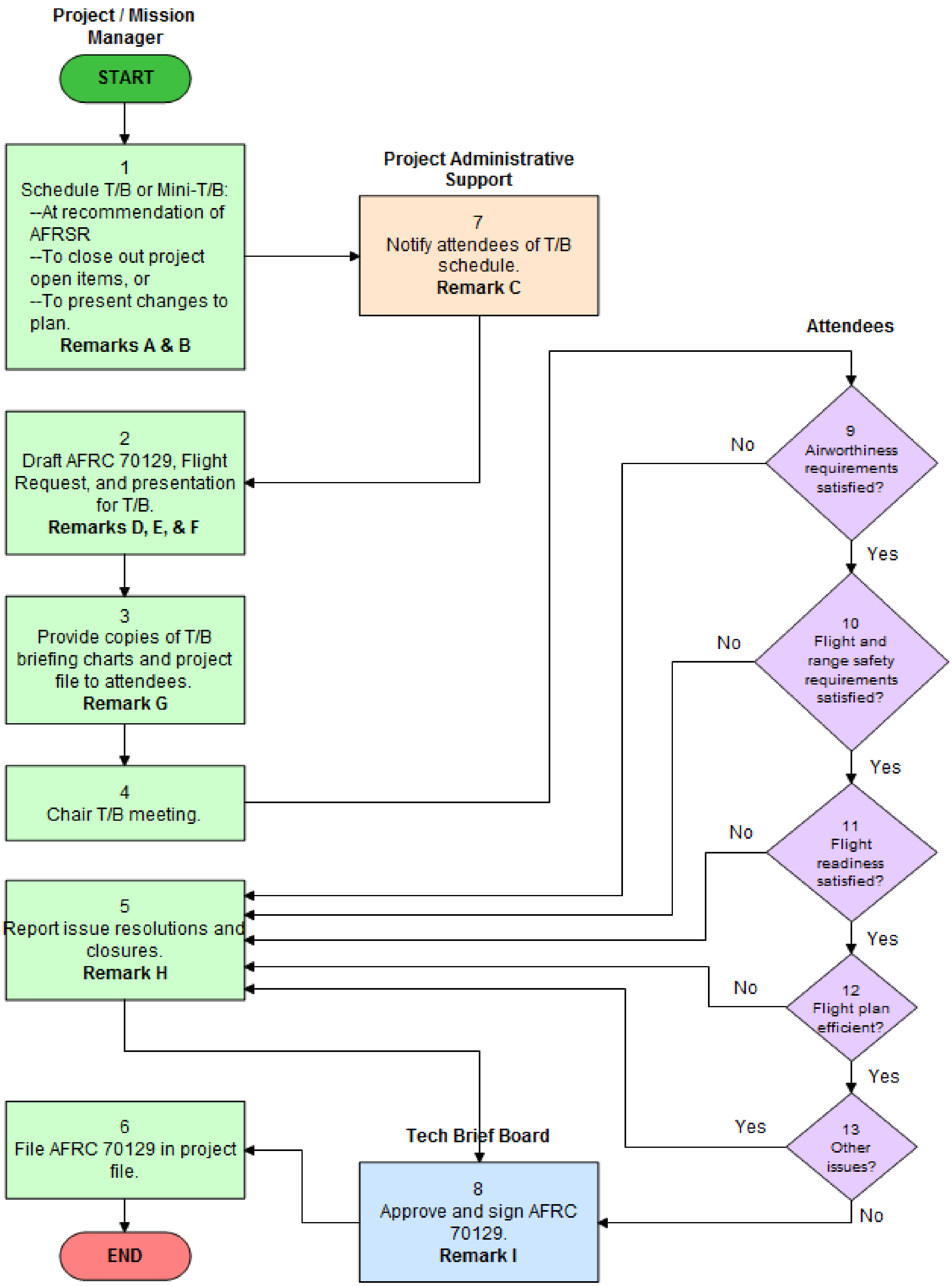
Chief Engineer: Lead the Center's airworthiness and flight safety review process. Serve as the Chairperson of the Tech Brief Board. Coordinate tech brief review content and agenda with the project team. Communicate residual risks to the Center Director for acceptance.

Tech Brief Board Members: Serve as signatories on the Flight Request. Review and assess the project team's plans and approach to accomplish their objectives safely. Evaluate the project's residual hazard stance and its acceptability to the Center.

Project Team: Present the project's objectives, plans, and approach to accomplish the project's goals and objectives. Conduct hazard analysis and present results to the Tech Brief Board. Coordinate meeting agenda with the Chief Engineer.

Center Director: Establish the Center's airworthiness and flight safety review process. Receives the recommendation of the Tech Brief Board. Evaluate and accept or reject residual hazards that fall into the accepted risk category.

5.0 T/B or MINI-T/B FLOWCHART



6.0 FLOWCHART REMARKS

Remark A

Technical Briefings or mini-T/Bs are to be scheduled by the project manager in consultation with the Chief Engineer. The project manager will inform all mandatory attendees and the Center Director's Office (for inclusion on the Center calendar) of the meeting place and time.

Technical briefings will be scheduled at least two working days in advance of the proposed flight date.

Briefing materials will be distributed to mandatory attendees two days before briefing.

Hard copies of the presentation should be provided at the T/B to facilitate Board member note taking and situational awareness.

One paper copy of the briefing material presented will be provided by the project to the Tech Brief Board Chair for the record.

Remark B

Mini-T/Bs are typicallty less than 20 minutes and may be combined with the crew brief to explain minor anomalies and to brief incremental flight plans.

There is no requirement to provide briefing materials in advance.

One paper copy of the briefing material presented will be provided by the project to the Tech Brief Board Chair for the record.

Remark C – Attendees

1. Mandatory Board Attendees or Designee
   a) Center Chief Engineer (Chair)
   b) Director for Research and Engineering
   c) Director for Flight OperationsDirector for the Office of Safety & Mission Assurance
   d) Chief Pilot
   e) Aviation Safety Officer (ASO)
   f) Range Safety Officer (RSO) (UAS activities only)
   g) Other Organization Representatives, for joint projects
2. Mandatory Project Attendees or Designee

   a) Project Manager
   b) Project pilot
   c) Project Chief Engineer (if assigned)
   d) Project Operations Engineer (if assigned)
3. Desired Attendees
   a) Principal investigator
   b) Appropriate discipline representatives / technical monitors from Research Engineering
   c) Director for Mission Information and Test Systems
4. Director for Aerospace Projects

The Chief Pilot and Aviation Safety Officer (ASO) position may be filled by the qualified Director or designee. The Range Safety Office is a required attendee only when unmanned aerial system (UAS) operations are being conducted.

The Chief Engineer has the authority to augment the T/B mandatory attendee list, as appropriate, to cover project areas where additional expertise is warranted.

Remark D – Briefing Guide

1. Review of past flight conduct and results (if applicable)
2. Objective of proposed flight or flight block
3. Flight plan
   a) Maneuvers
   b) Flight profiles
4. Aircraft status
   a) Maintenance status
   b) Time Compliance Technical Order (TCTO), Technical Directive (TD), Airworthiness Directive (AD), Service Bulletin (SB) status
   c) Instrumentation status
   d) For non-Center aircraft, is an aircraft inspection required in accordance with AFCP-O-025, Aircrew Flight Operations Manual, Chapter 10, for external aircraft operations?
5. Configuration
   a) Configuration changes
   b) Status of configuration management (CM) documentation
   c) Open waivers

6. Control Room operations
   a) Staffing plan/responsibilities
   b) Radio procedures (Control room, inter-plane, etc.)
   c) Intercom procedures (Control room, intra-plane, etc.)
   d) Call definition and maneuver terminate procedures
7. Hazard review
   a) List of all identified hazards
   b) Human Safety and Loss of Asset Hazard Action Matrix (HAM) charts
   c) Accepted risk list, including mitigations and mitigation type for each
8. Range safety analysis
9. Mandatory mission requirements
   a) Go/No Go list, with changes highlighted
   b) Mission rules, with changes highlighted
   c) Weather constraints
   d) Operating limitations
   e) Test-specific emergency procedures
   f) Required documentation
10. Center range, facility, and information technology requirements
    a) Normal operations
    b) Effect of scheduled outages
    c) Contingency plan for unscheduled outages
11. Open items from AFSRB, if required

The above checklist is tailored for typical research test missions. Airborne science research missions and some research test missions may not include all of the elements above, or may have additional elements that should be briefed. Use the checklist as a guide for required topics to be presented.

With Chief Engineer approval, a T/B may cover a block of flights. Additional envelope expansion requires an additional T/B.

Mini-T/Bs are used to address minor system anomalies, review flight test results, and cover changes to briefed blocks of flights or for other purposes. Mini-T/Bs may be used by management to provide increased supervision of more hazardous testing. There is no briefing guide. Each meeting agenda is determined by the project manager in consultation with the Chief Engineer and other Tech Brief Board members.

Remark E – Hazard & Risk Reporting Guidelines

Mitigation types fall into one or more of the following categories: design, safety device, procedure, training, or warning/placard.

For all accepted risks, provide very brief discussion on how residual risk levels were derived (i.e., through what level(s) in the hierarchy of risk management: design, devices, processes / procedures, training, placards).

Provide depiction of accepted risks and remaining residual hazards based on phase of flight (if appropriate). This is generally done using the HAM (Note E).

Test point risk level will be assessed as HIGH, MEDIUM, or LOW. MEDIUM risk test points will have an accompanying accepted risk requiring Center Director approval for flight. HIGH risk test points will have an accompanying accepted risk requiring NASA Headquarters approval for flight.

Provide assessment of probability of achieving technical objectives for flight / flight block being briefed.

Remark F – Hazard Action Matrix (HAM)

Multiple versions of the HAM (human safety and loss of asset) are presented. There may be HAMs for each flight phase for complex, multi-phased flight activity.

Remark G

Briefing materials may be distributed electronically prior to the T/B.

Sufficient paper copies should be provided at the T/B by the project for the mandatory attendees at the briefing to facilitate note taking.

One paper copy of the briefing material presented at the T/B will be provided by the project to the Tech Brief Board Chair for the record.

Remark H
Verification of closure may be provided via a mini-T/B or email to the Chair. The method of reporting closure of action items will be provided to the project at the end of the T/B by the Tech Brief Board Chair.

Remark I

Tech Brief Board approval refers to concurrence from the following directors (or designated representative):

1. Director for Research and Engineering

2. Director for Flight Operations
3. Assigned Project's Mission Director, if required (Programs & Projects Directorate)
4. Director for Safety & Mission Assurance
5. Chief Pilot (Flight Crew Branch)
6. Director for Mission Operations Directorate, if required
7. Aviation Safety Officer
8. Range Safety Officer, if required
9. Other Organization Representatives, as approppriate, for joint projects
10. Center Chief Engineer (Chair)

At the conclusion of a mini-T/B, all required attendees will either sign the unsigned or initial and date an already signed Flight Request (AFRC Form 70129).

7.0 MANAGEMENT RECORDS & RECORDS RETENTION

Destruction of any records, regardless of format, without an approved schedule is a violation of Federal law.

Tech Brief and mini-Tech Brief records will be kept per the Code X record types and records plan for the records associated with this procedure.

Meeting records include at a minimum:

A. Attendance list
B. Action Items for the project
C. Presentation material (hard copy)
D. Copy of signed Flight Request (AFRC form 70129)

An electronic version of the presentation material will be filed by the project on the MARS server in the Center's Tech Brief folder under the appropriate project. The Flight Request is kept as part of the Project's records.

8.0 RELEVANT DOCUMENTS

AFRC documents may be found at https://odie.ndc.nasa.gov/SitePages/Home.aspx.

8.1. Authority Documents

NPR 7900.3	Aircraft Operations Management
AFCP-X-009	Airworthiness and Flight Safety Review Process

8.2. Referenced Documents

AFPR-7123.2-001	Waivers and Deviations to Technical Requirements and Standards
AFCP-O-025	Aircrew Flight Operations Manual

8.3. Informational Documents

AFG-7900.3-001	Airworthiness and Flight Safety Review, Independent Review, Technical Brief, and Mini-Tech Brief

8.4. Forms

NASA forms may be found at https://nef.nasa.gov/nef/

AFRC 70129	Flight Request

APPENDIX A, Definitions

Can or may	Denotes discretionary privilege or permission.
Will	Denotes expected outcome.
Mini-Tech Brief	A short (typically 20 minutes in length) review to approve readiness for a flight, addressing only one or two issues (close-out of a problem, resolution, or experimental data). Attendees are the same as those for a standard Tech Brief.
Tech Brief	A review by various designated Senior Management personnel to assure readiness for a research/science flight (or block of flights).

APPENDIX B, Acronyms

AD	Airworthiness Directive
AFCP	Armstrong Flight centerwide procedure (temporary document acronym)
AFG	Armstrong Flight guidance (document type)
AFPR	Armstrong Flight procedural requirements (document type)
AFRC	Armstrong Flight Research Center
AFSRB	Airworthiness & Flight Safety Review Board
ASO	Aviation Safety Officer
CM	configuration management
HAM	Hazard Action Matrix
MOA	Memorandum of Agreement
NASA	National Aeronautics and Space Administration
NF	NASA form
NPR	NASA procedural requirement
SB	service bulletin
T/B	Tech Brief
TCTO	time compliance technical order
TD	technical directive
UAS	unmanned aerial system

Document History Log
Review Date: 11-02-15

This page is for informational purposes and does not have to be retained with the document.

Baseline, 01-04-11

Revision A, 04-15-99

- Modified signature block from "Approved" to "Electronically Approved by"
- Separated responsibilities of "Technical Support and Coordination Office" to "Flight Scheduling Office" and "Project Administrative Support" on page 1 of flowchart.
- Modified the last block of "Project Manager/Mission Manager" on page 2 of flowchart.
- Page 2 of flowchart: Combined last two blocks of "Attendees" and moved the responsibility to "Directors For".

Revision B, 11-17-99

- Page 1: Revised Note 1 and Note 2.

Revision C, 05-05-00

- Page 1: Deleted "Each mandatory attendee shall provide the Chief Engineer with a list of 3 acceptable alternates Chief Engineer will publish the list" from Note 2.

Revision D, 07-26-00

- Page 1: Added "or DOP-Y-003" to block 2 of Project Manager / Mission Manager and modified Note 2.

Revision E, 10-02-00

- Page 1 of flowchart: Added "(Chair of T/B Committee)" after "DFRC Chief Engineer" in Note 1and modified Note 2.
- Page 2 of flowchart: Changed "Directors For" to "Tech Brief Committee"
- Modified Note 5.

Revision F, 07-31-01

- Page 1: Added “or a designee” to Mandatory Attendees in Note 2.

Revision G, 02-14-06

- Rebuilt flowchart
- Removed reference to cancelled document DCP-O-009
- Inserted flowchart in Word template

Revision H, 02-26-10

- Updated format to current template
- Added required sections
- Amplified checklist of briefing topics
- Updated flowchart and added flowchart notes section to accommodate large number of notes

Admin Change Revision H-1, 03-26-10

- Section 6.0, Note 5: Added bullet item Dryden range, facility, and information technology requirements and 3 sub bullets

Admin Change Revision H-2, 04-22-10

- Page 7, Note 5: Added Aircraft status for non-DFRC aircraft
- Page 9, Section 8.1: Added DOP-O-300

Admin Change Revision H-3, 11-17-10

- Updated footer to show that the document may distributed outside of Dryden.

Admin Change Revision H-4, 02-15-13

- Replaced references to cancelled DOP-O-300 with DCP-O-025.

Revision I, 03-04-16

- Removed DFRC/Dryden references.
- Updated to current format.
- Added concurrence signatures.
- Updated flowchart.
- Updated flowchart notes.
- Removed metrics.
- Added authority documents.
- Updated referenced documents.
- Added informational documents.
- Updated form numbers.

Admin Change, Revision I-1, 09-13-17

- DCP-X-008 renumbered to AFOP-7900.3-022 in accordance with Center instruction.
- Relevant document list numbers updated.
- References to organizations by “Code” deleted. Directorate or branch names inserted where needed.

Annex D – AGARD, RTO AND STO FLIGHT TEST INSTRUMENTATIONAND FLIGHT TEST TECHNIQUES SERIES

1. Volumes in the AGARD, RTO and STO Flight Test Instrumentation Series, AGARDograph 160

Volume Number	Title	Publication Date
1.	Basic Principles of Flight Test Instrumentation Engineering (Issue 2)	
	Issue 1: Edited by A. Pool and D. Bosman	1974
	Issue 2: Edited by R. Borek and A. Pool	1994
2.	In-Flight Temperature Measurements by F. Trenkle and M. Reinhardt	1973
3.	The Measurements of Fuel Flow by J.T. France	1972
4.	The Measurements of Engine Rotation Speed by M. Vedrunes	1973
5.	Magnetic Recording of Flight Test Data by G.E. Bennett	1974
6.	Open and Closed Loop Accelerometers by I. McLaren	1974
7.	Strain Gauge Measurements on Aircraft by E. Kottkamp, H. Wilhelm and D. Kohl	1976
8.	Linear and Angular Position Measurement of Aircraft Components by J.C. van der Linden and H.A. Mensink	1977
9.	Aeroelastic Flight Test Techniques and Instrumentation by J.W.G. van Nunen and G. Piazzoli	1979
10.	Helicopter Flight Test Instrumentation by K.R. Ferrell	1980
11.	Pressure and Flow Measurement by W. Wuest	1980
12.	Aircraft Flight Test Data Processing – A Review of the State of the Art by L.J. Smith and N.O. Matthews	1980
13.	Practical Aspects of Instrumentation System Installation by R.W. Borek	1981
14.	The Analysis of Random Data by D.A. Williams	1981
15.	Gyroscopic Instruments and Their Application to Flight Testing by B. Stieler and H. Winter	1982
16.	Trajectory Measurements for Take-off and Landing Test and Other Short-Range Applications by P. de Benque D'Agut, H. Riebeek and A. Pool	1985

Volume Number	Title	Publication Date
17.	Analogue Signal Conditioning for Flight Test Instrumentation by D.W. Veatch and R.K. Bogue	1986
18.	Microprocessor Applications in Airborne Flight Test Instrumentation by M.J. Prickett	1987
19.	Digital Signal Conditioning for Flight Test by G.A. Bever	1991
20.	Optical Air Flow Measurements in Flight by R.K. Bogue and H.W. Jentink	2003
21.	Differential Global Positioning System (DGPS) for Flight Testing by R. Sabatini and G.B. Palmerini	2008
22.	Application of Fiber Optic Instrumentation by L. Richards, A.R. Parker Jr., W.L. Ko, A. Piazza and P. Chan	2012
23.	Application of IRIG 106 Digital Data Recorder Standards for Flight Test by J.M. Klijn and B.A. Lipe	2020

2. Volumes in the AGARD, RTO and STO Flight Test Techniques Series, AGARDograph 300

Volume Number	Title	Publication Date
AG237	Guide to In-Flight Thrust Measurement of Turbojets and Fan Engines by the MIDAP Study Group (UK)	1979

The remaining volumes are published as a sequence of Volume Numbers of AGARDograph 300.

Volume Number	Title	Publication Date
1.	Calibration of Air-Data Systems and Flow Direction Sensors by J.A. Lawford and K.R. Nippress	1988
2.	Identification of Dynamic Systems by R.E. Maine and K.W. Iliff	1988
3.	Identification of Dynamic Systems – Applications to Aircraft	
	Part 1: The Output Error Approach by R.E. Maine and K.W. Iliff	1986
	Part 2: Nonlinear Analysis and Manoeuvre Design by J.A. Mulder, J.K. Sridhar and J.H. Breeman	1994
4.	Determination of Antenna Patterns and Radar Reflection Characteristics of Aircraft by H. Bothe and D. McDonald	1986
5.	Store Separation Flight Testing by R.J. Arnold and C.S. Epstein	1986
6.	Developmental Airdrop Testing Techniques and Devices by H.J. Hunter	1987
7.	Air-to-Air Radar Flight Testing by R.E. Scott	1992
8.	Flight Testing under Extreme Environmental Conditions by C.L. Henrickson	1988
9.	Aircraft Exterior Noise Measurement and Analysis Techniques by H. Heller	1991
10.	Weapon Delivery Analysis and Ballistic Flight Testing by R.J. Arnold and J.B. Knight	1992
11.	The Testing of Fixed Wing Tanker & Receiver Aircraft to Establish Their Air-to-Air Refuelling Capabilities by J. Bradley and K. Emerson	1992
12.	The Principles of Flight Test Assessment of Flight-Safety-Critical Systems in Helicopters by J.D.L. Gregory	1994
13.	Reliability and Maintainability Flight Test Techniques by J.M. Howell	1994
14.	Introduction to Flight Test Engineering	
	Issue 1: Edited by F. Stoliker	1995
	Issue 2: Edited by F. Stoliker and G. Bever	2005

Volume Number	Title	Publication Date
15.	Introduction to Avionics Flight Test by J.M. Clifton	1996
16.	Introduction to Airborne Early Warning Radar Flight Test by J.M. Clifton and F.W. Lee	1999
17.	Electronic Warfare Test and Evaluation‡ by H. Banks and R. McQuillan	2000
18.	Flight Testing of Radio Navigation Systems by H. Bothe and H.J. Hotop	2000
19.	Simulation in Support of Flight Testing by D. Hines	2000
20.	Logistics Test and Evaluation in Flight Testing by M. Bourcier	2001
21.	Flying Qualities Flight Testing of Digital Flight Control Systems by F. Webster and T.D. Smith	2001
22.	Helicopter/Ship Qualification Testing by D. Carico, R. Fang, R.S. Finch, W.P. Geyer Jr., Cdr. (Ret.) H.W. Krijns and K. Long	2002
23.	Flight Test Measurement Techniques for Laminar Flow by D. Fisher, K.H. Horstmann and H. Riedel	2003
24.	Precision Airdrop by M.R. Wuest and R.J. Benney	2005
25.	Flight Testing of Night Vision Systems in Rotorcraft by G. Craig, T. Macuda, S. Jennings, G. Ramphal and A. Stewart	2007†
26.	Airborne Laser Systems Testing and Analysis by R. Sabatini and M.A. Richardson	2010
27.	Unique Aspects of Flight Testing Unmanned Aircraft Systems by A.E. Pontzer, M.D. Lower and J.R. Miller	2010
28.	Electronic Warfare Test and Evaluation by M. Welch and M. Pywell	2012
29.	Aircraft/Stores Compatibility, Integration and Separation Testing by O. Nadar	2014
30.	High Altitude Rotary Wing Flight Testing – Considerations in Planning Rotary Wing Performance Testing for High Altitude Operations by J. O'Connor, J. McCue, J. Holder and B. Carrothers	2018
31.	Reduced Friction Runway Surface Flight Testing – Wet Runway Taxi Test Procedures at Edwards AFB by T.E. Lundberg	2018

‡ Superseded by Volume 28.

† Volume 25 has been published as RTO AGARDograph AG-SCI-089.

Volume Number	Title	Publication Date
32.	Flight Test Safety and Risk Management by D. Morley, J. Newsome, D. Moore, P. Comeau, B.A. Neal, P.C. Stoliker, A. Karwal, C. Buck, Ö. Kirli, C.B. Rice, F.P. Henderson, J.R. Stevenson, and J.A. Mortensen	2021

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12. Distribution Statement
There are no restrictions on the distribution of this document. Information about the availability of this and other STO unclassified publications is given on the back cover.

13. Keywords/Descriptors
Flight Test Risk Management; Flight Test Safety; Flight Test Safety Management; Safety Management Systems

14. Abstract
This AGARDograph investigates the current approaches across the NATO Nations in the field of Flight Test Safety and Risk Management. It originates from a view held by the NATO STO Flight Test Technical Team (FT3) that there was broadly common process and a wish to demonstrate this through capturing examples of practice and analysing them. This became the mission of Task Group SCI-236 and this AGARDograph records the findings. It offers examples of practice captured in a broadly common format from a representative sample of Flight Test Organisations and an analysis of their content. It concludes that the views of FT3 are substantiated and that at the baseline level there is significant commonality of approach in relation to people, process, facilities and tools. Detailed content is clearly different, but the similarities offer a framework that can be used to support those embarking upon the creation of a Flight Test Safety Management System or desiring to compare and contrast an existing one.

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