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A presentation on: Cockpit Development & Assessment,
a Test Pilot School perspective
To: European Flight Test Working Group

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Cockpit Development & Assessment, a Test Pilot School perspective

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Empire Test Pilots’ School (ETPS) Fixed Wing Flight Test Tutor

30 October 2013
Overview

• ETPS & Systems Curriculum
• Design & Test Cycle
• Cockpit Assessment
• Systems Assessment
• Reporting
• Examples
Empire Test Pilots’ School
ETPS background -1

- Unique UK MOD training facility since 1943
- MOD Boscombe Down, UK
- Aircraft Test & Evaluation Centre
- Partnership UK MOD and QinetiQ
- UK MOD and foreign customers training
  - Test Pilots (TP)
  - Flight Test Engineers (FTEs)
  - Rotary and Fixed Wing tracks
ETPS Aircraft

46 aircraft types, incl. QE aircraft in 2012
ETPS Graduate Courses -1

• Class A (1 year) [Class B (6 months)]
  – Meets EASA CAT-1 rating requirements [CAT-2 FT]

• Ground School
  – 400 (50 systems)

• Flying
  – 110 hours, 15 types

• Content
  – Stability & Control, Handling Qualities
  – Performance
  – Systems
ETPS Graduate Courses -2

Specific Course Objectives:

- teach a philosophy which can be applied to any type of flight testing
- develop sound academic background to flight test
- teach and practice airborne test techniques
- develop skills in the analysis and presentation of flight test results
- develop a broad knowledge of all aviation matters
- promote team building skills by providing the opportunity of working with pilots and FTEs from a wide variety of nationalities and backgrounds
- for FTE students, to teach and develop the skills required to operate in the airborne environment
Systems Exercises -1

1. Cockpit Assessment (any type in hangar)
2. Intro to Workload (CBT)
3. Intro to Systems (KingAir, Gazelle, Tornado)
4. Integrated systems (ASTARS)
5. ACAS (KingAir, A109)
6. Night Vision (test house)
7. Head Mounted Display (F16 rig, Bell 205, MAT Huey, Apache)
8. Integrated Flight Decks/FMS (Airbus, Boeing, Merlin)
9. Military Systems (Gripen, C130J, Apache)
10. Preview (relevant type)
Systems Exercises -2

- Cycle: Groundschool > Demo > Exercise
- Syndicates vs Individual
- Exercise Cycle
  - Planning, Execution, Reporting
- Systems
  - Quantitative/Performance assessment
  - Qualitative assessment
  - Design and Interface development
Acquisition, Development & Test Cycle
Life Cycle, V-model

DT&E vs OT&E
Lifecycle

• Iterative design & evaluation process
• Initial design
  vs
• In-service:
  – Changes of Role
  – Changes of capability
  – Modifications
  – Changes of population
• Assess Suitability of Operational Role
Test Type vs Standard (vs customer?)

- Experimental T&E: Research objectives
- Developmental T&E: Design specs/requirements
- Operational T&E: Key User Requirements*
- Certification: CS/FAR series, MilSpec, DefStan 00-970
- Acquisition: Key User Requirements*
- Acceptance: Contract

* Critical Operational Issues (operational effectiveness, suitability)
Roles

• Need for Role definition
• Need for Task definition
• Need for Authority Specification?
• Need for Design Specification/description?

Aircraft Role

&

Tester Role
Development & Test Assets -1

• Operator/Testpilot involvement
• Continuous assessment loop
  – Drawing board, Powerpoint
  – Mock-up
  – Rig, Simulator
  – Virtual Reality
  – Cockpit
    • Ground Test
    • Flight Test: DT&E, OT&E
Development & Test Assets -2

- All have their pros & cons
  - Levels of efficiency, realism, flexibility
  - Limitations, cost, availability

- All have their Value and Place in time

- Essential:
  - Changes to developers and testers
    - Obtain continuity to maximum extent
  - Design trade-off/priorities
    - Keep record of design decisions
Cockpit Assessment
Purpose of Cockpit

• 3 basic functions:
  – Control
  – Information
  – Accommodation

• Suitability
  – Depends on Role
All very different cockpits, but they may each be (un)satisfactory for the Role.
Cockpit Design

• Cockpit design
  – Ergonomics / Human Factors
  – Human Machine Interface (HMI or PVI)
  – Physical & Mental component

• Elements
  – Control: Steering, Systems
  – Information: Display video, Audio, Tactile
  – Accommodation Environment, Field of View, Lighting, Access, Comfort, “Basic” needs
Assessment Objectives

- To determine if cockpit provides suitable environment for effective and efficient operation and control of the aircraft and its systems during the mission
  - Assess suitability for a Role
  - Identify Design specs/assumptions
  - Define scope/conditions
  - Identify shortcomings/deficiencies
  - Role Relate
  - Recommend improvements or further testing
Typical Cockpit Assessment items -1

– Opening/Closing doors/canopies
– Normal entry/exit
– Seat adjustment (DEP/REP)
– Strap-in
– Field of Regard/View
– ........
Cockpit Ingress

First action: lower the seat to make room

Crouch and lean forward, place leg far side of control column

Slide over the seat, lack of hand holds made this tricky

Lift left leg over the centre console
Emergency Egress .....
Why is FoV important?
Field of View plot (DEP/REP)
Typical Cockpit Assessment items -2

– Aircraft Inceptors/Flying Controls
  • Reach, adjustment
  • Deflection, fouling

– Actuators/Controls
  • Buttons, Switches, Knobs, Cranks, Levers, etc
  • Location, Reach, Feel, Shape, Labelling, Colour, Operation

– Displays/Instruments:
  • Location/Priority, Arrangement, Grouping
  • Size, readability, scaling, info/failure/limit presentation
  • Visibility/Lighting

– Warning/Attention getting, incl. tactile + audio
Considerations/Limitations

- Static vs Dynamic: often done on ground/sim/rig
- Environment
  - Day/night, Lighting, wind/precipitation, hangar/ship/platform, vibration, temp
- Variation in anthropometrics
- Flying Clothing
- “Fly” representative tasks
  - Operational tasks
  - Normal/emergency proc’s
- Multiple evaluators: opinion
Assessment Tools

- Tasks/Testcards
- Flight Manual, checklist
- Inclinometer, Protractor, String, pencil
- Tape measure, Stopwatch
- Camera
- Flight Gear
Cockpit Assessment: Risks

– Aircraft Safe for Maintenance
  • Ejection seat, Canopy, Gear pins
– Operating APU
  • Noise
– Electrical/Hydraulic systems
  • Switches live with power off or battery on
  • Fire extinguisher buttons, Hook release
  • Flaps
– Operating Flight controls
  • Irreversible vs Reversible, cordon
– Operating at height
Cockpit vs Systems

• Non-MFD:
  – Assess operations of separate navigation, comms, transponder subsystems
  – powering on/off, testing, changing modes, codes, settings and frequencies

• MFD:
  – Assess hardware
    • Controls, reach
  – Assess displays
    • visibility
  – Don’t assess software functionality and menu structure
Test Plan

- Objectives
- Requirements
- Scope/Conditions
- Tasks
- Methods
- Recording
- Risks
- Test Cards
Systems Assessment
System vs Roles/Tasks: Questions

• Descriptions for both?
• Expertise in both?
• Experience with both?
• Crew concept/roles?
• Standalone vs Integrated system?
• External signals/input/support required?
• Performance and/or HMI?
HMI/PVI

• Control and Display

• Information:
  – clear, timely, correct, unambiguous
  – Not too little/early, too much/late, incorrect, ambiguous, confusing etc

• Representative Tasks and Environment

• Ground vs Flight
  – build up

• Setting options: low end, middle and high end
Test data: generic questions

1. Effectiveness
   • can I accomplish something I need/want to

2. Efficiency
   • can I accomplish this quick and easy

3. Error
   • can I accomplish this without chance of making an input/output error

4. Inadvertent
   • can I accomplish this without messing up something else
Test Data

• Quantitative:
  – Measurements: FoV, Reach, Head movement
  – Time required
  – Actions/Steps required
  – Workload?

• Qualitative:
  – Subjective
    • Opinion, Background, Experience, Culture, Bias
    • Multiple testers
  – Workload?
Taskload vs Workload

• Taskload:
  – Task demands
  – Objective measure (number of operations, cycle time)

• Workload:
  – Experience of the task demands (i.e. a feeling)
  – Subjective measure (perceived level of cognitive and physical load)
Subjective Workload Ratings

- Can be used “real-world” (vs “simulated”)
- Administered during/after task execution
  - Non-intrusive to primary task
  - Ease and speed of application, low cost
  - Risk of “fading”: assign immediately after task
- Multi-dimensional: more complicated
- Uni-dimensional: simple and quick
  - Usually ordinal and non-linear
  - Flight Test: sensitivity, simplicity, non-intrusiveness
Multi-dimensional

• Good diagnosticity, relatively complex, interval data

• Example: NASA TLX
  – Derives an overall WL rating based on 6 sub-scales
    1. Mental Demand (+ perceptual activity)
    2. Physical demand (physical activity)
    3. Temporal demand (time pressure)
    4. Effort (how much work)
    5. Performance
    6. Frustration level
Uni-dim­en­sion­al

• Easy, sim­pli­city, sen­sitivity
• Low di­ag­nost­i­city, ordi­nal, non-linear
• Ex­am­ples
  – Modified Cooper-Harper (MCH)
  – Bedford
  – Sub­jec­tive Work­load As­sess­ment Tech­nique (SWAT)
  – Sub­jec­tive Work­load Do­mi­nance (SWORD)
  – Mal­ver­n Cap­acity Es­ti­mate (MACE)
Bedford Workload Rating Scale

Always start here
Display Readability Scale

**Haworth-Newman Display Readability Rating Scale (From Haworth 1993)**

**Parameter Characteristics**
- Excellent, highly desirable
- Good, negligible deficiencies
- Fair, some mildly unpleasant deficiencies
- Minor but annoying deficiencies
- Moderately objectionable deficiencies
- Very objectionable but tolerable deficiencies
- Major deficiencies
- Major deficiencies
- Major deficiencies
- Major deficiencies

**Demands on pilot in selected task of required operation**
- Pilot compensation not a factor for desired performance
- Pilot compensation not a factor for desired performance
- Minimal pilot compensation required for desired performance
- Desired performance requires moderate pilot compensation
- Adequate performance requires moderate pilot compensation
- Adequate performance requires extensive pilot compensation
- Adequate performance not attainable with maximum tolerable pilot workload
- Considerable pilot compensation is required to interpret symbology
- Intense pilot compensation is required to interpret symbology
- Symbology cannot be used for required operation

**Pilot Rating**
- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10
Tolerances

• Applying Desirable vs Adequate tolerances
  – 100 vs 75% of time
  – <½ dot vs <1 dot
  – <20 vs <30 sec
  – Used on MCHs

• Bottom Line: Need clearly defined tasks
Examples of Tasks

• Context: Manual ILS in crew concept
  – PF tasks:
    • Primary task: Maintaining LOC/GS on speed
      – physical, mental, temporal, performance
      – so not just the aircraft handling
    • Secondary task: listening radios/crew, read back, checks
  – PNF tasks:
    • Primary Task: Programming ILS box, no error, <20 sec
    • Secondary: monitor instruments, making radio calls etc.
Test Reporting
7-part paragraph

1. Test and Test Conditions
2. Present the Data
3. Analyse & Discuss the Data
4. Role Relate
5. Conclude
6. Recommend
7. Specification Compliance

*optional: supporting imagery
Reporting considerations

- Detailed data and analysis
  - Ratings used to standardise and categorise, still need to describe and analyse results
- Unambiguous
- Scope, Limitations
  - To include detail on hardware/software config
- Repeatable
  - Seat adjustment, DEP/REP
  - Anthropometrics
  - Task, Methods, Environment
A few Examples
Yak-52 Gear/Flap design
F-16 M3 HMD design
F-16 HSI to COTS E-HSI modification
1. ORIGINAL EHSI DISPLAY

2. REVISED BASELINE EHSI DISPLAY

- Yellow Hdg Marker
- Outer Portion of Hdg Marker Moved Beyond Heading Tics
- HDG and CRS Labels on Knobs
- CRS Arrow Made Thinner and Moved Outward to 5-Degree Hdg Tics
- Allow CDI Deflection Beyond Two Dots
- CDI Lengthened, Gap Created Between Course Needle and CDI (See 4 below)
- PLS Replaced with ILS (consensus)
- Digital Heading Indication Removed
- Triangular Compass Indices Replaced with Bold Tic Lines
Bottom Line

• Test crew involved in design cycle from start
• Understand Requirements and Role
• Assess by executing representative tasks
• Understand limitations
• Maintain records of results and decisions
• Identify assessment risks
• Testing is not a trick, but a philosophy
• Never forget who the real customer is ....
The User

Questions & Discussion
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