Creating Models of Truth to Describe Very Complex Automated Systems

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Introduction – My Experience
Outline

- Introduction
- Why Pilots Need to Understand Systems?
- What Systems?
- Visualizing Systems
- Methods of System Description
- Complex Systems Problems
- Describing Systems
- Who Can Help?
Why Pilots Need to Understand Systems?

- EHEST HE-9 – Outlines the problem
- Understanding Limitations
  - Flight Manual
  - OMB
- Delivering Operational Safety
  - What mode is right and when?
  - What is best practice?
- Emergency and Malfunction Response
  - What the aircraft is really telling you?
  - How should you react?
Visualising Systems

It Used to be Easy....

To model this....
Visualising Systems

But now....

How can this be modelled?
A simple SAS modelled graphically and easy to understand
Methods of System Description – Diagrams 2

A complex AFCS FM - boxes and lines with no ability to really drive understanding
Complex Software Systems – Problems of Explanation

- Difficult to Model and Visualise
- Tends to Drive Block Diagrams and Copious Requirements
- Engineering Rather than Operational Philosophy
- Over-Reliance on Limited Simulator/Aircraft Time – Especially for Failure Modes
For each Series Actuator, the Series Actuator Control Function shall enter the Failed State and remain in the Failed State for 5 sec when any of the AFCS Series Actuator Monitors relevant to the corresponding axis actuator of the considered channel is not satisfied.

- Does this help operator understanding?
- There are 1000s of these for the Flight Control System attempting to describe, in requirements speak, how the system should work
Complex Software Systems Design Documentation

But sometimes they contain gold dust like this
OEB Defines the Key Areas and Training Issues

8.8 Specifications for particular emphasis during training

The OEB recommends the Training Organisations to put particular emphasis for all the variants the correct use of:

- manual engine and acknowledgement of related chart from engine maintenance manual;
- OEI TNG and limitations, WAT chart and correct profiles.

Furthermore for the AW109SP, while is considered to have high level of automatism, to pay particular attention to the correct use of:

- 3D Displays;
- F/D upper modes and limitations;
- VFR/IFR approach and limitations;
- GATU button and difference;
- Highway in The Sky (HTS);
- Terrain Awareness & Warning System (TAWS);
- TCAS;
- Flight Planning

But in scant detail and invariably textually based.
## Describing Systems - RFM

### Section 1: Limitations

**AW189**

### Airspeed Limitations

- **Vne (Never Exceed, Cannot Be Exceed):** 450 KIAS
- **Maximum Approached:** 370 KIAS
- **Maximum Maintained:** 320 KIAS
- **Minimum Required:** 250 KIAS
- **Minimum Climb:** 150 KIAS

### Ground Speed Limitations

- **On Paved Surfaces:** 20 knots
- **On Grass Surfaces:** 15 knots

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### Section 7: System Description

- **AFCS - Controls and Displays**

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- **Lots of text**
- **Small pictures**
- **Too much data/numbers etc**
Describing Systems – Training Materials and Manuals

- Some good notes but variable quality
- Some enthusiastic instructor-produced diagrams
- CBT – the (nearly)good, the bad and the ugly

Training Notes

OEM Guides
Describing Systems - OMB

AFCS

Take off is not permitted with a SSA engaged

When operating in a degraded AFCS mode, the pilot will be attentive to the flight controls when in ATT mode and will manually control the aircraft when flying in SAS mode.

Max demoed IFR App Gradient > 91 kts: 4° (6.93%) 750' min @ 100 kts
Max demoed IFR App Gradient < 90 kts: 7° (12.13%) 1250' @ 50 kts
Min ht for coupled ops > 121 kts: 200' AGL
Coupled flight < 100' AGL is only permitted when VMC
Min ht for coupled ops < 120 kts: 50' AGL
Coupled SAR Ops < 200' ASL: Pilot hands on
Min ht for coupled SAR ops: 30' ASL
Coupled SAR Ops will only be conducted < 50 KIAS when the pilot has adequate visual cues to maintain hover height using external refs
RADALT setting: 30' + ½ wave ht for waves < 10', x 2 wave ht for waves > 10'
Collective axis power limiting: when coupled, system will limit power to avoid exceedances as follows:
Min
Max Continuous Tq: (100% or 86% x 2 Eng, 120% x 1 Eng)
TGT: (93.5 x 2 Eng, 988 x 1 Eng)
Ng: (99.9% x 2 Eng, 102.4% x 1 Eng)
CFD in collective axis will change from Max Contin to Take Off pwr when descending < 200 AGL and will revert to Max Contin when climbing > 300' AGL.

AFCS DGRD indicates that one or more sensors in the AFCS has failed or lost comms. May be accompanied by an FD DGRD.
Emergency & Malfunction Procedures

AFCS DEGRADED

- Poorly described FM
- Doesn’t really tell you what has gone?
- Some ambiguity

AP DEGR

Loss of ADI Stby data
Be aware that a subsequent AHRS failure may cause both AP channels to disengage

- Continue flight attentive reducing speed to 110 KIAS
- Below 500 ft AGL fly manually
So What Models Can be Used?

- **Simulators**
  - Whole Aircraft System?
  - Often compromised
  - Certification is poor at detailing failure mode operation

- **Partial Task/System Devices**
  - Tend to be engineering focused?
  - Emerging technologies

- **Videos and Animations**
  - Not widely used
  - Expensive to produce

- **Documents and Notes**
  - Context and language
  - Avoid Lists
  - Make use of diagrams and flow charts
Better Visual and Pictorial Models - 1

Flow Charts and Diagrams rather than text
Better Visual and Pictorial Models -2

- Don’t be afraid to simplify

- Pilots are human, aid understanding don’t emphasize complexity
What Can ATOs do to Help?

- Avoid engineering focused ground training materials
- Look for intermediate flight training devices that focus on practical demonstration of system operations including failure modes
  - Remember that old school broken parts based training was highly effective
  - Seek to fully model flight control input to rotor blade output
- Structure progressive training with intermediate steps between classroom and simulation
- Consider a little and often approach to training delivery
What Can OEMs do to Help?

- Take Operator derived design support at the earliest possible opportunity
- Offer continuous design improvement – Golf 1 to Golf 7
- Improve Flight Manual sections for Automatic Flight Control Systems
- Provide design engineering support to Training Providers – Recognise that the aircraft OEM is not the only provider.
- Consider training methodologies and requirements during the design process – make the models early
- Consider new types of training devices that model AFCS modes and failures
  - Online Continuous
  - Desktop
  - Partial System Simulation
  - Animations
- Is there a new way to model complex AFCS systems that focusses on how it works/fails outside of a simulator?
Summary

- New Systems demand new models
- Whole aircraft FSTD does not necessarily build deep technical knowledge
- Coordinated OEM, ATO and Operator engagement required
- FOBN a great first start but it should be wider.
- The earlier you link design engineers with operational pilots the better.