Lecture 13
Handling Qualities

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Handling Qualities

- The pilot's judgement of the flying qualities of an aircraft is based on the feel of the stick (and rudder pedals) and on the aircraft's response to commands like these. Ideally, the aircraft should feel the same throughout the flight envelope.

- There are established criteria for assessment of handling qualities, longitudinal and lateral, derived from tests using *variable-stability aircraft* and *ground-based simulators*.

Handling Qualities

- but there are many others which are less amenable to simple measurement:

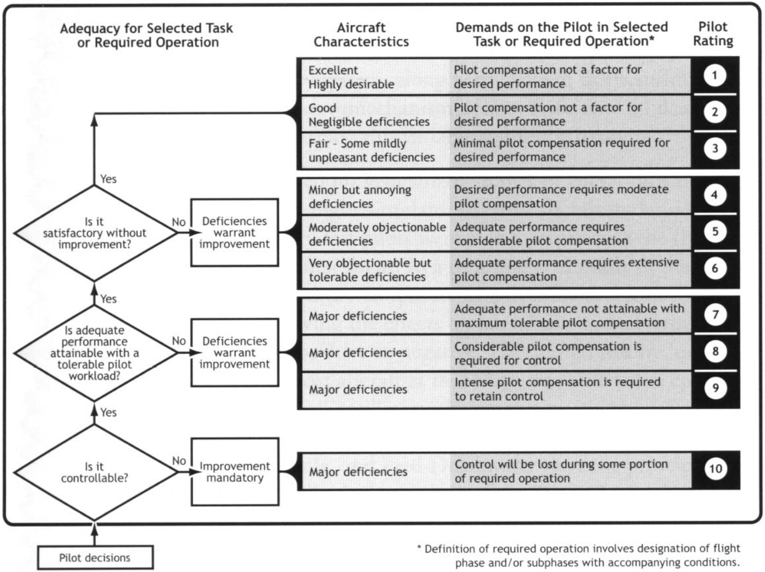
  - pilot's workload
  - pilot's view/visibility
  - control linearity
  - instrument layout
  - ride quality in gusts
  - response while flying at high α.

- Such studies of HQ are a large specialist field and we look here at only one small range of HQ criteria - those for short period and phugoid roots.

The Cooper-Harper Rating Scheme

- The Cooper-Harper rating scale is a set of criteria used by test pilots and flight test engineers to evaluate the handling qualities of aircraft during flight tests.
- The scale ranges from 1 to 10, with 1 indicating the best handling characteristics and 10 the worst.
- Pilot Opinion sometimes difficult to evaluate!

Handling Qualities Rating Scale



* Definition of required operation involves designation of flight phase and/or subphases with accompanying conditions.

Short Period

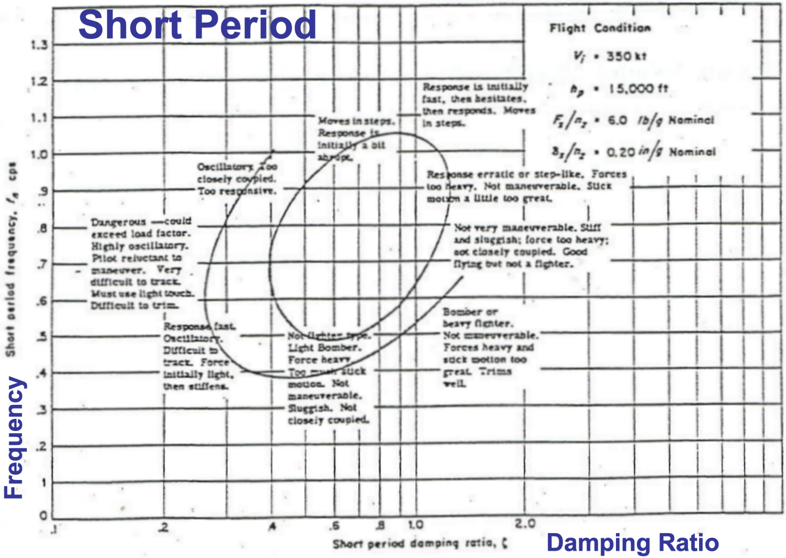


Fig. 4a Pilots' attitudes to dynamic response factors

Plot taken from Kolk, Prentice-Hall 1961, shows flight test results from late 1950's.

Desired HQ: $\zeta = 0.7$, $\omega_n = 0.5$ Hz

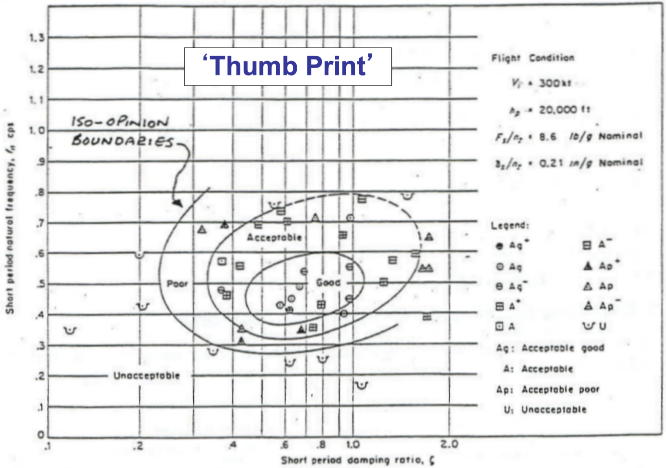
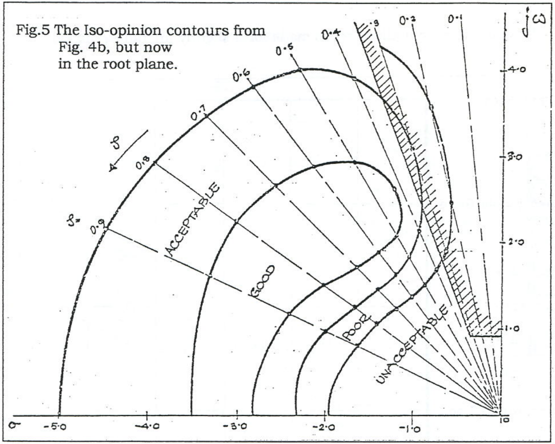


Fig. 4b The infuence of Short-Period roots on Handling Qualities

Short Period Handling Qualities



Note the boundary defined by a constant damping ratio $\zeta = 0.35$ is marked (above a minimum frequency), as this is part of a U.S. Mil. Spec.

Phugoid Handling Qualities

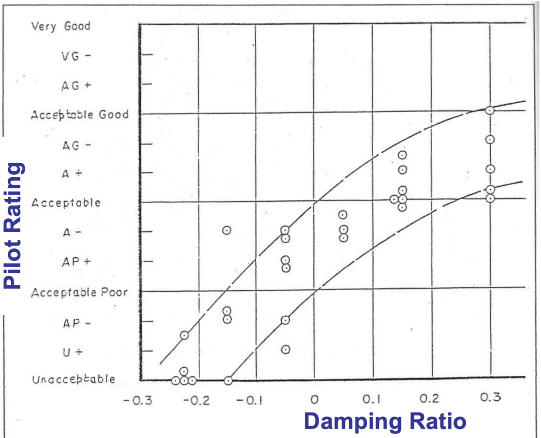


Fig. 6 The influence of Phugoid Roots on pilot opinion

- More difficult!
- Generally pilot rating improves with phugoid damping
- Small <u>negative</u> damping of the phugoid is tolerable

Short Period and Phugoid - Flight Dynamics Principles

Table 10.4 *Short period mode damping*

Flight phase	*Level 1* ζ_s *min*	*Level 1* ζ_s *max*	*Level 2* ζ_s *min*	*Level 2* ζ_s *max*	*Level 3* ζ_s *min*
CAT A	0.35	1.30	0.25	2.00	0.10
CAT B	0.30	2.00	0.20	2.00	0.10
CAT C	0.50	1.30	0.35	2.00	0.25

Table 10.5 *Phugoid damping ratio*

Level of flying qualities	*Minimum* ζ_p
1	0.04
2	0
3	Unstable, period $T_p > 55$ s

Roll Subsidence and Spiral Mode - Flight Dynamics Principles

Table 10.6 *Roll subsidence mode time constant*

		Maximum value of T_r (seconds)		
Aircraft class	*Flight phase category*	*Level 1*	*Level 2*	*Level 3*
I, IV	A, C	1.0	1.4	—
II, III	A, C	1.4	3.0	—
I, II, III, IV	B	1.4	3.0	—

Table 10.7 *Spiral mode time to double bank angle*

	Minimum value of T_2 (seconds)		
Flight Phase category	*Level 1*	*Level 2*	*Level 3*
A, C	12	8	5
B	20	8	5

Dutch roll - Flight Dynamics Principles

Table 10.8 *Spiral mode time constant*

Flight phase category	*Minimum value of T_s (seconds)*		
	Level 1	*Level 2*	*Level 3*
A, C	17.3	11.5	7.2
B	28.9	11.5	7.2

Table 10.9 *Dutch roll frequency and damping*

		Minimum values							
		Level 1			*Level 2*			*Level 3*	
Aircraft class	*Flight phase*	ζ_d	$\zeta_d\omega_d$	ω_d	ζ_d	$\zeta_d\omega_d$	ω_d	ζ_d	ω_d
I, IV	CAT A	0.19	0.35	1.0	0.02	0.05	0.5	0	0.4
II, III	CAT A	0.19	0.35	0.5	0.02	0.05	0.5	0	0.4
All	CAT B	0.08	0.15	0.5	0.02	0.05	0.5	0	0.4
I, IV	CAT C	0.08	0.15	1.0	0.02	0.05	0.5	0	0.4
II, III	CAT C	0.08	0.10	0.5	0.02	0.05	0.5	0	0.4

Short Period - Flight Dynamics Principles

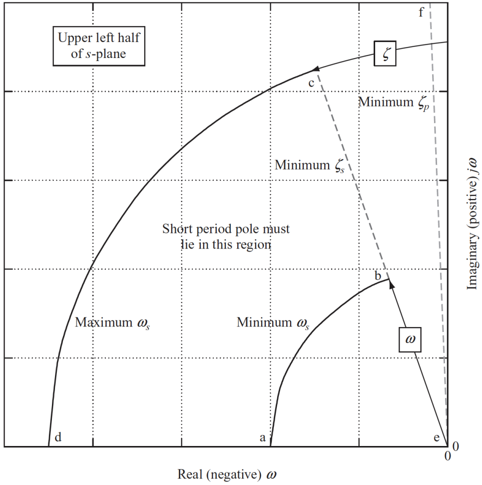


Figure 10.9 *Longitudinal flying qualities requirements on the s-plane.*

Dutch Roll - Flight Dynamics Principles

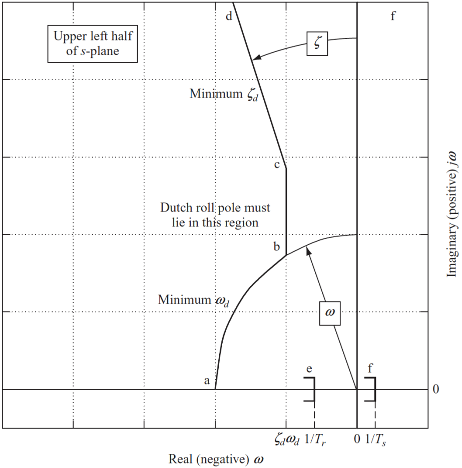
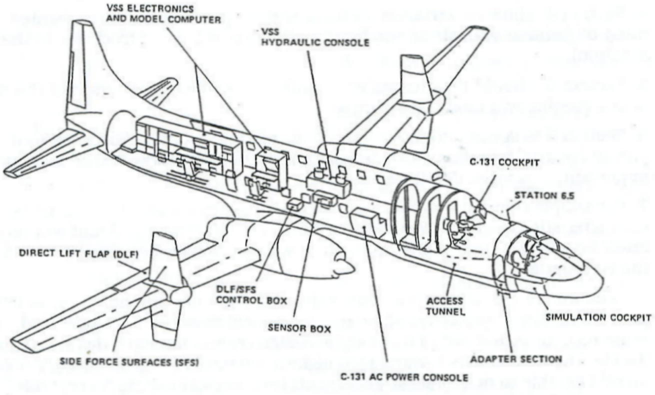


Figure 10.10 *Lateral–directional flying qualities requirements on the s-plane.*

'In Flight Simulator'

Computers Force the real aircraft to follow a trajectory mapped out for a theoretical aircraft – e.g. Shuttle!



TIFS : TOTAL IN-FLIGHT SIMULATOR.

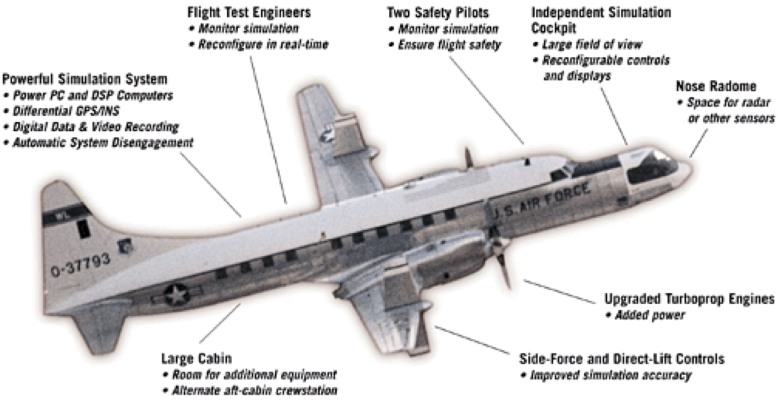
‘In Flight Simulator’

- The TIFS is the most capable in-flight simulator. It is operated by Calspan under a Cooperative Research and Development Agreement (CRADA) for the US Air Force Research Laboratory (AFRL).
- The TIFS is a highly modified Convair-580 (AF C-131) twin turboprop transport. Calspan finished the development of this IFS in 1970 and has operated it ever since on over 30 major aircraft development and research programs.
- The TIFS unique features include a separate two-place evaluation cockpit and control over all six rigid-body degrees-of-freedom.
- Special aerodynamic controls (including sideforce and direct lift surfaces) and a model-following control system permit the TIFS to produce motions at the simulation cockpit that completely duplicate the computed responses of the simulated aircraft.

TIFS - Reconfigurable Simulation Cockpit

The primary use has been in the development and evaluation of new aircraft flying qualities, flight controls, and cockpit displays, as well as general flight research in these areas.

‘In Flight Simulator’



Variable-Stability In-Flight Simulator Test Aircraft

- The U.S. Air Force Test Pilot School Variable-Stability In-Flight Simulator Test Aircraft (VISTA) NF-16D
- It was delivered to the USAF in 1995. VISTA is used as a research and training tool by the USAF Test Pilot School and customers worldwide.
- VISTA's unique features include a front evaluation cockpit which allows the pilot to fly the aircraft through a separate simulation flight control computer which can be programmed to simulate the response characteristics of any aircraft.
- It has a five degree-of-freedom simulation system which reproduces the three rotational, and normal and axial force characteristics of the modelled aircraft.

Variable-Stability In-Flight Simulator Test Aircraft


VAAC
QinetiQ
Active Control
Technology

Variable-Stability In-Flight Simulator Aircraft

- The Learjet Model 24 and 25 aircraft provide three degree-of-freedom (3-DOF) airborne simulation capabilities for advanced stability, control and flying qualities demonstrations and research. They are also used to test/demonstrate advanced flight control systems concepts.
- Learjet Model 24 first flew in its modified state in January of 1981.
- Learjet Model 25 began service in March of 1991.
- A third Learjet, Model 25, was purchased in 2005.

Variable-Stability In-Flight Simulator Aircraft

Variable Stability Learjet 24

Variable Stability Learjet 25

Shuttle Training Aircraft

Next Lecture

Trimming and Linearisation