

# 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  $\alpha$ .
- 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

Adequacy for Selected Task or Required Operation	Aircraft Characteristics	Demands on the Pilot in Selected Task or Required Operation*	Pilot Rating
<pre> graph TD     A{Is it satisfactory without improvement?} -- Yes --&gt; B{Is adequate performance attainable with a tolerable pilot workload?}     A -- No --&gt; C[Deficiencies warrant improvement]     B -- Yes --&gt; D{Is it controllable?}     B -- No --&gt; E[Improvement mandatory]     C --&gt; F[Deficiencies warrant improvement]     D -- Yes --&gt; G[Improvement mandatory]     D -- No --&gt; H[Major deficiencies]     E --&gt; I[Major deficiencies]     F --&gt; J[Excellent Highly desirable]     F --&gt; K[Good Negligible deficiencies]     F --&gt; L[Fair - Some mildly unpleasant deficiencies]     G --&gt; M[Major deficiencies]     G --&gt; N[Major deficiencies]     G --&gt; O[Major deficiencies]     H --&gt; P[Excellent Highly desirable]     H --&gt; Q[Good Negligible deficiencies]     H --&gt; R[Fair - Some mildly unpleasant deficiencies]     I --&gt; S[Minor but annoying deficiencies]     I --&gt; T[Moderately objectionable deficiencies]     I --&gt; U[Very objectionable but tolerable deficiencies]     J --&gt; V[Minor but annoying deficiencies]     J --&gt; W[Moderately objectionable deficiencies]     J --&gt; X[Very objectionable but tolerable deficiencies]     K --&gt; Y[Minor but annoying deficiencies]     K --&gt; Z[Moderately objectionable deficiencies]     K --&gt; AA[Very objectionable but tolerable deficiencies]     L --&gt; BB[Major deficiencies]     M --&gt; CC[Major deficiencies]     M --&gt; DD[Major deficiencies]     N --&gt; EE[Major deficiencies]     O --&gt; FF[Major deficiencies]     P --&gt; GG[Desired performance requires moderate pilot compensation]     P --&gt; HH[Adequate performance requires considerable pilot compensation]     P --&gt; II[Adequate performance requires extensive pilot compensation]     Q --&gt; JJ[Adequate performance not attainable with maximum tolerable pilot compensation]     Q --&gt; KK[Considerable pilot compensation is required for control]     Q --&gt; LL[Intense pilot compensation is required to retain control]     R --&gt; MM[Control will be lost during some portion of required operation]     </pre>	Excellent Highly desirable	Pilot compensation not a factor for desired performance	1
	Good Negligible deficiencies	Pilot compensation not a factor for desired performance	2
	Fair - Some mildly unpleasant deficiencies	Minimal pilot compensation required for desired performance	3
Minor but annoying deficiencies	Desired performance requires moderate pilot compensation	4	
Moderately objectionable deficiencies	Adequate performance requires considerable pilot compensation	5	
Very objectionable but tolerable deficiencies	Adequate performance requires extensive pilot compensation	6	
Major deficiencies	Adequate performance not attainable with maximum tolerable pilot compensation	7	
Major deficiencies	Considerable pilot compensation is required for control	8	
Major deficiencies	Intense pilot compensation is required to retain control	9	
Major deficiencies	Control will be lost during some portion of required operation	10	

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

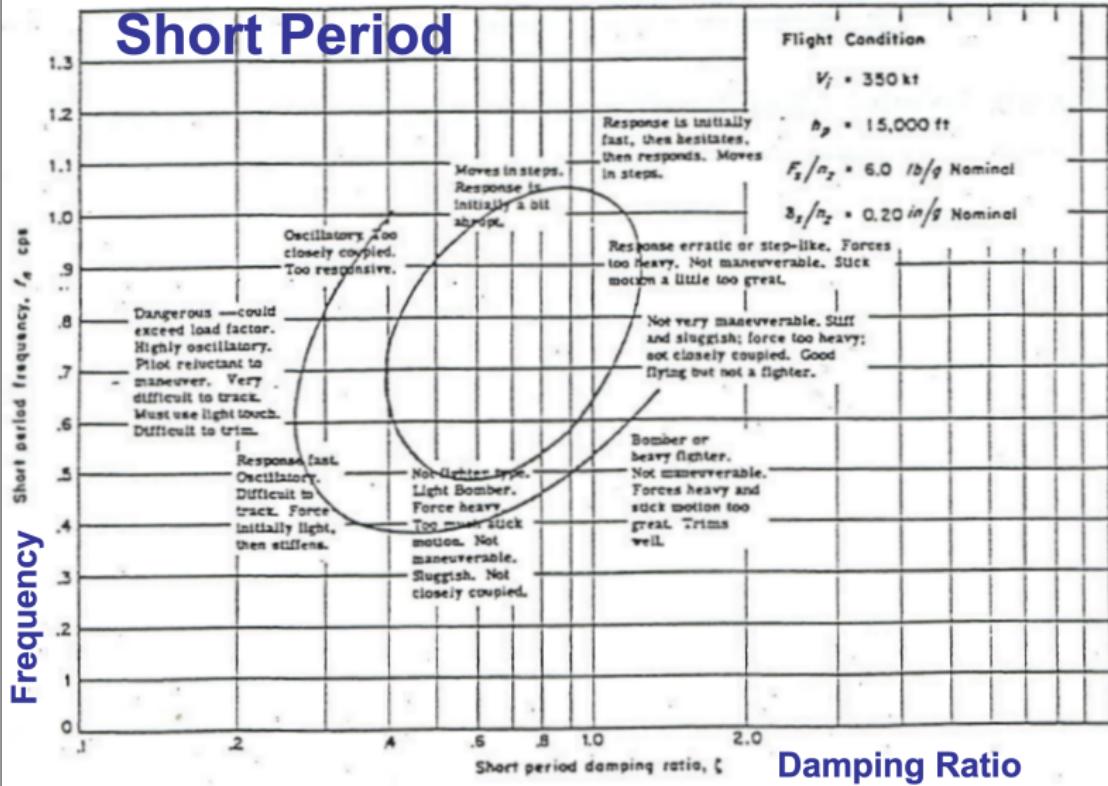


Fig. 4a Pilots' attitudes to dynamic response factors

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

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

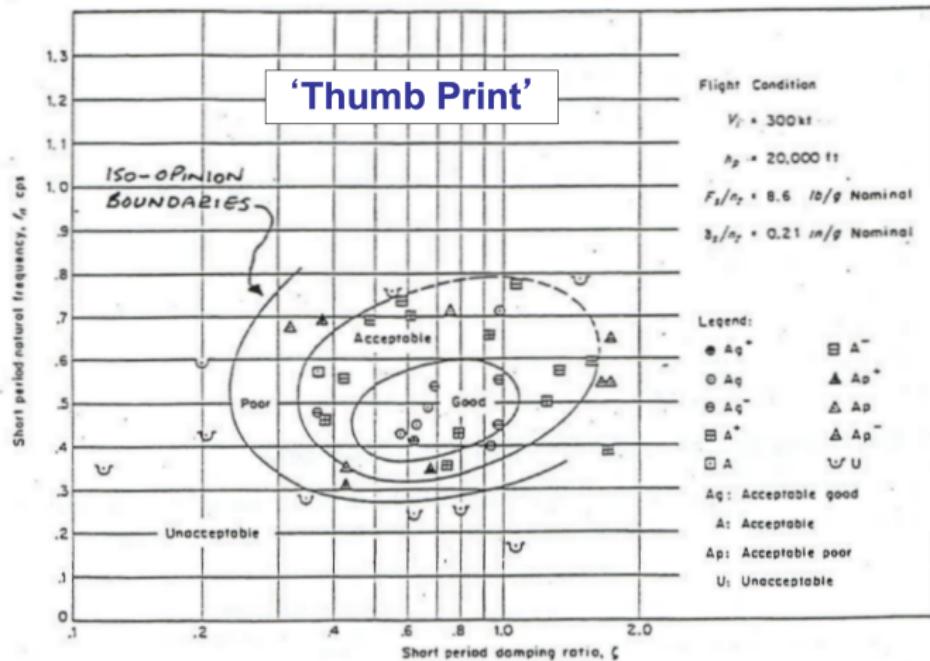
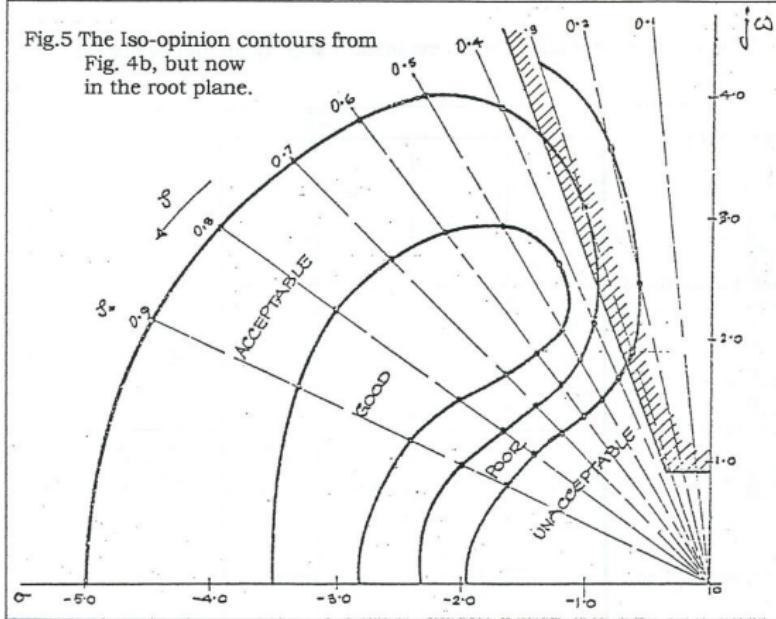


Fig. 4b The influence of Short-Period roots on Handling Qualities

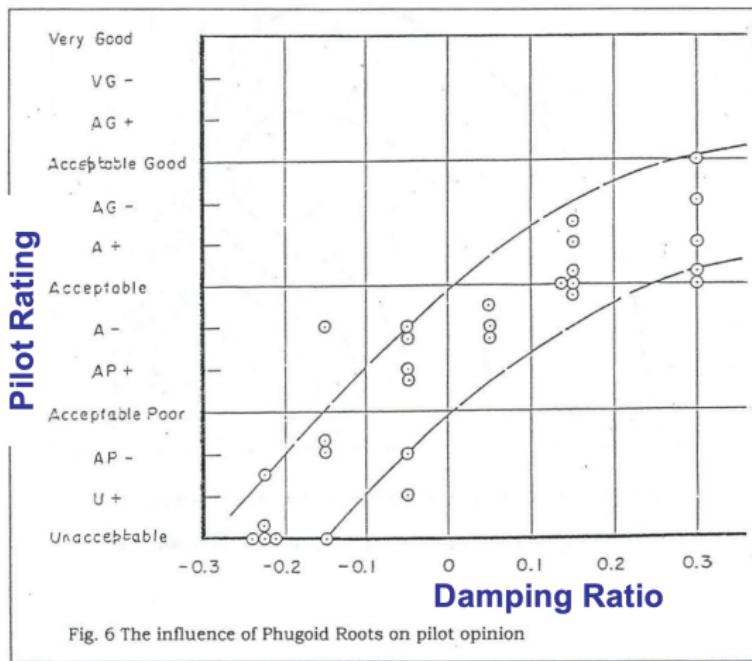
# Short Period Handling Qualities

Fig.5 The Iso-opinion contours from Fig. 4b, but now in the root plane.



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



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

# Short Period and Phugoid - Flight Dynamics Principles

**Table 10.4** Short period mode damping

Flight phase	Level 1		Level 2		Level 3
	$\zeta_s$ min	$\zeta_s$ max	$\zeta_s$ min	$\zeta_s$ max	$\zeta_s$ 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 $\zeta_p$
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

Aircraft class	Flight phase category	Maximum value of $T_r$ (seconds)		
		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

Flight Phase category	Minimum value of $T_2$ (seconds)		
	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

Aircraft class	Flight phase	Minimum values							
		Level 1			Level 2			Level 3	
		$\zeta_d$	$\zeta_d \omega_d$	$\omega_d$	$\zeta_d$	$\zeta_d \omega_d$	$\omega_d$	$\zeta_d$	$\omega_d$
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

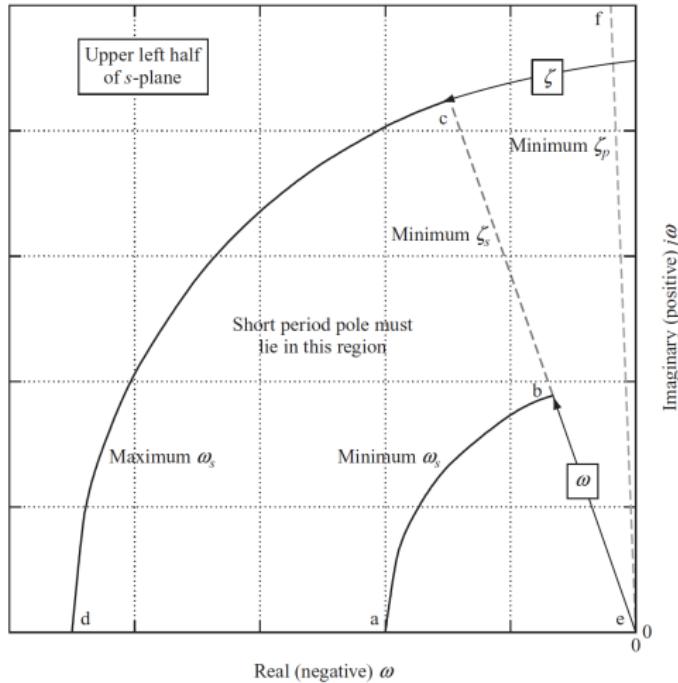
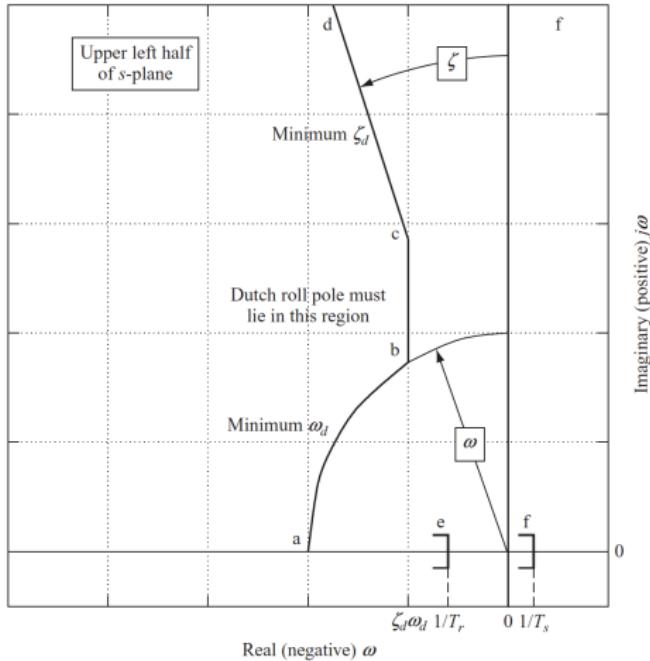


Figure 10.9 Longitudinal flying qualities requirements on the *s*-plane.

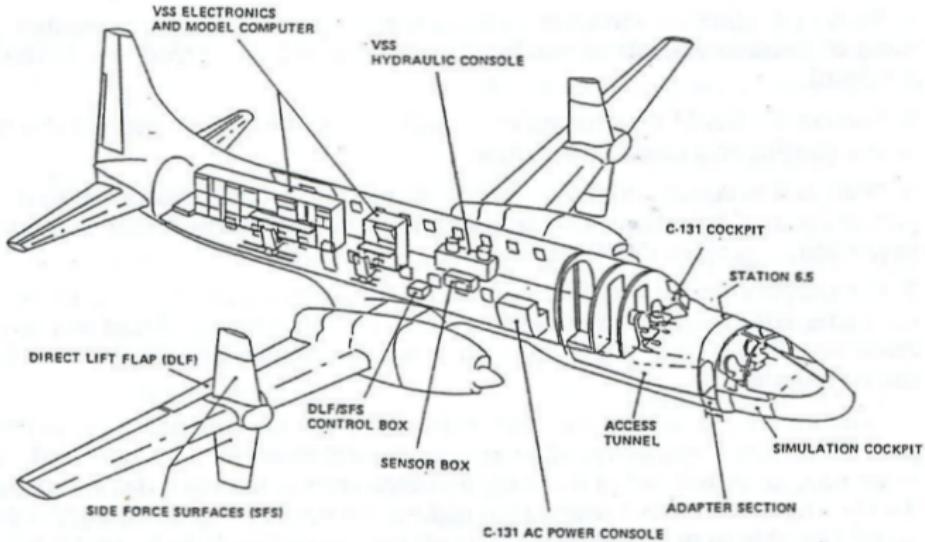
# Dutch Roll - Flight Dynamics Principles



**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.

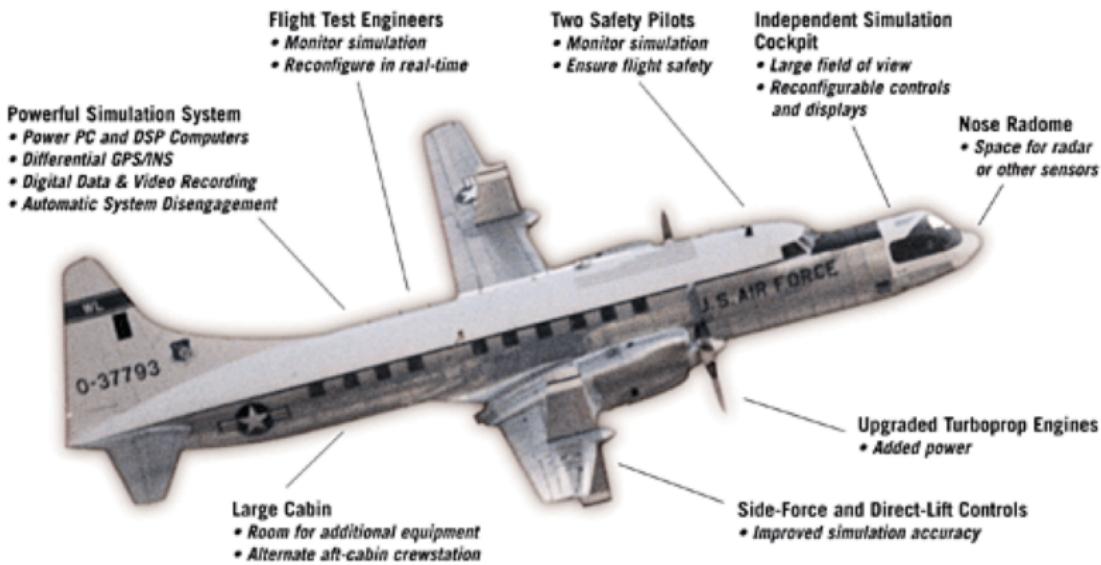
# TIFS - Reconfigurable Simulation Cockpit



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





## 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