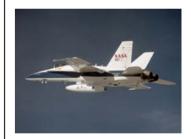# Flight Dynamics & Control
Flight Control Introduction

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Outline

- Flying Qualities
- Levels of Computer Control

Flying Qualities: Specification Level

- Level I
  - Flying qualities clearly adequate for mission flight phase
- Level II
  - Flying qualities adequate to mission flight phase but some increase in pilot workload or degradation in mission effectiveness
- Level III
  - Airplane can be controlled safely but pilot workload is excessive or mission effectiveness is inadequate

Flying Qualities: Airplane Class

Classification of Airplanes	
Class I	Small, light airplanes: light utility, primary trainer, light observation
Class II	Medium weight, low to medium maneuverability
Class III	Large, heavy, low to medium maneuverability
Class IV	High-maneuverability: fighter/intercepter

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Flying Qualities: Flight Phase Categories

Flight Phase Categories	
Nonterminal Category A	Nonterminal flight phases that require rapid maneuvering, precision tracking or precise flight control, e.g., air combat, ground attack, aerial recovery, in-flight refueling, formation flying
Nonterminal Category B	Nonterminal flight phases accomplished with gradual maneuvers without precision, e.g., climb, cruise, descent
Terminal Category C	Terminal flight phases normally require gradual maneuvers and accurate flight path control, e.g.,takeoff, catapult takeoff, approach, landing

Longitudinal Flying Qualities

Phugoid mode

Level	
I	$\xi > 0.4$
II	$\xi > 0$
III	$T_2 > 55\ s$

Level III can have unstable Phugoid mode, T_2 denotes 'time to double' amplitude.

Short-period mode

Level	Categories A & B	Category C
I	$0.35 < \xi < 1.30$	$0.3 < \xi < 2.0$
II	$0.25 < \xi < 2.00$	$0.2 < \xi < 2.0$
III	$0.15 < \xi$	$0.15 < \xi$

Lateral Flying Qualities

Time constant for roll mode

Class	Category	Level I	Level II	Level III
I, IV	A	1.0	1.4	10.0
II, III	A	1.4	3.0	10.0
All	B	1.4	3.0	10.0
I, IV	C	1.0	1.4	10.0
II, III	C	1.4	2.0	10.0

Spiral mode 'time to double' amplitude

Class	Category	Level I	Level II	Level III
I, IV	A	12s	12s	4s
1, IV	B, C	20s	12s	4s
II, III	All	20s	12s	4s

Lateral Flying Qualities, 2

Dutch roll mode parameters

Level	Category	Class	min ξ	min $\xi\omega_n$ rad/s	min ω_n rad/s
I	A	I, IV	0.19	0.35	1.0
I	A	II, III	0.19	0.35	0.4
I	B	All	0.08	0.15	1.0
I	C	I, II-C, IV	0.08	0.15	1.0
I	C	II-L,III	0.08	0.15	0.4
II	All	All	0.02	0.05	0.4
III	All	All	0.02		0.4

-C denotes carrier based, -L denotes land based,
Governing damping is largest of the two.

Flight Control Systems

- Typical system will include
  - Multiple operational modes
  - Each mode includes various protections
- May have alternate control configurations
  - Normal operation
  - Various abnormal operational/failure scenarios

Example: Airbus, a typical commercial aircraft

- Normal Law
  - Normal operating configuration of the system.
  - 3-axis attitude control.
  - 3 modes according to phase of flight (ground, flight, flare).
  - Protections: high angle of attack, load factor limitation, high speed protection, bank angle protection.
- Alternate Law
  - Triggered by multiple failures of redundant systems.
  - Yaw damping only.
  - Has two modes (ground, flare).
  - Protections: load factor limitation, low speed protection (replaces AOA), high speed protection.

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Example Continued

- Abnormal alternate – intention is to recover from abnormal attitude
  - Yaw damping is the only compensation
  - Load factor limitation is the only protection
  - Returns to alternate law on recovery
- Direct – lowest level of computer control
  - Pilot commands transmitted directly to control surfaces
- Mechanical backup