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10 – Buffet

Vibraciones y Aeroelasticidad
Dpto. de Vehículos Aeroespaciales
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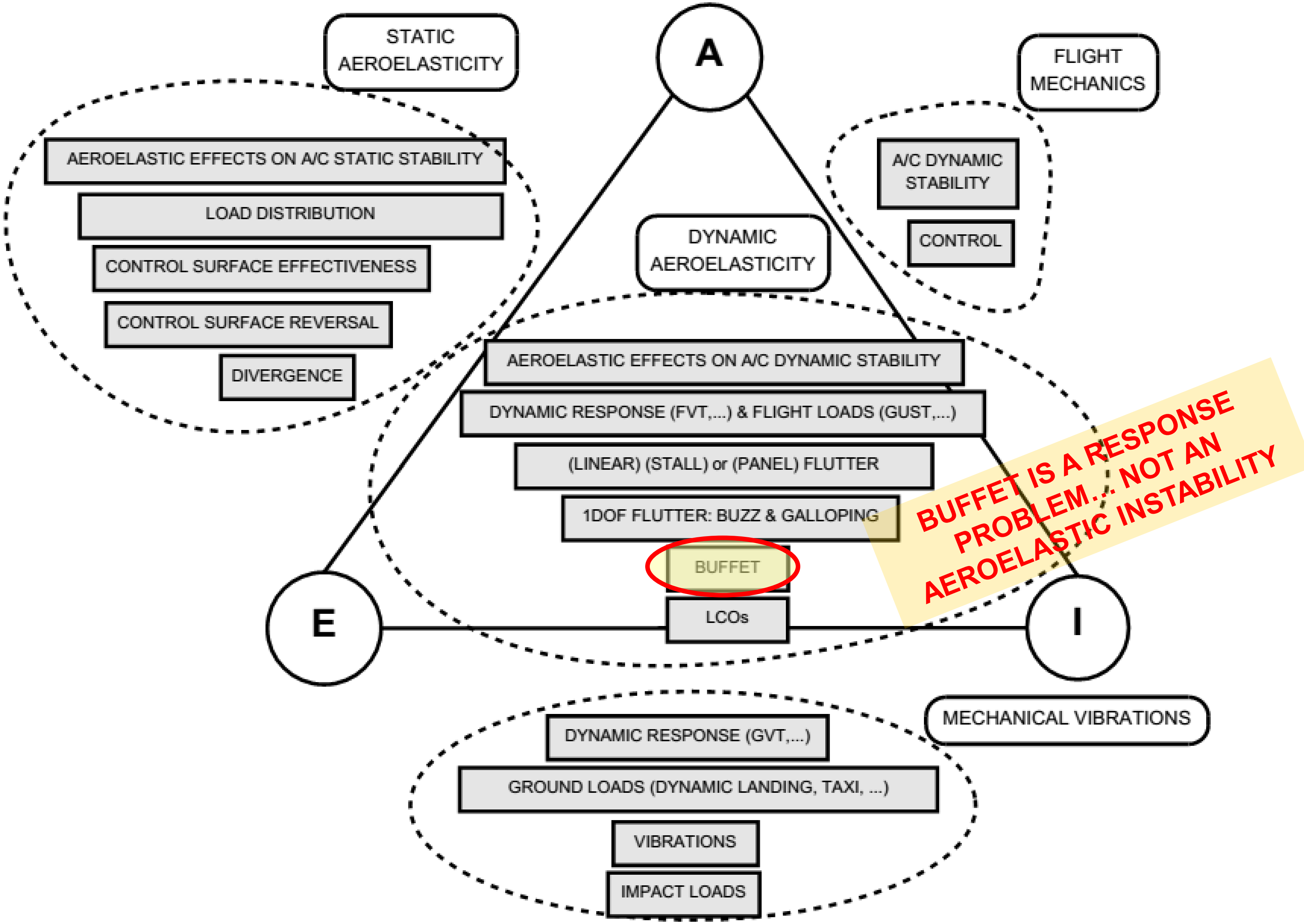
BUFFET
WHERE WE ARE IN THE COLLAR'S DIAGRAM ?



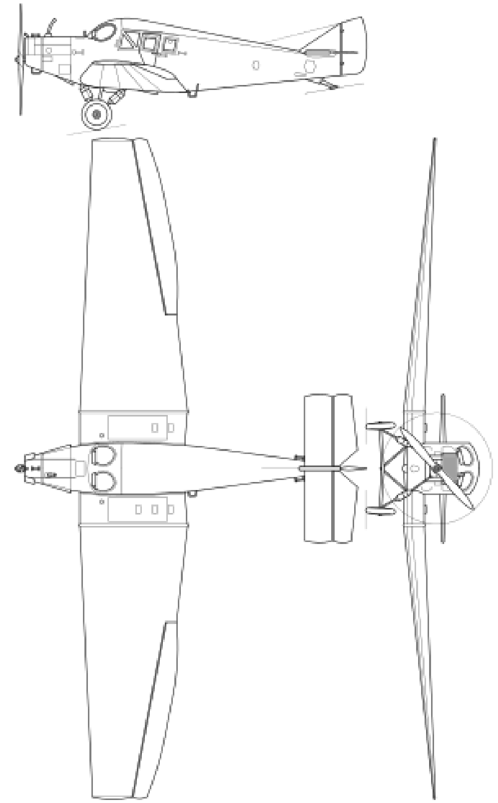
THE FIRST ACCIDENT RELATEDTO BUFFET ONSET

JUNKERS F13 crashed at Meopham, England, July 21, 1930

The Junkers F.13ge registered G-AAZK which was owned by the pilot Lieutenant-Colonel George Henderson had been loaned to the Walcot Air Line to operate a charter flight between Le Touquet in France and Croydon Airport south of London. As the aircraft was above Kent it appeared to have disintegrated and crashed near the village green at Meopham five miles south of Gravesend. Witnesses reported a rumbling noise just before the crash and that the aircraft emerged from a cloud and then broke apart in mid-air. The crash happened at 2:35 pm.

The final report was issued in January 1931 and the committee concluded the cause to be the "failure of the tailplane under **severe buffeting from air eddies produced by the centre section of certain low-wing monoplanes when the aircraft approaches the stalling attitude**".

They reported that the aircraft, flying in clouds, may have been thrown into an unusual attitude. This resulted in buffeting of the tailplane, causing the port tailplane to fail, and the aircraft entered a dive. The flutter effect on the starboard tailplane caused it to fail next. The aircraft was moving at high speed and reached a stalling attitude, causing the port wing to break away. The rapid angular acceleration caused the engine supports to break and the engine to fall away. Nine other causes were investigated but dismissed by the committee.



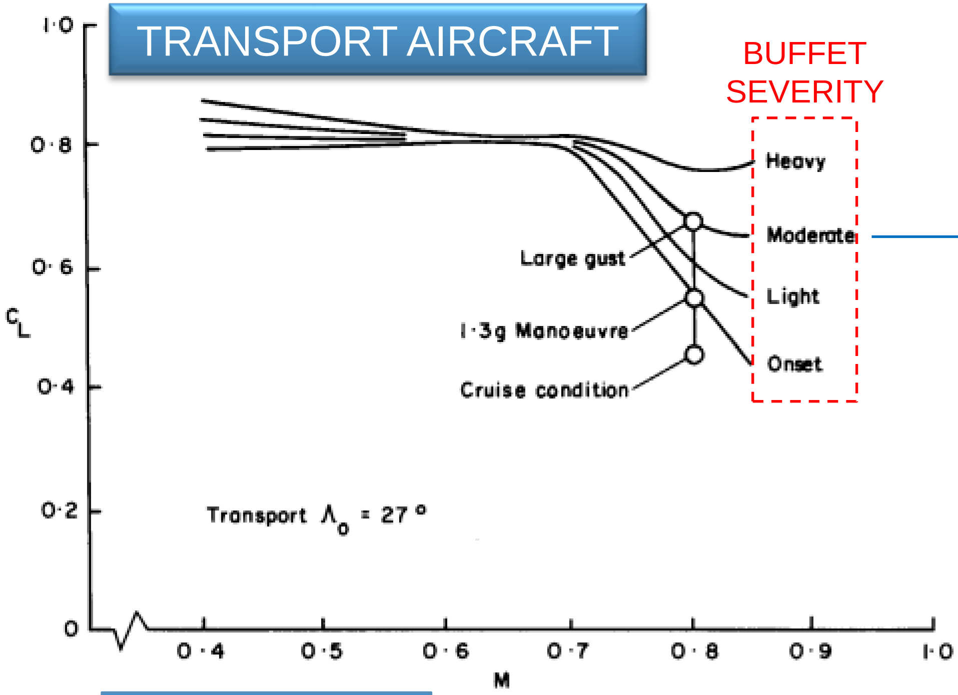
GENERAL CONSIDERATIONS

- **BUFFET** is the excitation given to a structure by **separated flows**:
  - ► The excitation at a point may be generated by:
    - (a) a local separation (e.g. pod/pylon separation,…)
    - (b) an upstream separation (e.g. when a rear tailplane is immersed in a separated wake from a wing, an aircraft flying thru the wake of othr aircraft, …)
    - (c) a downstream separation (e.g. when a rear fuselage is excited by separations on the afterbody)
  - ► The excitation covers a wide range of frequencies and is RANDOM in character. However, in certain separated flows the excitation may be confined to a single frequency and be periodic (e.g. flow around an antenna or any other aircraft excrescence).

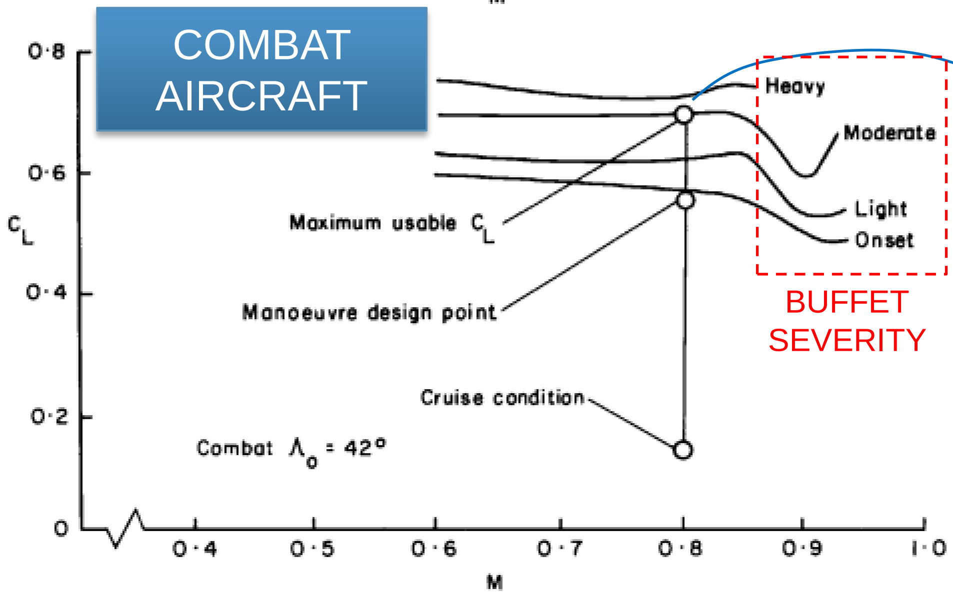
- **BUFETTING** is the response of the structure to the buffet excitation:
  - ► The structure acts as a selective filter and may response both in its main structural modes (often in the first bending and torsional modes) or in local panel modes, which are often of higher frequencies.
  - ► <u>The response of the structure leaves the buffet excitation essentially unaltered</u> → UNCOUPLED response

- Buffeting in transport and combat aircrafts:
  - ► Transport A/Cs avoid buffet conditions → Not relevant from fatigue standpoint
  - ► Combat A/Cs will manoeuver above buffet conditions → Need to consider for fatigue

TRANSPORT vs COMBAT AIRCRAFT



Buffet can lead to high design loads if appears in the gust encountering event



Buffet can effect to fatigue life as combat aircraft perform high-perfo maneuvers

VIDEO:
PUGACHEV'S COBRA MANEUVER
SUKHOI SU 35

TYPES OF FLOW SEPARATIONS

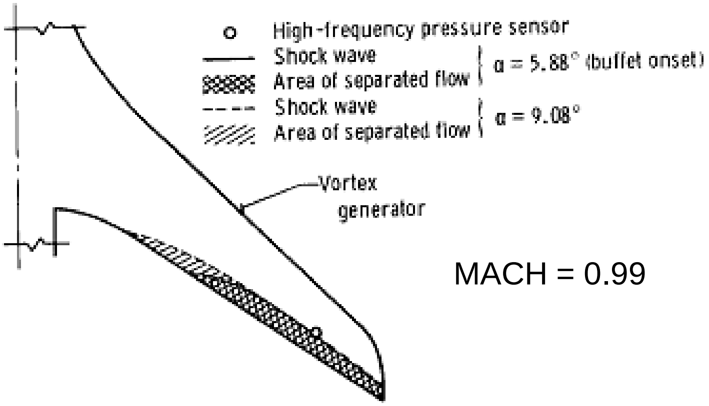
LOCAL FLOW SEPARATIONS

The unexpected vibration cropped up during flight tests when airflow separation around the pylon connecting the refuelling pod to the wing set up a buffet in the structure. "We're working it hard and aggressively, and we have what we believe is a solution," says Boeing. "We are discussing that with the Italians right now."

UPSTREAM FLOW SEPARATION

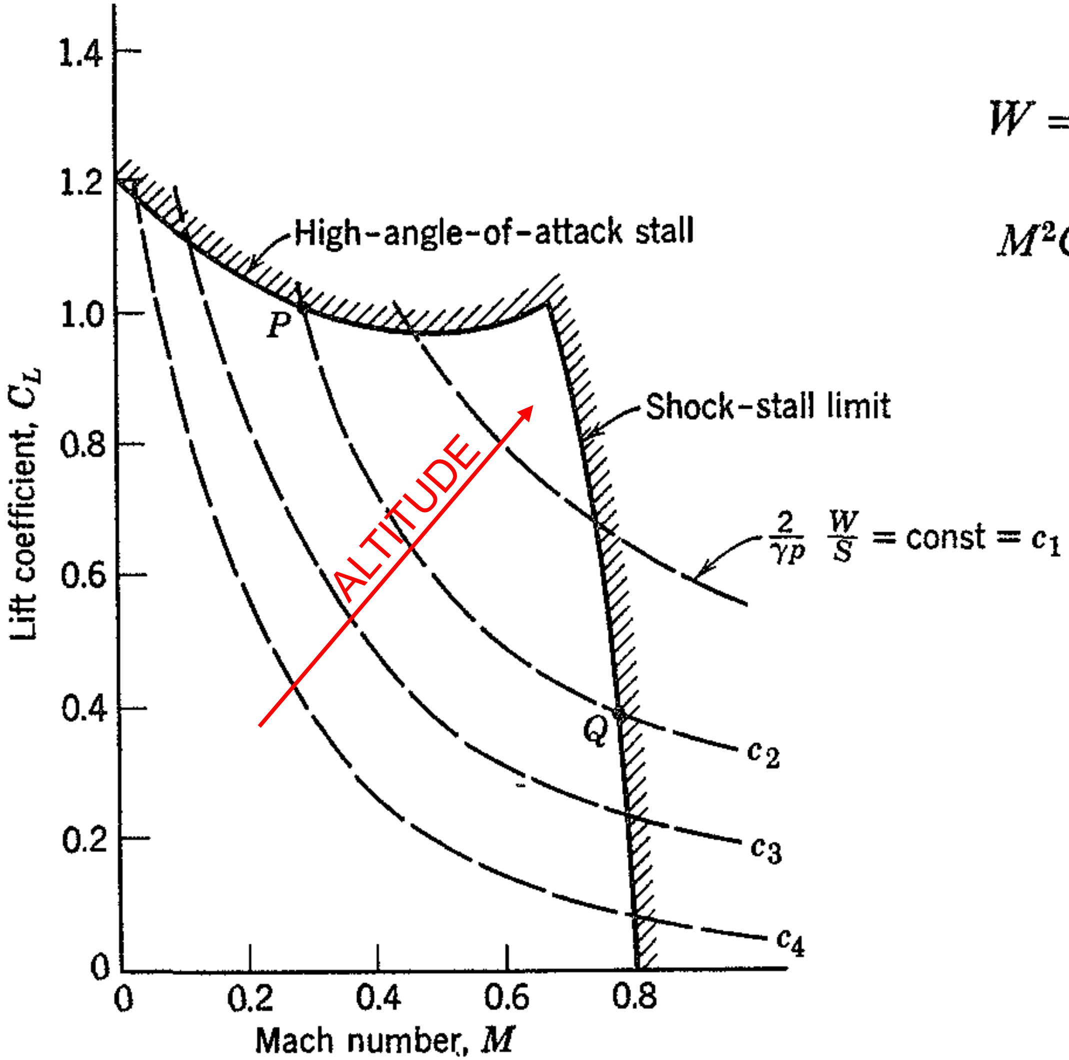
Figure 1. NASA F-18 High Angle of Attack Research Vehicle (HARV). Photo Courtesy of NASA Dryden.

LOCAL/DOWNSTREAM SEPARATION



MACH = 0.99

F-8 Supercritical Wing Airplane



Stall boundary of the NACA 2409–34 airfoil (steady-state wind-tunnel tests).

$$W = L = \tfrac{1}{2}\rho U^2 S C_L$$

$$M^2 C_L = \frac{W}{S}\frac{2}{\rho a^2} = \frac{W}{S}\frac{2}{\gamma p}$$

- Unfortunately no theoretical method is yet available to predict the random excitation normally characteristic of buffet onset.
- Current industrial method is based on inferring buffet PSD input from flight test or wind tunnel test measurements. Example:

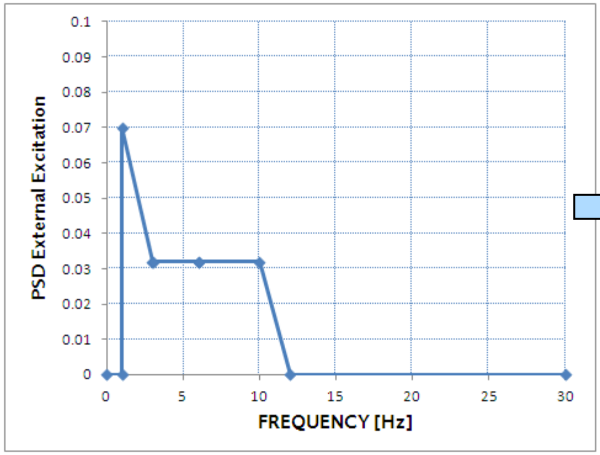
$$PSD_{OUTPUT} = |H(\omega)|^2 \cdot PSD_{INPUT} \quad \Rightarrow PSD_{INPUT} = PSD_{OUTPUT} / |H(\omega)|^2$$

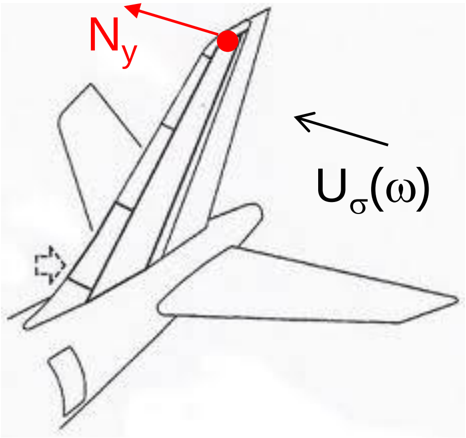
PSD_{OUTPUT} → Accelerations from Flight Test Data measured at different locations

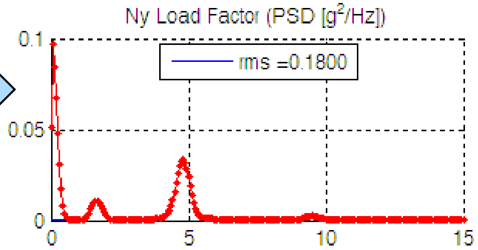
$H(\omega)$ → Harmonic-Gust Frequency Response Function (obtained with Aeroelastic Model).

PSD_{INPUT} → Unknown but … the right one to obtain PSD_{OUTPUT} through $H(\omega)$.

BUFFET EXCITATION (INPUT) → **LOADS MODEL** (TRANSFER FUNCTION) → **FLIGHT TEST DATA** (OUTPUT)







ALLEVIATION OF BUFFET

- Eliminate or at least reduce flow separations
  - Improve stall behavior: reducing the leading-edge suction by deflecting slats at leading edge in high angle-of-attack conditions
  - Boundary layer wing fences (or “stall fences”) to reduce spanwise flow tendency
  - Leading edge blowing and blown flaps to reduce or delay onset flow separation

MiG-17 with wing fences

- If separation cannot be prevented… stabilization of separations:
  - The stabilized separations have much lower levels of buffet and generally have lower drags
  - Vortex generators, streamwise strakes, base-bleed, …

F-18: The impact on tail of the Leading Edge Extensions Vortex was reduced by wing strakes

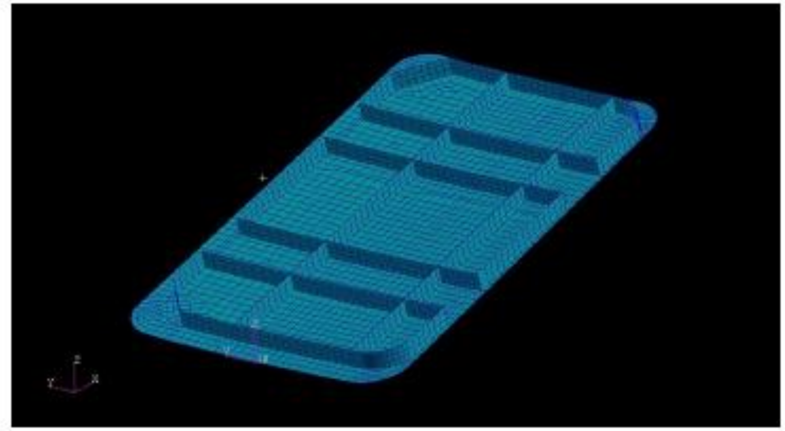
- Active control:
  - Increase aerodynamic damping

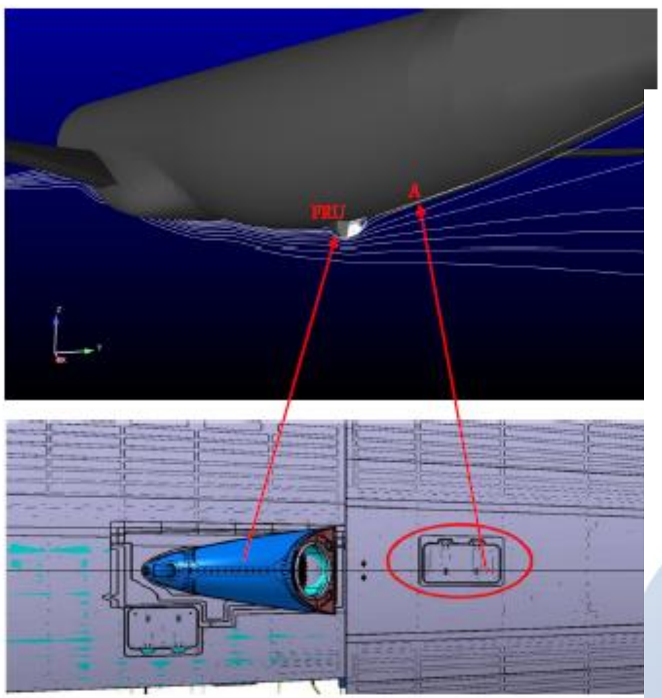
- And… reinforcement of the structure to move up the normal modes frequencies

PRACTICAL EXAMPLE: STRUCTURAL REINFORCEMENT TO REMOVE NORMAL MODES FROM THE BUFFET EXCITATION

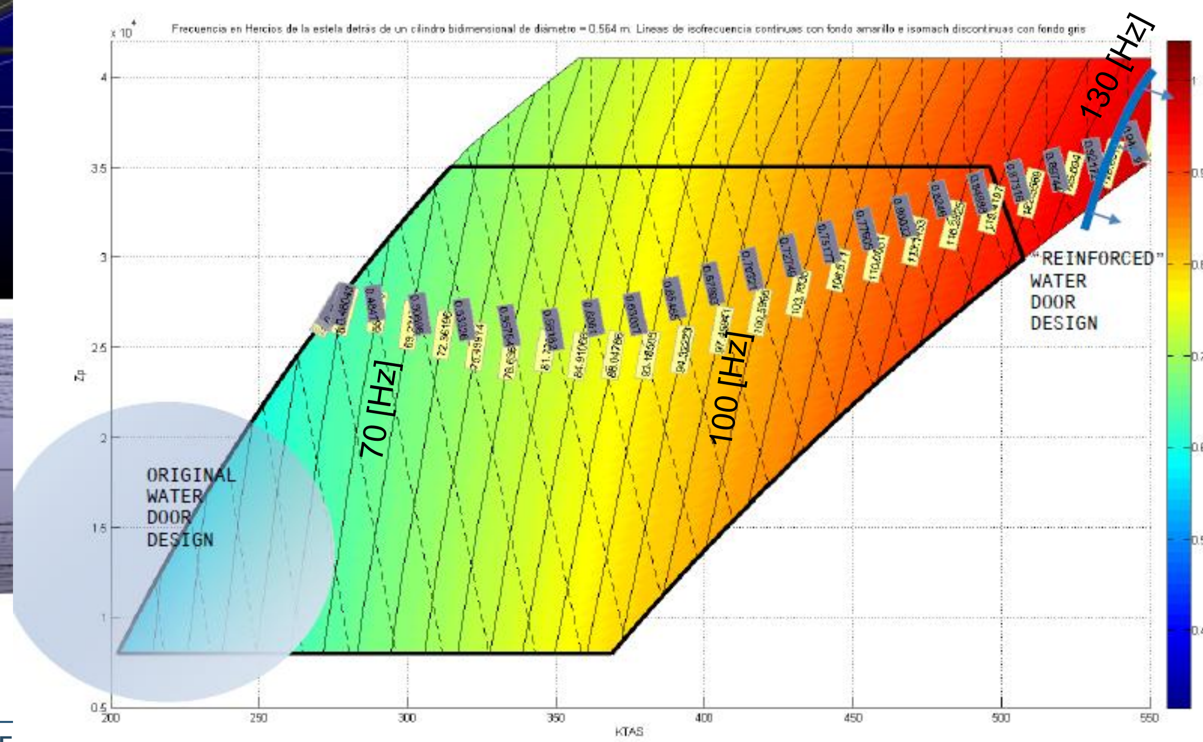
Aircraft excrescence (point FRU) creates a turbulence flow than affect to the “water door”, a plate located downstream the excrescence (point A)

The characteristic frequency of the eddies is shown in the flight envelope (70 [Hz], 100 [Hz], …)





The original “water door” low-freq normal modes coupled with turbulence. The updated design (reinforced plate shown above) moved up the lowest frequency up to 130 [Hz] and decoupled the structural modes from the excitation.



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