Boeing B-777: Fly-By-Wire Flight Controls. System Overview and Design Philosophy.

I. Read the text and underline the main advantages of the system.

Conventional primary flight controls systems **employ** hydraulic actuators and control valves controlled by cables that are driven by the pilot controls. These cables run the length of the airframe from the cockpit area to the surfaces to be controlled. This type of system, while providing full airplane control over the entire flight regime, does have some distinct drawbacks. The cable-controlled system comes with a **weight penalty** due to the long cable runs, pulleys, brackets, and supports needed. The system requires periodic maintenance, such as lubrication and adjustments due to cable stretch over time. In addition, systems such as the yaw damper that provide enhanced control of the flight control surfaces require dedicated actuation, wiring, and electronic controllers. This adds to the overall system weight and increases the number of components in the system.

In a FBW flight control system, the cable control of the primary flight control surfaces has been removed. Rather, the actuators are controlled electrically. At the heart of the FBW system are electronic computers. These computers convert electrical signals sent from position **transducers** attached to the pilot controls into commands that are transmitted to the actuators. Because of these changes to the system, the following design features have been made possible:

• Full-time surface control utilizing advanced control laws. The aerodynamic surfaces of the 777 have been **sized** to afford the required airplane response during critical flight conditions. The reaction time of the control laws is much faster than that of an **alert** pilot. Therefore, the size of the flight control surfaces could be made smaller than those required for a conventionally controlled airplane. This results in an overall reduction in the weight of the system.

• **Retention** of the desirable flight control characteristics of a conventionally controlled system and the removal of the undesirable characteristics.[...]

• Integration of functions such as the yaw damper into the basic surface control. This allows the separate components normally used for these functions to be removed.

• Improved system reliability and **maintainability**.

The philosophy employed during the design of the 777 Primary Flight Control System maintains a system operation that is consistent with a pilot's past training and experience. What is meant by this is that however different the actual system architecture is from previous Boeing airplanes, the presentation to the pilot is that of a conventionally controlled mechanical system. The 777 retains the conventional control column, wheel, and rudder pedals, whose operation are identical to the controls employed on other Boeing transport aircraft. The flight deck controls of the 777 are very similar to those of the Boeing 747-400, which employs a traditional mechanically controlled Primary Flight Control System.

Because the system is controlled electronically, there is an opportunity to include system control **augmentation** and **envelope** protection features that would have been difficult to provide in a conventional mechanical system. The 777 Primary Flight Control System has made full use of the capabilities of this architecture by including such features as:

• Bank angle protection
• Turn compensation
• Stall and overspeed protection
• Pitch control and stability augmentation

• **Thrust asymmetry** compensation
[...]What should be noted[...]is that none of these features limit the action of the pilot. The 777 design utilizes *envelope protection* in all of its functionality rather than *envelope limiting*. Envelope *protection* deters pilot inputs from exceeding certain predefined limits but does not prohibit it. Envelope *limiting* prevents the pilot from commanding the airplane beyond set limits. For example, the 777 bank angle protection feature will significantly increase the wheel force a pilot encounters when attempting to roll the airplane past a predefined bank angle. This acts as a **prompt** to the pilot that the airplane is approaching the bank angle limit. However, if **deemed** necessary, the pilot may override this protection by **exerting** a greater force on the wheel than is being exerted by the backdrive actuator. The intent is to inform the pilot that the command being given would put the airplane outside of its normal operating envelope, but the ability to do so is not **precluded**. This concept is central to the design philosophy of the 777 Primary Flight Control System.[1]

II. Read the text again and answer the following questions:

1. What are the two main drawbacks of the conventional primary flight control system?
2. Why can the primary flight control surfaces in FBW system be smaller than in the conventional system?
3. Why is it easy for pilots to transfer to FBW controlled B777 from conventional Boeing aircraft?
4. Is it possible for the pilot to overstress B777?

III. Explain the words in bold in the text.

IV. Complete the sentences with some of the words from ex. III. You may need to adjust the form of the words.

1. The surrounding air _____ great force on the fuselage.
2. Landing without flaps is dangerous but is not _____ if they are inoperative.
3. The company needs to improve its training and _____ of staff.
4. Pilots need to stay _____ while taxing.
5. This component doesn't fit. It needs _____.

V. Look back at the text and complete the sentences with appropriate prepositions. If no preposition is needed, leave the gap empty.

1. Most of the problems have been due _____ human error.
2. The avionics architecture is almost identical _____ the previous model.
3. The system prevents the pilot _____ overstressing the aircraft.
4. The systems provides _____ full airplane control.
5. The results are entirely consistent _____ our previous research.

1 Bartley F. Gregg, "Boeing B-777: Fly-By-Wire Flight Controls", in: *The Avionics Handbook*, CRC Press, 2001, pp 208-9

Language function – expressing past actions with present results

I. Look at the sentence from the text and answer the questions below.

"In a FBW flight control system, the cable control of the primary flight control surfaces has been removed."

1. Does FBW flight control system have cable control?
2. Do we know exactly when the cables were removed?
3. Does the removal have effect on FBW flight control?
4. What verb do we use in this situation? Is the sentence active or passive?
5. How would the sentence change if we added the words "at the early design stage" at the end of this sentence?

II. Complete the sentences with appropriate forms of the verbs in brackets.

1. We _____ (replace) the transducers, so the system is operative now.
2. We _____ (not implement) the changes yet.
3. _____ (you/finish) the project yesterday?
4. He _____ (never/work) on this type of plane.
5. When _____ (you/start) working here?
6. I _____ (just/be) promoted to a senior engineer.

III. Work in pairs and discuss the following questions.

1. How useful has your university education been so far? What is the most useful thing you have learnt?
2. What did you achieve last year?
3. What has been your biggest professional achievement so far?