APPENDIX 6: Study of Spatial Disorientation

1. General

Spatial disorientation is a human being's inability to correctly sense his position, attitude or motion with respect to the earth's surface and the gravitational vertical plan. In flight, it may take different forms depending on the flight phase and the pilot response to the situation. Spatial disorientation results from gaps in interpreting and integrating the information, sometimes altered in certain conditions, from sensory receptors (mainly the eyes, vestibular system and proprioceptive receptors) by the central nervous system that provides situational awareness. The responses to these perceptions depend on the personality, physical and mental condition and experience of each individual. These are limited by the characteristics of tasks to be performed by pilots as well as the environment in which these tasks must be performed.

2. Somatogravic perceptual illusions

On the surface of the earth, Man is accustomed to living in the earth's field of gravity, which is always constant, and represents a stable reference of verticality. During a flight, because of the movements of the aeroplane, the body is subjected to inertial and gravitational forces which combine into a gravito-inertial resultant equivalent to a variation in intensity and/or direction of the gravity field vector. This set of forces can change the perception of the body's orientation relative to the gravitational vertical. For example, an acceleration of the aeroplane can give the same impression as a backward tilt, i.e. the perception of a climbing aeroplane. The reference of verticality taken into account by the pilot's central nervous system is no longer the earth's gravity but the resulting gravito-inertial force, which is the sum of the earth's gravity and the inertial forces. The somatogravic perceptual illusion therefore leads to a misperception of the body's orientation in space.

During go-around or takeoff phases in low visibility conditions, while the aeroplane is accelerating, pilots may try to counteract this perception of climb by dropping the aeroplane's nose until the dive counterbalances the apparent backward tilt caused by acceleration, which may end in impact with the ground. Furthermore, if this false- climb illusion is reinforced by the presence of a false visible horizon (such as a shoreline or a string of lights with the ocean or unlit background terrain), a pilots' desire to push the stick may become difficult to control.
The conditions required for the occurrence of a somatogravic perceptual illusion are listed below:

- Lack of monitoring of the artificial horizon; Degraded external visual reference points;
- Sufficient linear acceleration experienced between the moment when the pilot begins to perceive acceleration and the moment when he stops pulling on the side stick;
- Acceleration maintained so that the illusion persists and the pilot always feels nose up in spite of an actual descending flight path;
- No correction by the pilot by collecting information on the actual position of the aeroplane.

The state of awareness and experience (training and actual experience of go- around) may be factors favouring the occurrence of this type of illusion.

3. Model for estimating the perceived orientation

Certain existing models can be used to calculate an estimate of the orientation perceived by the pilot based on different accelerations. These models, of course, cannot predict the perception of a given pilot but do provide an estimate of the influence of inertial forces and rotational movements on the orientation perceived by a pilot during flight. The estimate calculated by these models assumes that pilots have no external visual information, and that they do not watch their instruments, especially the artificial horizon, during the flight phase studied. It is precisely in such circumstances that spatial disorientation occurs most often.

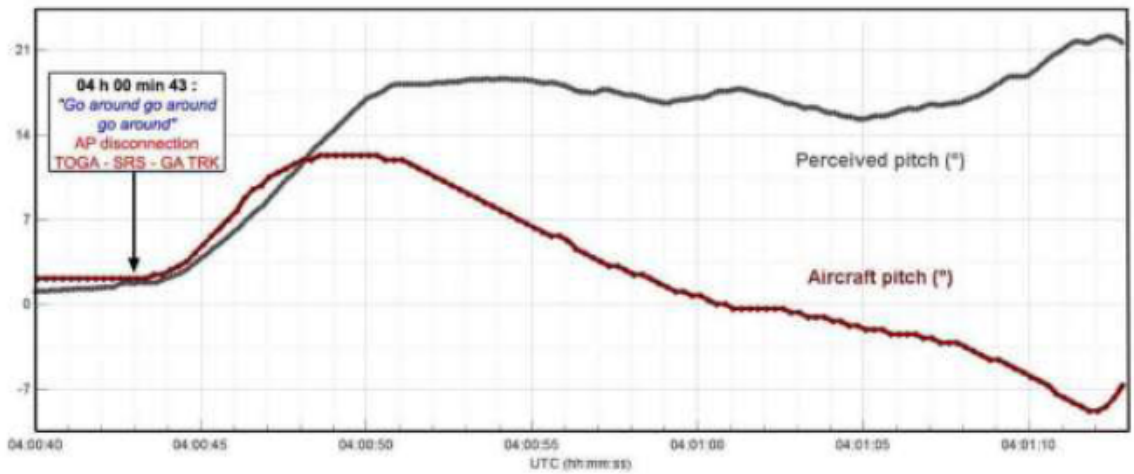
The model developed by the BEA is based on a theory for estimating the spatial orientation using filters or constant gain estimators for the vestibular organs (Merfeld, 2001). This model uses the parameters recorded by the flight data recorder from the physical characteristics of the vestibular organs (equivalent to three accelerometers and three gyroscopes).

Nevertheless, it is not possible to have knowledge of the pilot's head movements and the influence of proprioceptive receptors. Therefore the estimate does not take these parameters into account. The pilot's head is thus assumed to be fixed, its position corresponding to a position directly related to the seat position. The different axes of the vestibular organs are thus considered parallel to the axes of the aeroplane.

4. Results and applications

As part of the investigation, the model for estimating the perceived orientation was used with SSFDR parameters. The figure below shows that at the time of the missed approach, the attitude perceived by a pilot, provided that his perception is based exclusively on the interpretation of vestibular inputs (without external visual reference and without monitoring the artificial horizon), is initially close to the real attitude. It then deviates from the actual attitude from about 11 degrees to increase and remain between 15 and 22 degrees nose up. The first nose-down inputs recorded for the co-pilot's side stick occur at a moment corresponding to this deviation. The difference observed between the actual attitude and estimation of the perceived attitude may be related to the occurrence of a somatogravic perceptual illusion.

The following diagram shows the aeroplane pitch attitude against perceived pitch estimated by the model. It is taken from a plate that is included in appendix 10.



Real and perceived pitch attitudes during the missed approach