The Giant Hand Illusion Experienced on a Simulator

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BACKGROUND: This paper discusses a special kind of a sensory illusion—the Giant Hand illusion—that was experienced during an exercise on a flight simulator equipped with a VR headset. In the first part we describe spatial disorientation and the function of the vestibular apparatus during flight and its consequences. In this part, the sensory illusion simulator used for the experiment is mentioned. In the second part we describe the simulator and test flight. In the third part we discuss data retrieved during simulator flights that are important for explaining the Giant Hand illusion.

CASE REPORT: A well-trained pilot experienced the Giant Hand illusion while executing instrument flight rules flight on a simulator. The Giant Hand illusion was detected from the simulation data and confirmed by the pilot afterward.

DISCUSSION: The Giant Hand illusion is a rare type of sensory illusion. The pilot falsely evaluated the situation as a malfunction of the aircraft controls. If the pilot had not been informed by the operator that he might have been influenced by the illusion, he would probably have crashed the simulated aircraft. An unrecognized Giant Hand illusion during a flight can lead to fatal consequences. This case report shows the symptoms and data that can be used for early recognition of this type of illusion.

KEYWORDS: spatial disorientation, sensory illusions in aviation, simulation.

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An in-flight illusion that develops into spatial disorientation may have fatal consequences for the pilot. Therefore, it is imperative to understand the situations that may cause spatial disorientation and its effects.

Spatial disorientation caused by the vestibular system is the most common cause of nonstandard situations on board airplanes and helicopters.[1,6,9] The body's vestibular system subconsciously records the movement of the head. Its function is most often noticed when one of the body's most important sensors—sight—is compromised. In everyday life the vestibular system has a postural function—helping to keep the body and head upright and balanced, and enabling the eyes to fix on one object even when the head is moved by a vestibulo-ocular reflex.

The vestibular apparatus and hearing receptors are located in a bone labyrinth in which a system of pellicular vesicles and canals called the membranous labyrinth is situated. The membranous labyrinth is an apparatus for detecting both angular and linear acceleration in three axes, and the position of the head relative to the vector of gravitational force. It consists of three mutually perpendicular, semicircular, blunt canals ending with an extension called an ampoule and two fleshy sacks—the sacculus and utriculus. The entire membranous labyrinth is filled with fluid (endolymph).[3] Knowledge of the above is very useful for pilots as well as for simulator designers.

According to the FAA and other researchers, the leans illusion is one of the most common spatial disorientations—a flight illusion that can cause great problems if the pilot fails to detect it.[4,7] It is caused by the pilot's inability to evaluate or detect angular velocity or the banking of the aircraft. The cause of this disorientation is a sufficiently slow change in the bank angle or a sufficiently long flight in a stable curve (e.g., a holding pattern).

In the case of a slow change of bank below the detection level of the human organism, or in the case of a long, banked flight, the vestibular apparatus has enough time to stabilize the fluid in the semicircular canal. When returning to horizontal flight, the vestibular system will behave in precisely the opposite manner

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to which it is designed: it starts from the initial bank conditions and returns to the horizontal flight. By unconsciously following the suggestions obtained from his or her vestibular apparatus, the pilot will then misinterpret wings-level flight as a bank and seek to overcorrect back to the original bank.[2,4]

Unfortunately, spatial disorientation cannot be predicted, it can be only evaluated based on measured flight parameters. According to measured data, it is possible to deduce the time when spatial disorientation occurred to such an extent that it began to influence the flight.[8]

To create a feeling of spatial disorientation, a special simulator was designed. The main task was to introduce the leans illusion to pilots during instrument meteorological conditions (IMC) using a relatively simple simulator. The simulator consisted of mechanical and electronic parts and was designed to minimize prototype costs based on previous projects. To simulate motion during flight, a simple moving platform was used, allowing changes of ±10° of bank. Platform software was especially designed to maintain the pilot's sensation during all airplane banks. This design allowed us to use only a few degrees of platform bank, but this was sufficient because the pilot flying the instrument landing system (ILS) under IMC used relatively small changes of bank angle. The controller software tilted the platform in order to set up the initial bank sensation according to the aircraft movement in the simulator software. Because the motion platform was simplified, some unusual feelings may have been experienced during the first short time on the simulator, but would disappear quickly with familiarization during flight.[5] The software of the prototype was based on two commercial programs (Microsoft Flight Simulator X and FlyInside), a communication application to interconnect these programs, a simulator control, and a data recording application for evaluating the experiment. The pilot used Oculus Rift VR goggles, which enabled them to be visually separated from the surrounding environment. The pilot used an engine control lever and a joystick (used as a side stick for the experiment) to control the airplane. Direction control was set to automatic to simplify the evaluation and control of the simulated airplane.

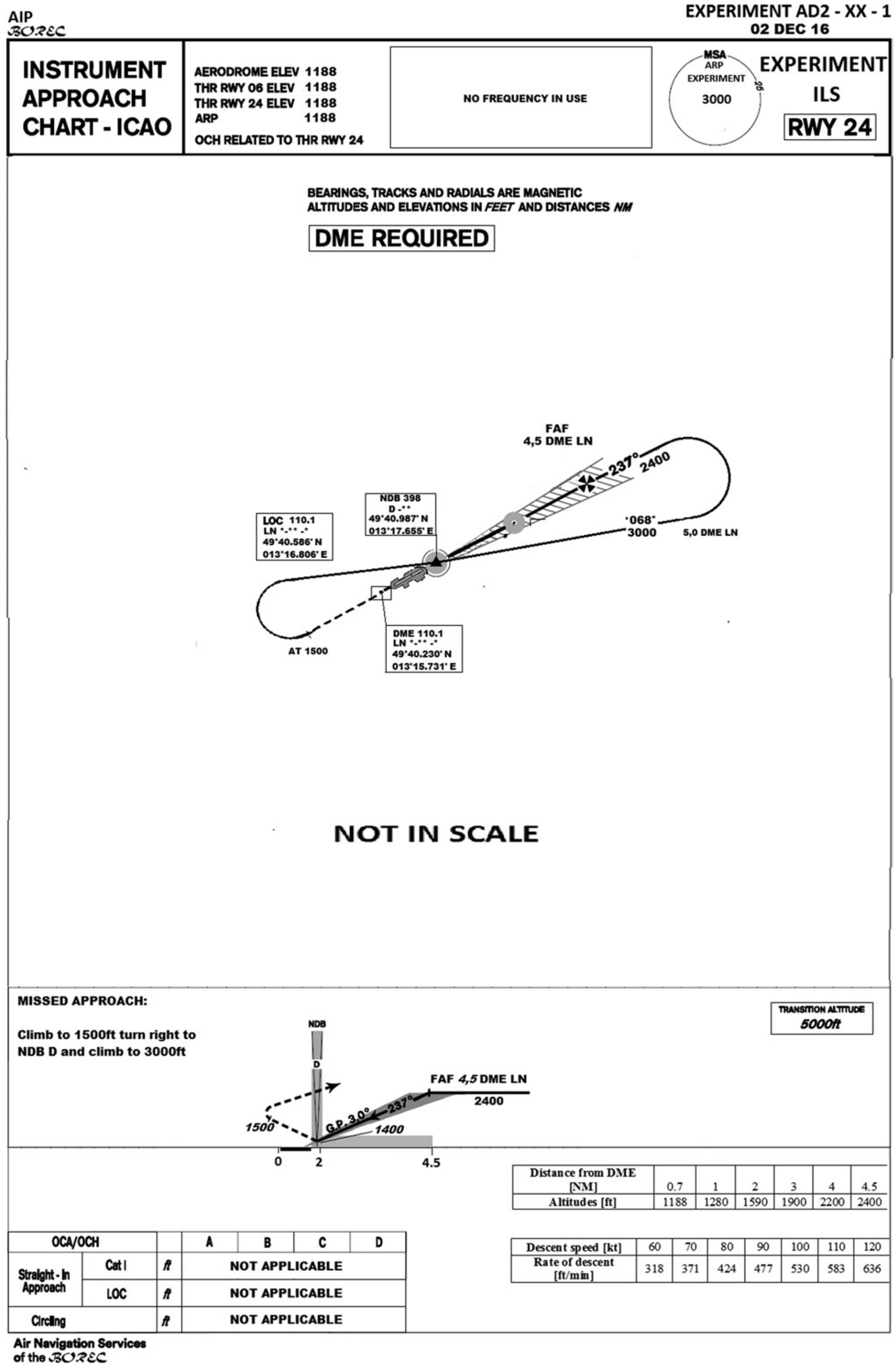

Fig. 1. Instrument approach chart for the experimental flight.

CASE REPORT

The simulator flight can be divided into several phases. These phases are called takeoff, NDB inbound, outbound, final turn, final approach, and go-around. An ILS approach scheme was created for the simulator flight to make it simple for pilots and to help evaluate the flight. The airport approach system uses a nondirectional beacon (NDB) and ILS precision approach system. The NDB position is used as a missed approach point (go-around) in case no visual references on the ground are obtained. The simulator flight aerodrome has the following parameters:

- Altitude: 1188 ft AMSL;
- Runway direction: 237° magnetic;
- Precision approach path indication lights system;
- Medium intensity approach light system to allow the pilot to have earlier visual contact with the airport; and
- A distance measure equipment (ILS/DME) system with a glide slope of 3°.

The weather for the flight was selected to be similar to real instrument flight rules conditions within the minima for the airport.

The simulator flights were flown by military pilots with visual flight rule, instrument flight rules, and night qualifications, with an average 2000 flight hours and with experience piloting both airplanes and helicopters. Of all pilots who have flown a simulator with the same conditions, 80% recognized some kind of sensory in-flight illusion, which was marked by a specially assigned button on the joystick or reported immediately after the flight. All pilots, prior to the experiment, were briefed with all aspects of the flight, such as the flight pattern to follow, airport and airplane characteristics, flight instruments, and their behavior on board. A short visual meteorological conditions flight was taken by all pilots prior to the start of the experimental simulator flight. The pilot's task was to fly according to the chart (**Fig. 1**). The first circuit was aimed at familiarization with the control and behavior of the simulated airplane under IMC conditions on that day and to be "broken in to" the conditions. During this phase, the simulator simulates normal flight conditions with no illusions. The two following circuits were aimed at creating spatial disorientation—the in-flight sensory illusion. During these two circuits, an additional platform angle (5° of tilt offset) was introduced during the first turn of the airplane toward the NDB inbound. The platform offset lasted until the final turn, when the offset was inactivated to make the bank angle of the simulator platform identical to the bank of the airplane so that the pilot did not notice the different behavior of the platform during the flight.

Fig. 1 shows the instrument approach chart used for simulator flight. The pattern shows step by step how to fly the airplane and safely bring it to land under IMC. After takeoff, the pilot

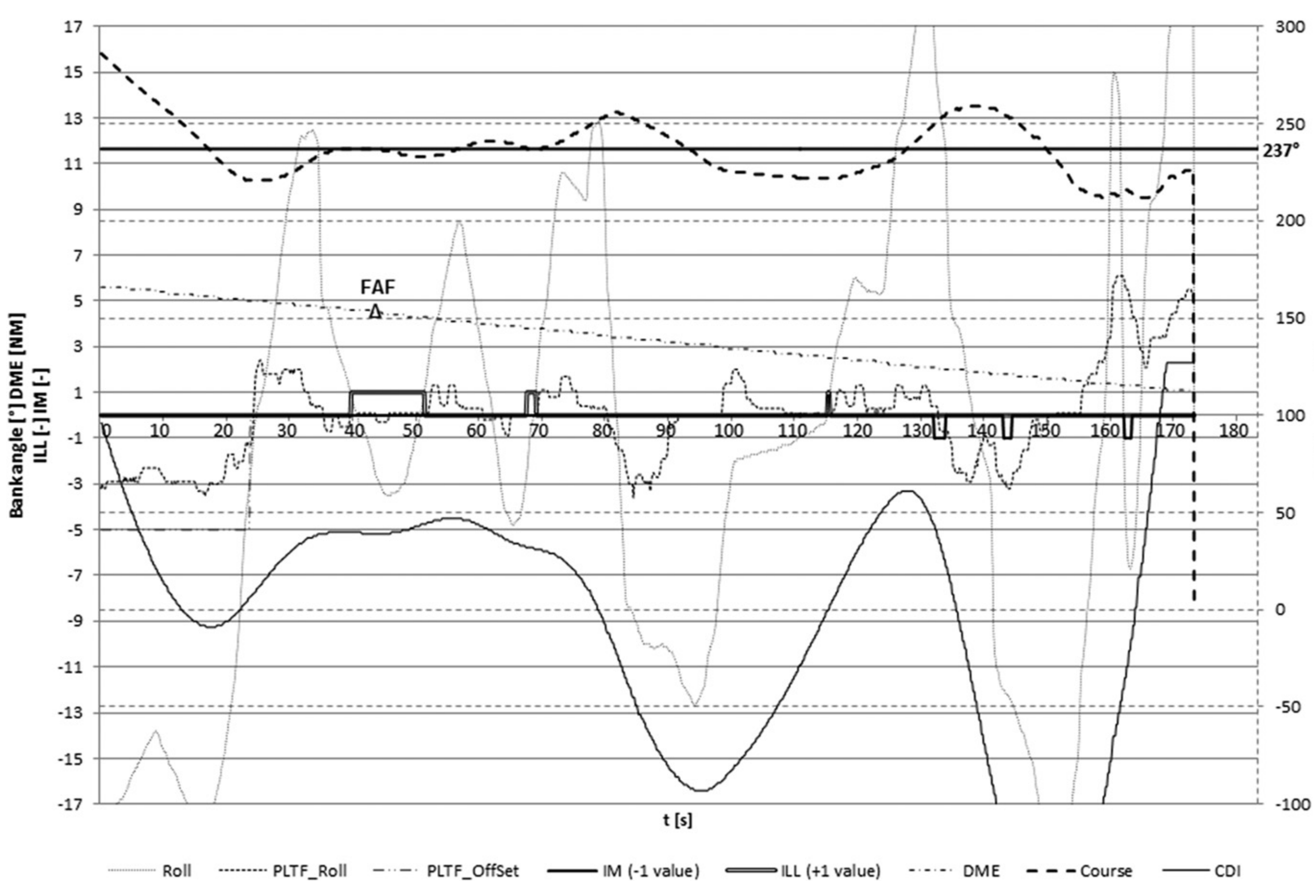

Fig. 2. The second approach. PLTF: platform; IM: illusion mark; ILL: illusion; DME: distance measure equipment; CDI: course deviation indicator.

has to climb to an altitude of 1500 ft (457.2 m) AMSL and turn to right inbound NDB "D". After passing NDB "D", they follow the outbound course 068MAG to 5NM from DME "LN." From this position they have to turn left to the runway heading 237MAG and descend to 2400 ft (731.5 m) AMSL intercept FAF. They then follow the ILS indication. This chart was created for experimental purposes only.

Fig. 2 explains the conditions that preceded the Giant Hand illusion, which were recorded during the second ILS approach (**Fig. 3**). During this approach the descent path was approached almost perfectly, while maintaining small course differences. After about 90 s of descent, however, the situation on board began to worsen when a large lateral deviation from the flight path developed, along with the pilot's signs of experiencing illusion (IM curve). This is what can be considered the trigger mechanism for the events displayed in Fig. 3, which comprehensively describes the ILS third descent situation.

Fig. 2 shows an automatically-judged illusion during the final approach (ILL value). Based on comprehensive information, it was most likely a residual bank offset that continued to affect the pilot's vestibular system after canceling the platform offset in the 25th second of the record. Based on an evaluation of the parameters obtained by the in-flight measurements, the pilot experienced spatial disorientation, shown as ILL after the 40th second, that he then overcame a few moments later. The final approach fix (FAF) mark indicates the position where the airplane on the final approach should be within the ILS needle's indication.

Fig. 4 shows the flight path during the third circuit and the position of the extended airport centerline. The curve of the flight path is divided into two parts: the dashed line indicates the flight path of the airplane after departure to the end of the right turn to inbound, and also the final path during ILS approach to the airport; the continuous line shows the flight path with the platform offset to ensure an in-flight sensory illusion on a glide path when the offset ends. The intersection of both curves is the position of NDB "D" (the small deviation is due to piloting inaccuracy). The final approach leg between the FAF and NDB "D" is divided into nautical miles for better understanding and comparability with other figures.

From the analysis of the graphical representation of all displayed parameters recorded during the third circuit, it can be concluded that the pilot only began to concentrate on the airplane course in the 10th second after the first movement of the CDI boom (the CDI boom on the left side has a value −125 of the value on the right vertical axis; on the glide path position the value is 0 and the right side position has a value of +125). This statement confirms the course curve of the airplane between the 20th and 75th seconds, which is characterized by a subdued oscillation with a final value close to 237°. The fact that the pilot knew all the parameters of the approach well and was very experienced makes it difficult to believe that he could not

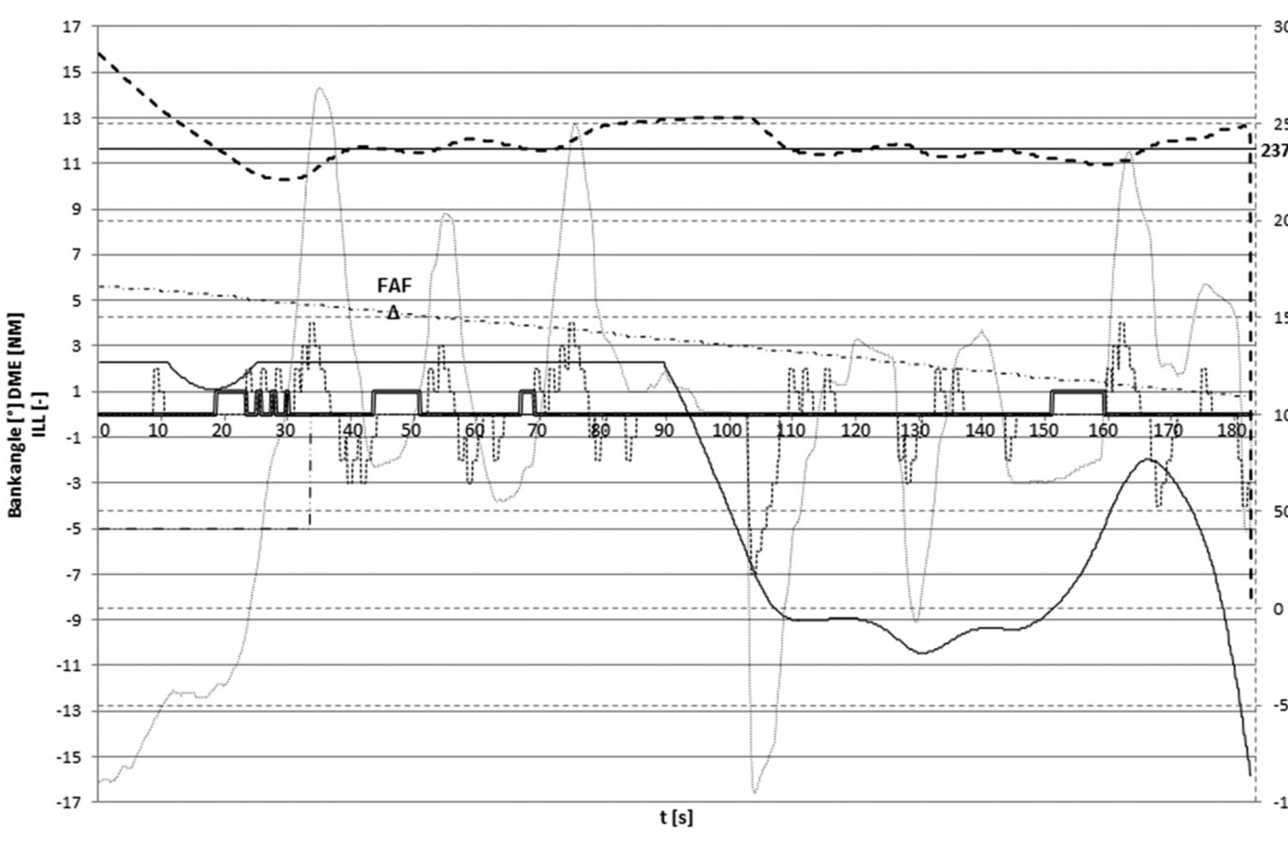

Fig. 3. The Giant Hand illusion (third approach). PLTF: platform; ILL: illusion; DME: distance measure equipment; CDI: course deviation indicator.

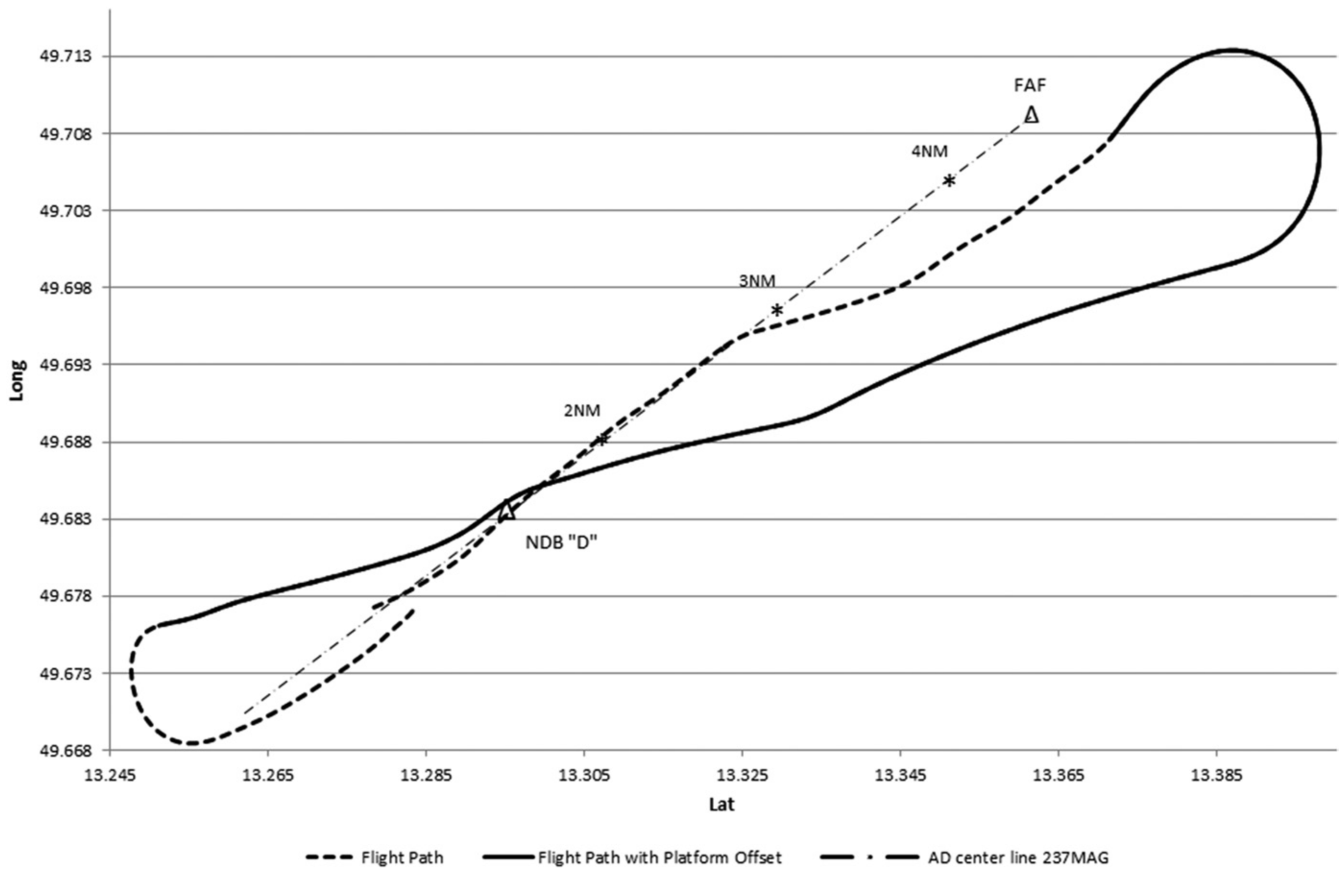

Fig. 4. Horizontal profile of flight.

reach the glide path at the beginning of the approach (according to Fig. 4 he flew parallel to the glide path). This is likely to be explained by his failure during the previous approach to the airport, with large side deflections beginning on the third NM on the glide path (Fig. 2).

During the mentioned time period, there was a rapid change in the bank of the airplane and also at the same time the pilot reported a steering malfunction to the simulator operator (malfunction = no response to the control stick). This information was verified by the operator immediately during the flight and the pilot was informed of the faultless operation of the simulator, which resulted, in the 75th second, in a change in the airplane's course and the visible moving of the vertical bar of the ILS indicator (the CDI value in Fig. 3). The pilot started approaching the zero value of the CDI, which indicates the exact position on the glide path. Approach to the glide path is characterized by changes in airplane bank, with a subdued oscillation between the 90th and 160th seconds on the record.

The set of in-flight sensory illusions signs (ILL curve) is the result of the automatic flight record evaluation, based on a specially developed algorithm (the algorithm is not important for this paper). Based on these signs, the curve can be considered as describing the periods when the pilot might have been under the influence of spatial disorientation or in-flight sensory illusion. The 150th second of the record again shows signs of in-flight sensory illusion which corresponds to the CDI value and bank of the airplane value. This further inaccuracy during the final approach may be a result of the great stress experienced during the previous situation. Flight parameters such as air speed were maintained within safe limits for the ILS approach.

DISCUSSION

During the simulator flight, the pilot verbally reported experiencing symptoms of flight sensory illusion. When the simulator function was checked by the operator and the pilot was assured about the actual situation the symptoms disappeared. The in-flight illusion probably occurred due to the pilot focusing only on maintaining the course of the airplane and not paying attention to the other flight instruments (Fig. 4). In the period at the beginning of the graph, when the pilot was out of the ILS beam (the boom on the right side of the indicator, the airplane left of the glide path), the pilot probably artificially created a steering lock because he was primarily focused on only one flight parameter, in this case on runway direction. The Giant Hand illusion disappeared probably because the pilot was assured that the systems were working properly and he probably started to do a better instrument crosscheck.

The presence of the operator and his communication with the pilot, and the subsequent confirmation that all simulator components were operating without fault, restored the pilot's normal behavior and helped him to fly the airplane properly. We can conclude that if the simulator operator had been absent, the feeling that flying the airplane was impossible would have increased, which could have resulted in an uncontrolled flight with all its consequences.

The pilot's in-flight report and the flight record show that the pilot was most likely experiencing the Giant Hand illusion. The pilot announced the malfunction of the control system and yet still followed almost the same course. This situation happened to only one pilot flying the simulator. The other pilots reported the influence of the leans illusion during their simulator flights. No other pilot noticed and reported any control malfunction which could be interpreted as a case of the Giant Hand illusion. The measured data and results show that a relatively simple simulator can create an in-flight sensory illusion in a pilot. The recorded data of the flight parameters consistently characterized the experienced illusion in flight and allowed us to identify the origin of the illusion. According to the authors and based on the experiment, the Giant Hand illusion is most likely a psychological issue combined with an incorrect focus on flight and navigation devices.

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