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# STUDIES OF PERCEPTION OF INFORMATION ON THE SPATIAL POSITION OF AN AIRCRAFT

Translation of "Badania nad spostrzeganiem informacii o polozeniu przestrzennym samolotu," Technika Lotnicza i Astronautyczna, Vol. 26, 1971, pp. 35-37, 39



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16. Abstract
In the article, methods are presented for studying perception by means of pilots' information on spatial position, and the results are discussed for studies conducted using an electronic method of creating flight information, laboratory studies, simulation, and statistical determinations. Conclusions are presented at the end.

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# STUDIES OF PERCEPTION OF INFORMATION ON THE SPATIAL POSITION OF AN AIRCRAFT

M. Zebrowski

In studies on a method of presenting pilots with basic flight information, much space has been devoted to processes of perception. For they play a fundamental role in setting criteria for minimum visibility, with the aim of identifying the surface of the earth at the moment of transition from flight-instrument observation to maintaining orientation by this means. /35*

The subject of the studies was three groups of problems of a perceptive nature:

- the accuracy of defining the slope of the flight path during lack of visibility of the actual line of the horizon
- the accuracy of predicting the time remaining before landing under conditions of limited external visibility
- the structure of the shape of the earth's surface necessary for the maximum accurate determination of flight-path slope and prediction of time remaining to landing.

## Methods of Study

Studies of the perception of information on spatial position by pilots at the moment of transition from flight-instrument observations to observations of the earth's surface originated from a test of their presentation in artificial form - in the form of television. The medium is called the Contact Analog Display. It is a method of electronically creating flight information used by the pilot during flight with visibility of the actual surface of the earth. It is based on six fundamental problems of spatial orientation:

1) the internal reference grid relative to the shape of the window glass in the cabin ensures the pilot of feeling good inside the cabin

2) external reference grid: the line depicting the position of the actual horizon

3) line perspective: the network of lines running to the line of the horizon permits one to fix position, height, and course changes

4) structure of the terrain surface: horizontal lines indicate changes and convergent lines height and distance

5) the size and shape of objects flying in the field of vision indicate distance and relative mutual position of the objects in front of one

6) parallax of motion: movement along the surface of the earth depicts the rate of motion and distance from the surface.

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* Numbers in the margin indicate pagination in the foreign text.

## Results of the Studies

The study results have permitted the formulation of three basic findings.

1. During flight in near-surface darkness or under conditions in which the contour of the horizon line cannot be seen distinctly, the pilot locates himself as being lower than he really is. This gives rise to a tendency to bring the forward end of the aircraft down too low.

This phenomenon is observed for the first time as an artificially-created fact on the simulator. Initial technical difficulties with lighting and the character of the television screen caused the lack of image depth. Where one ought to have found a distinct horizon line on the screen, there occurred a blurry, gray area.

Pilots estimating the position of the horizon line invariably put it lower than its correct position. According to their estimates, it is lower by about 1/3 of the distance between the vanishing image of the earth's surface and the actual position of the horizon line. The response to this was to lower the "forward end" of the simulator downward. Later experiments in the air confirmed this fact. Fig. 1 illustrates the state of the illusion (line B represents the actual position of the horizon). With level visibility of 800 m, the angle of vision between the plane of the actual horizon and a straight line connecting the eye of the pilot located at a height of 60 m with that detail of the earth's surface which was last distinguished amounts to about $4.9^{o}$ (Fig. 2). On the basis of the studies, one may predict that the pilot, unaided by other information, will place the horizon about $2.9^{o}$ lower than the actual position.

From the moment of glimpsing the actual horizon, the pilot changes as fast as possible the inclination of the aircraft, with the aim of correcting the flight path. Overload caused by bending of the flight path causes additional loss of hegiht. The amount of height loss will depend on the class of aircraft (Fig. 3). For example, heavy aircraft (DC-8), in changing the slope of a $5\text{-}5.5^{o}$ flight path, loses about 18 m in height. This fact comforces an increase in minimum height to begin circling once more (decision height), to at least 25 m. /36

2. Approaching the earth's surface without information other than its apparent movement in the direction of the observer, there is normally an underestimation of the time remaining to landing.

It is established that pilots (but not just pilots) predict the time left before landing surprisingly well, even in the case of lack of knowledge of the rate of their movement, the size of

Fig. 1

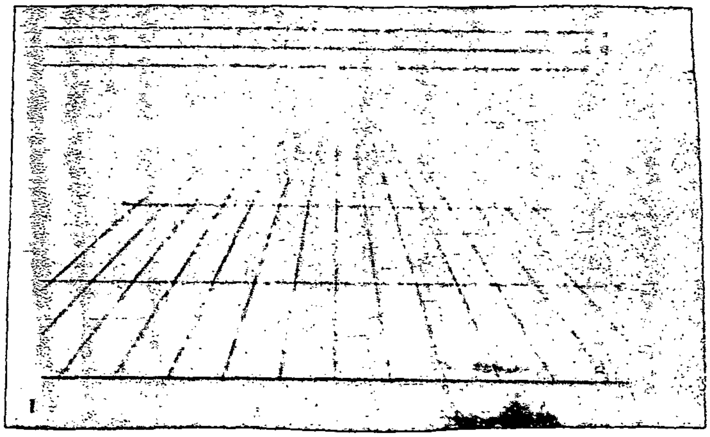
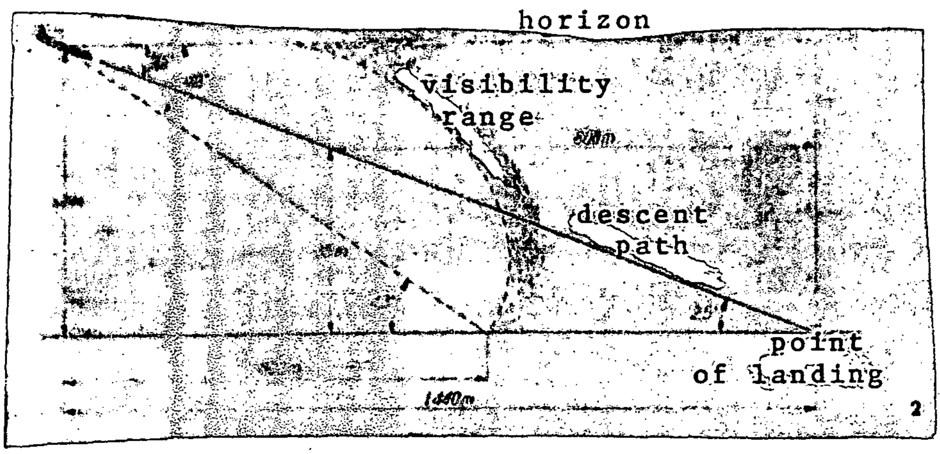
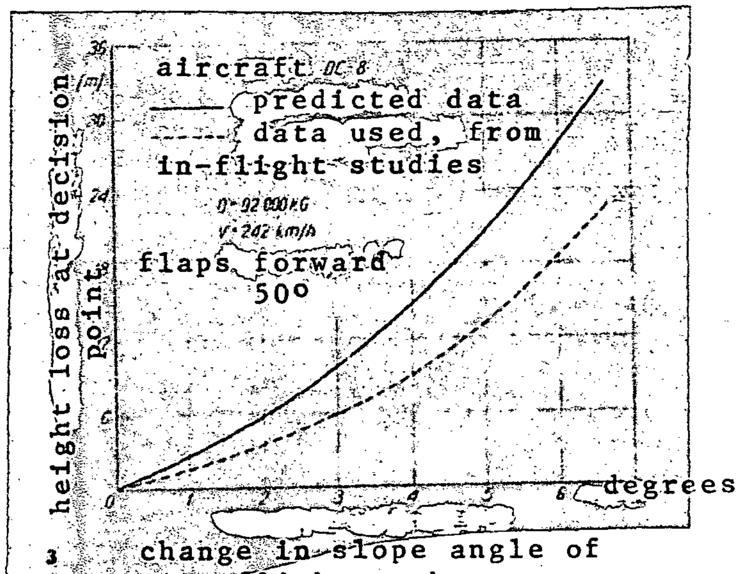


Fig. 2




observed objects, or the distance from the surface of the earth. For the studies, six seconds was assumed remaining to landing. The existence of a general tendency to underestimate the time remaining was established. It is known that if the aircraft has 5 seconds to land, pilots estimate this at 4 seconds, on the average, and level the flight off a little too early (Fig. 4). The dotted line on this diagram illustrates the ideal time estimate. The area under the curve represents cases of underestimation of time left to landing; this is called the "safe" area. On the basis of a statistical analysis of the results obtained based on a normal-distribution curve, it may be predicted that when 4 seconds remain to landing, pilots estimate this time as 3.2 seconds, on the average, leveling off the aircraft 0.8 seconds too early.

Fig. 3



change in slope angle of flight path

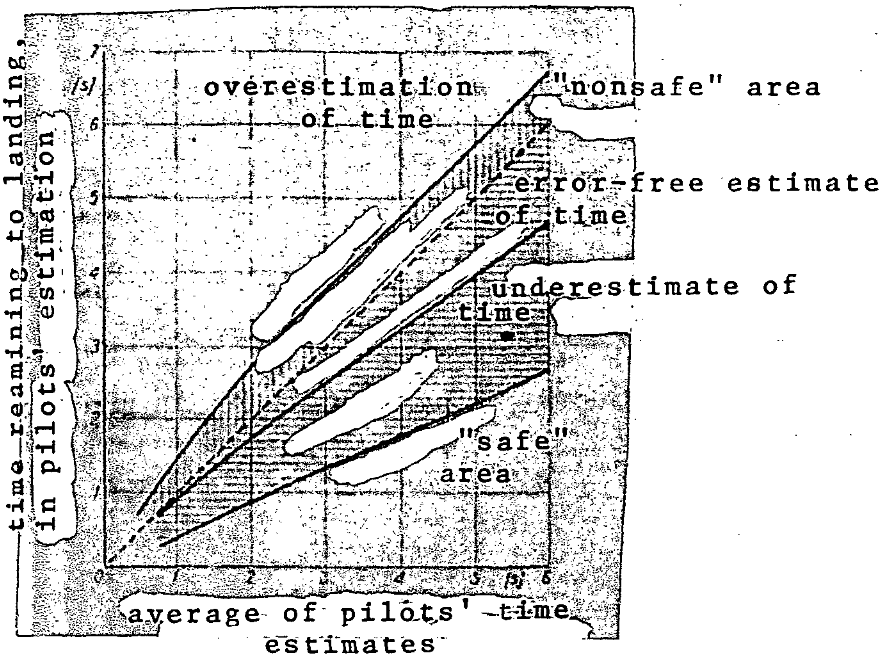
Such an estimate is too low in approximately 68% of the cases. At least once in 100 pilots the time was underestimated with an error of 4 seconds, and so the leveling off was too early.

The upper side of the diagram plays the most important role - overestimation of the time remaining to landing, the side called "nonsafe". In an average of 28.5% of the cases, the pilot overestimates the time and in effect levels off too late. In everyday aircraft use, this is manifested as a "hard" landing. At times, this could turn out even worse.

Taking the vertical rate of aircraft descent to be 5 m/sec, the decision height of 25 m remains about 5 seconds time to landing. Meanwhile, studies have shown that the minimum time during which the earth must be seen before landing in order for the number of unsuccessful landings not to exceed 28% is aout 7 seconds. From this, at a descent rate of 5 m/sec, the earth must be seen from a height of about 60 m (7 sec X 5 m/sec + 25 m).

This part of the studies was based in large part on laboratory studies, simulations, and statistical calculations. The smaller results not hereby established should be considered in establishing the meteorological minima for a class I landing. /37

Fig. 4

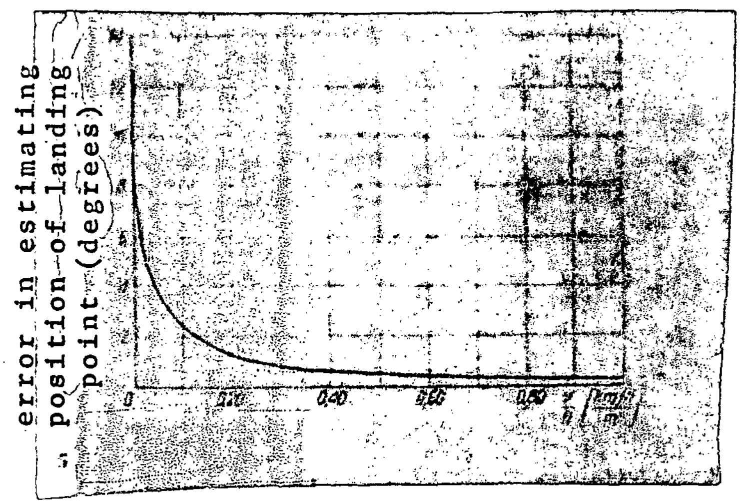



3. Maximum safety of actual aircraft landing requires a suitable design for approach lights and other visual aids defining the earth's surface. Their density or separation in meters should be equal to the distance covered in one second by the aircraft coming up to land.

The most important source of perceiving the depth of an image and of estimating distance and spatial orientation is constructtion of an image of the earth's surface or else its structural gradient. If individual elements of the same size and shape create the surface, the distant elements seem to more densely set than those in the foreground. This causes the occurrence of image perspective. Studies have shown that the accuracy of estimating surface slopes depends on the density of the structural size of the optical image. When the number of structural elements is less than that useful for establishing the gradient (theoretically three elements are sufficient), estimation accuracy falls to zero. Estimate accuracy increases with an increase in the number of structural elements, but only until the point at which their size or position reaches the eye's discrimination threshold. After crossing it, estimate accuracy again falls to zero. It is shown that moderate accuracy is estimating slope of the flight path, determinations of the landing point, and location of the target point may be used if the structural plan of the earth's surface is allowed to distinguish the distance equal to the least distance which the aircraft travels in 20 seconds. The greatest accuracy of predicting the landing point occurs when the ratio of the rate of aircraft motion to the height of its flight is equal to unity, $V/h = 1.0$ (Fig. 5).

Because of the height of the landing aircraft steadily decreases, the ratio V/h tends toward infinity. From an analysis of this relationship, it is understood that the separation of the structural elements should be equal to the distance covered by the aircraft in the time of a second. On this basis, the separation is assigned between individual lamp sets of approach lights for landing, the runway path, or various visual designations for it.

Fig. 5

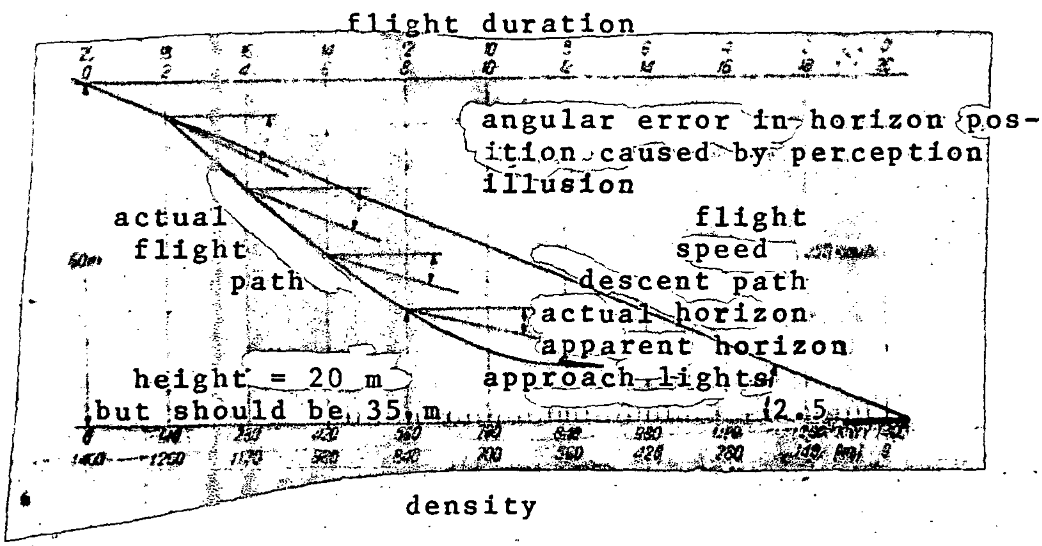



## Results

Errors of pilot perception and delay in reacting make meteorological minima for a class I landing the limit for the safe, actual landing of a transport plane, accomplished by a pilot on the basis pf external observations. Landing with lower meteorological minima requires the use of automatic landing systems without regard to the role which the man will then fill.

In Fig. 6 is presented the deviation of the aircraft flight path from the descent path, caused by an illusion in horizon-perception by the pilot. Such a situation occurs approximately when a pilot has completed the entire landing approach. As long as he flies exclusively with the aid of flight-instrument indications, the aircraft will be flown along ILS descent planes. At the moment the earth's visibility is used, the pilot passes into a new descent pattern for his observation and maintenance of spatial position. Illusion in perception of the horizon causes a decrease in the descent path. An increase in flight-path slope implies an increase in the vertical rate of descent and in flight speed. A decrease in the power of the propulsion unit is responsible for this, as a rule. But above the approach lights, where the apparent horizon occupies more or less the same position as the actual, the pilot begins by dipping the aircraft to correct the flight path. This often means the necessity for a power increase. Sudden changes in power and slope in the final phase of /39

Fig. 6




landing approach are useless and actually may be dangerous. These facts require allowing for the introduction of an exact division of staff functions during landing under severe weather conditions and its visualization in the operating instructions of a given flight crew. Generally it depends on the fact that the pilot approaching using flight instruments monitors their indications before the run at the edge of the runway path, without attaining greater slopes. At this time, a second pilot is waiting for the appearance of the earth and the approach lights. At the moment their image is established, the pilot takes over the steering and

and executes the landing. If at a critical height, nothing is seen, he executes another circle without interfering with the steering. Different flight crews apply different variants in function division according to many factors. Operating instructions on a "Flight" PLL for such a division of staff functions under difficult weather conditions are not included.