## AUTOMATIC CONTROL SYSTEMS

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# SUGGESTIONS TO THE METHODS FOR ASSESSING THE QUALITY OF THE GLIDE PATH ENTRANCE

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***Abstract—****The article deals with issues related to the assessment of the aircraft piloting quality. Also, the factors affecting the technique of piloting crews in emergency situations in flight were analyzed. As the result, the special anti-stress training for pilots was proposed.A method for determining the quality of piloting according to the boundaries in space has been proposed. This method is considered on the example of the approach of an aircraft regading the estimated accuracy of the glide path entrance in three-dimensional coordinate system.*

**Index Terms—**Flight path; glide path; human factor; parameter amplitude.

## I. INTRODUCTION

One of the main issues in civil aviation is safety of flight. It depends on many factors, in particular, on the quality of the crew training. As flight experience shows, the quality of piloting deteriorates most often when special situations arise in flight. They have either multiple hazards, or they occur sequentially at short intervals. Such a phenomenon is called factor overlay.

The danger of it the crew is became in a state of severe stress. At the same time, the crew cannot assess the current situation and take an appropriate decision on how to get out of it.

One potential solution of the problem is the anti-stress training of pilots.

There was developed and tested methods for such training at the Avionics Department of National Aviation University.

The success of the most difficult part of the flight approach also depends on the quality of crew training. According to world statistics during this segment of the flight, more than one third of all accidents occur. This happens because the approach is characterized by a significant speed decrease and the increase of angle of attack to a critical value. Also, very short amount of time is given for the implementation of this phase of flight.

This circumstance can lead to the impossibility of parrying by air of external disturbances and to an increase of control errors. Also, high congestion of pilots can lead to mistakes at the landing stage: landing gear release, flap cleaning, communication with ground services, change of engine operating modes, visual control of space. In addition, pilots require high attentiveness and accuracy of maneuvers to be performed in order to ensure precise control of the angular and trajectory flight parameters when entering aircraft gliding.

So at the landing stage of the aircraft. There are a number of tasks that require complex solutions. As the result, the application of methods based on the probability-physical model was suggested.

## II. PROBLEM STATEMENT

The main goal of this article is the development of methods for defing the deviation from the flight path by the aircraft during the glide path entrance, due to the increased psycho-physiological tensity of pilots.

The aircraft carries out its evolutions in space. Accordingly, the quality assessment of the flight should be determined within the boundaries of the volume measurement. On the vertical plane, the integral difference between the ideal and real trajectories ($\Delta$) and the flight length on the glide path ($L$) are compared with the help of following formula:

$$\frac{\Delta}{L}=\frac{h^2}{L^2}\chi^2,$$

where $h$ is the flight altitude; $\chi$ is the value of deviation.

In the same way $\frac{\Delta}{L}$ is determined in the horizontal plane. It makes sense to determine the flight quality in a three-dimensional coordinate system. For the solution of this problem, the analysis of correlation functions are used.

The comparison of the ideal and real glide pathentry points in the horizontal and vertical planes were alerady analyzed before. In this article, a technique of the volumetric measurement for determining the acceptable limits of the glide path entry was proposed.

Previously, the phenomenon of the flight data amplitudeincrease (IAAFP) was considered due to the increase of psychophysiological stress of the pilot. IAAFP can be determined by comparing flight parameters under normal conditions and in special situations according to the formula

$$\Delta\Delta\grave{A}_{\gamma,\psi,\vartheta}=\sqrt{\Delta\grave{A}_{\gamma}^{2}+\Delta\grave{A}_{\psi}^{2}+\Delta\grave{A}_{\vartheta}^{2}},$$

where $\gamma$ is the angle of roll; $\psi$ is theyaw; $\theta$ is the pitch [1].

In this article it is proposed to define thevariation of flight parameters limitsin a three-dimensional system.

Currently, modern aircraft are equipped with digital avionics systems. Glitches in the system exists more often than it’s failures. In this case the crew should reload certain systems. This has a negative effect on the psychophysiological state of the pilots.

Currently, the development of avionics systems often involves the calculation of reliability with the help of exponential failure model. A more correct calculations can be done using a diffusion-nonmonotone failure model. It is also necessary to develop a general plan of activities in this direction.

## III. THEORETICAL RESULTS

Problem solution of optimal flight trajectory on a glide path.

In article [2] variants of deviation from the ideal glide path entery point in the vertical plane were considered. A formula for comparing the integral difference between the $\Delta$ and $L$ was obtained (Fig. 1).

$$\frac{\Delta}{L}=\frac{1}{3}h^{2}-\frac{2h^{2}}{3}+\frac{h^{2}}{L}\chi+\frac{h^{2}}{3}+\frac{h^{2}}{L^{2}}\chi$$
$$-\frac{h^{2}}{L}\chi+\frac{h^{2}}{L^{2}}\chi^{2}=\frac{h^{2}}{L^{2}}\chi^{2}.$$

On the conference [3] the results of the analysis of deviations from the ideal entry point into the glide path in the horizontal vertical plane were tested.

Let's consider the flight path of an aircraft when it leaves the glide path (Fig. 2), defined by the expression

$$z_{3}(y)=z-\frac{z}{L}x, \qquad (1)$$

where $z$ is the flight altitude while approaching the glide path; $\chi$ is the lateral deviation from the specified glide path point.

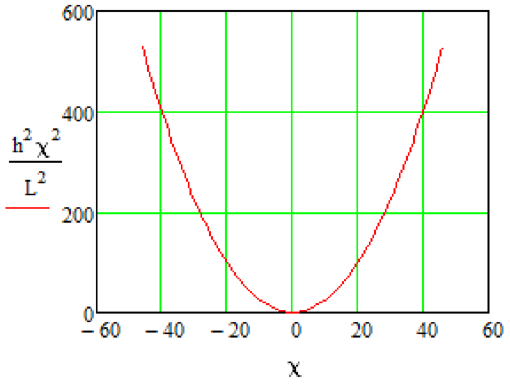


Fig. 1. The graph of dependency $\frac{\Delta}{L}$ from $\chi$

($\chi$ from – 46 m to 46 m)

It will be considered consider special cases of deviation from the given glide path

$$z_{P}=z-\frac{z}{L}(y-\chi), \qquad (2)$$

where $\chi$ is the value of the deviation.

Then the correlation and autocorrelation functions are equal to $\chi$ (deviation value).

$$\rho_{3}=\frac{1}{L}\int_{C}^{L}\left(z-\frac{z}{L}y\right)^{2}dy=\frac{z^{2}}{3}. \qquad (3)$$

$$\rho_{\rho 3}=\frac{1}{L}\int_{L}^{C}\int_{0}^{L}\left[\left(z-\frac{z}{L}y\right)\left(z-\frac{z}{L}(y-\chi)\right)\right]dy$$
$$=\frac{z^{2}}{3}+\frac{z^{2}}{2L}\chi. \qquad (4)$$

$$\rho_{k}=\frac{1}{L}\int_{L}^{0}\left[z-\frac{z}{L}(y-\chi)\right]^{2}dy=\frac{z^{2}}{3}+\frac{z^{2}}{L}\chi+\frac{z^{2}}{L^{2}}. \qquad (5)$$

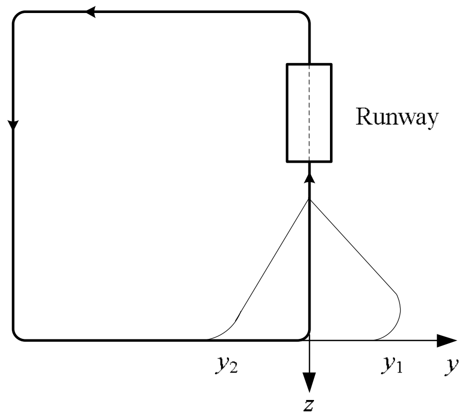


Fig. 2. Scheme of entering the glide path in the horizontal plane

Then the correlation and autocorrelation functions are equal.

In further calculations it was maked $\rho(-\chi)$.

Values of (3) were substituted (5) into (6) and find the integral difference between two trajectories.

This is written in the following form:

$$\Delta = L\frac{z^2}{3} - 2L\frac{z^2}{3} - h^2\chi + \frac{z^2 L}{3} - \frac{z}{L}\chi^2 + z^2\chi^2 = \frac{z^2}{L}. \quad (6)$$

At $\chi = 0$, $\Delta = 0$, $\chi = L$, $\Delta = z^2 L$.

This is written in the following formula:

$$\Delta = z^2 L\left(\frac{\chi}{L}\right)^2. \quad (7)$$

From formulas (3)–(5) it's understandable that with the increase of $\chi$ from 0 to $L$ the value of $\Delta$ increases.

Trajectory of advance flight on the glide path:

$$z(y+\chi) = z - \frac{z}{L}(y+\chi). \quad (8)$$

Spliting the range (0, $L$) into two parts (0, $L - \chi$) and (0, $L + \chi$). Crawl function ($L - \chi$, $L$) is equal to zero $z(y + \chi) = 0$. Consequently, the correction function forward is determined by integration only (0, $L - \chi$) = 0.

$$\rho_{3p} = \rho(+\chi) = \frac{1}{L}\int_0^{L-\chi}\left(-\frac{z}{L}y\right)\left[z - \frac{z}{L}(x-\chi)\right]dy = \frac{z^2}{3} - \frac{z^2}{2L}. \quad (9)$$

Comparing (3) and (9)

$$\rho(-\chi) - \rho(+\chi) = \frac{z^2}{L}\chi,$$

obtain $\rho(-\chi) > \rho(\chi)$.

Autocorrelation function of the improved path

$$\rho_k(+\chi) = \frac{1}{L}\int_0^L\left[z - \frac{z}{L}(x+\chi)\right]^2 dy = \frac{z^2}{L}\int_0^L\left[1 - \frac{y+\chi}{L}\right]^2 dy = \frac{z^2}{3} - \frac{z^2\chi}{L} + \frac{z^2}{L^2}\chi^2, \quad (10)$$

$\rho(-\chi) - \rho(+\chi) = 0$ under the condition $\chi = 2L$ (unreal condition).

Under the condition $L >> \chi$, autocorrelation function of the improved path

$$\rho_k(+\chi) = \frac{1}{3}z^2. \quad (11)$$

Substituting values $\rho_3, \rho_k(+\chi)$ and into (11), the following formula is obtained (Fig. 3).

$$\frac{\Delta}{L} = \frac{1}{3}z^2 - \frac{2z^2}{3} + \frac{z^2}{L}\chi + \frac{z^2}{3} + \frac{z^2}{L^2}\chi - \frac{z^2}{L}\chi + \frac{z^2}{L^2}\chi^2 = \frac{z^2}{L^2}\chi^2.$$

In the case of deviation from the input line to the glide path, the probability of not reaching the threshold level of runway increases, and, consequently, the probability of an accident increases.

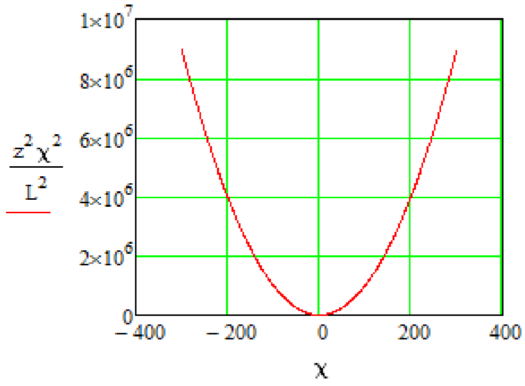


Fig. 3. The graph of dependency $\frac{\Delta}{L}$ from $\chi$ ($\chi$ from – 300 m to 300 m)

While considering the flight of the aircraft on a given trajectory at a constant height on the plane $z$ = const, the coordinate is a lateral deviation.On a fixed length of the trajectory $L - x_1$ starting point is, $x_2$ – end point $L = x_2 - x_1$.

The square of the integral difference of the trajectory of the planned and real flight in a certain area is equal to: $\Delta = \int_{x_1}^{x_2}\left[y_3(x) - y_p(x)\right]^2 dx$, where $y_3(x)$ planned flight path; $y_p(x)$ – real flight path.

The ratio of the square of the integral difference of the trajectoryΔ to length $L$, with a time lag $\chi$ is determined by the expression:

$$\frac{\Delta}{L} = \frac{1}{3}y^2 + \frac{3y^2}{L}\chi + \frac{2y^2}{L^2}\chi^2 - \frac{y^2}{3L^3}\chi^3.$$

Similarly, the following expression can be obtained if during the entrance zone of glide path, the flight height will vary $z$ = var:

$$\Delta = \int_{y_1}^{y_2}\left[z_3(y) - z_p(y)\right]^2 dy,$$

$$\frac{\Delta}{L} = \frac{1}{3}z^2 + \frac{3z^2}{L}\chi + \frac{2z^2}{L^2}\chi^2 - \frac{z^2}{3L^3}\chi^3.$$

Then for three-dimensional space with lateral deviation $y$ and vertical deviation $z$ ratio of the square of the integral difference $\Delta$ to the length of the trajectory is written in the following way:

$$\frac{\Delta}{L}=\left(\frac{1}{3}-\frac{3\chi}{L}+\frac{2\chi^2}{L^2}-\frac{\chi^3}{3L^3}\right)\left(y^2+z^2\right).$$

This feature with specific $L$ and $\chi$ will be the Fig. 5.

## IV. DETERMINATION OF FLIGHT PARAMETERS INCREASE

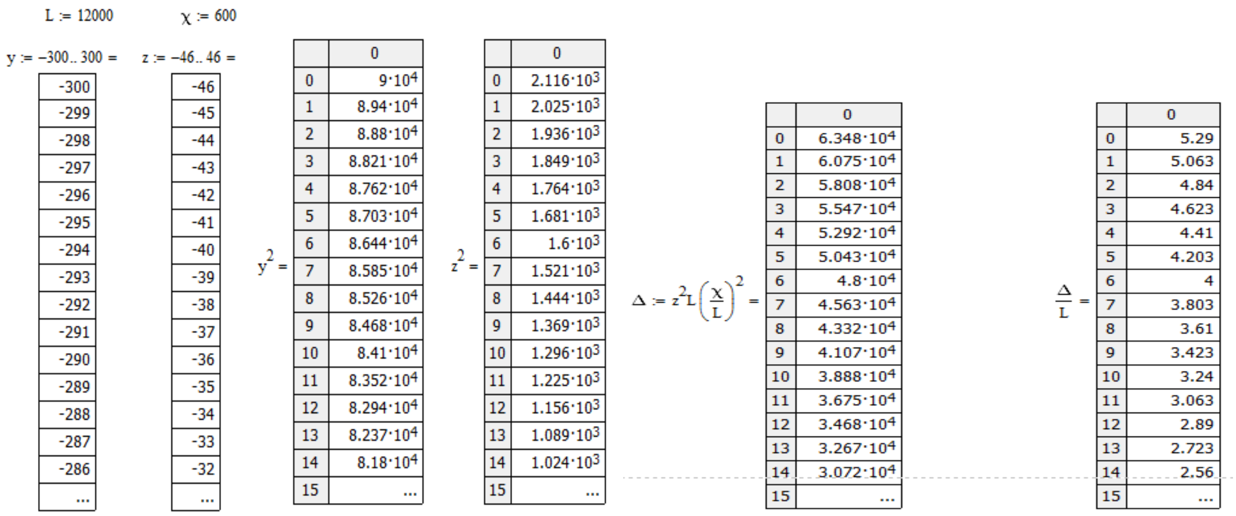
Currently, the main tasks of simulator training are procedural, decisive, preconceptual-motor): procedural – control of the communication system, work with navigation equipment, control of the fuel system, work with sensors; decisive-flight planning, actions in extreme situations, determining the order of operations, distribution of duties among crew members; preconceptual-motor – geographic orientation, piloting of aircraft, communication and identification of danger [4].

Also, all the trainings should take place in special situations. All of the above is necessary. However, this is not enough. Previous studies show that 80% of pilots exhibit increased tension under the action of the block of simultaneous failures, which leads to UAPPACE [5]. Therefore, it is necessary to conduct anti-stress preparation (Fig. 6).

So, have a technique for determining the points of entry into the glide path in the boundaries of a volumetric measurement.

The goal of transition to dimensionless coefficients in the processing of flight data oscillograms of the transition from moment to interval estimation is successfully solved by the use of trend algorithms [6].

Under the trend the stable changes in the observed process and an opinion on its prediction in the future is given. According to the processed statistics, a number of patterns have been identified, which shows the need to pass the anti-stress training course for most pilots [7].



$L := 12000$ $\chi := 600$

$y := -300..300 =$

| |
|---|
| -300 |
| -299 |
| -298 |
| -297 |
| -296 |
| -295 |
| -294 |
| -293 |
| -292 |
| -291 |
| -290 |
| -289 |
| -288 |
| -287 |
| -286 |
| ... |

$z := -46..46 =$

| |
|---|
| -46 |
| -45 |
| -44 |
| -43 |
| -42 |
| -41 |
| -40 |
| -39 |
| -38 |
| -37 |
| -36 |
| -35 |
| -34 |
| -33 |
| -32 |
| ... |

$y^2 =$

| | 0 |
|---|---|
| 0 | $9\cdot10^4$ |
| 1 | $8.94\cdot10^4$ |
| 2 | $8.88\cdot10^4$ |
| 3 | $8.821\cdot10^4$ |
| 4 | $8.762\cdot10^4$ |
| 5 | $8.703\cdot10^4$ |
| 6 | $8.644\cdot10^4$ |
| 7 | $8.585\cdot10^4$ |
| 8 | $8.526\cdot10^4$ |
| 9 | $8.468\cdot10^4$ |
| 10 | $8.41\cdot10^4$ |
| 11 | $8.352\cdot10^4$ |
| 12 | $8.294\cdot10^4$ |
| 13 | $8.237\cdot10^4$ |
| 14 | $8.18\cdot10^4$ |
| 15 | ... |

$z^2 =$

| | 0 |
|---|---|
| 0 | $2.116\cdot10^3$ |
| 1 | $2.025\cdot10^3$ |
| 2 | $1.936\cdot10^3$ |
| 3 | $1.849\cdot10^3$ |
| 4 | $1.764\cdot10^3$ |
| 5 | $1.681\cdot10^3$ |
| 6 | $1.6\cdot10^3$ |
| 7 | $1.521\cdot10^3$ |
| 8 | $1.444\cdot10^3$ |
| 9 | $1.369\cdot10^3$ |
| 10 | $1.296\cdot10^3$ |
| 11 | $1.225\cdot10^3$ |
| 12 | $1.156\cdot10^3$ |
| 13 | $1.089\cdot10^3$ |
| 14 | $1.024\cdot10^3$ |
| 15 | ... |

$\Delta := z^2 L\left(\frac{\chi}{L}\right)^2 =$

| | 0 |
|---|---|
| 0 | $6.348\cdot10^4$ |
| 1 | $6.075\cdot10^4$ |
| 2 | $5.808\cdot10^4$ |
| 3 | $5.547\cdot10^4$ |
| 4 | $5.292\cdot10^4$ |
| 5 | $5.043\cdot10^4$ |
| 6 | $4.8\cdot10^4$ |
| 7 | $4.563\cdot10^4$ |
| 8 | $4.332\cdot10^4$ |
| 9 | $4.107\cdot10^4$ |
| 10 | $3.888\cdot10^4$ |
| 11 | $3.675\cdot10^4$ |
| 12 | $3.468\cdot10^4$ |
| 13 | $3.267\cdot10^4$ |
| 14 | $3.072\cdot10^4$ |
| 15 | ... |

$\frac{\Delta}{L} =$

| | 0 |
|---|---|
| 0 | 5.29 |
| 1 | 5.063 |
| 2 | 4.84 |
| 3 | 4.623 |
| 4 | 4.41 |
| 5 | 4.203 |
| 6 | 4 |
| 7 | 3.803 |
| 8 | 3.61 |
| 9 | 3.423 |
| 10 | 3.24 |
| 11 | 3.063 |
| 12 | 2.89 |
| 13 | 2.723 |
| 14 | 2.56 |
| 15 | ... |

Fig. 4. Listing of calculating $\Delta/L = f(y,z)$

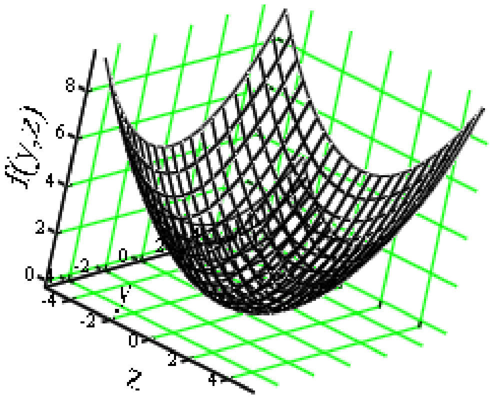


Fig. 5. The graph of dependency $f(y, z)$

Amplitude can be measured and applied to the axis of coordinates when working with numbers in degrees, and when working with schedules – in conditional units, and periods respectively in seconds and conditional units.

Using trend algorithms it is advisable to compare ( $\Delta\Delta\delta_{a.s,h}$ ) the deviation of the ailerons, the steering wheel of the direction and height with $\left(\Delta\Delta A_{\gamma,\psi,J}\right)$ changes in parameters:

$$\Delta\Delta\delta_{a,s,h}=\sqrt{\Delta\delta_a^2+\Delta\delta_s^2+\Delta\delta_h^2},$$

$$\Delta\Delta A_{\gamma,\psi,J}=\sqrt{\Delta A_\gamma^2+\Delta A_\psi^2+\Delta A_\vartheta^2}.$$

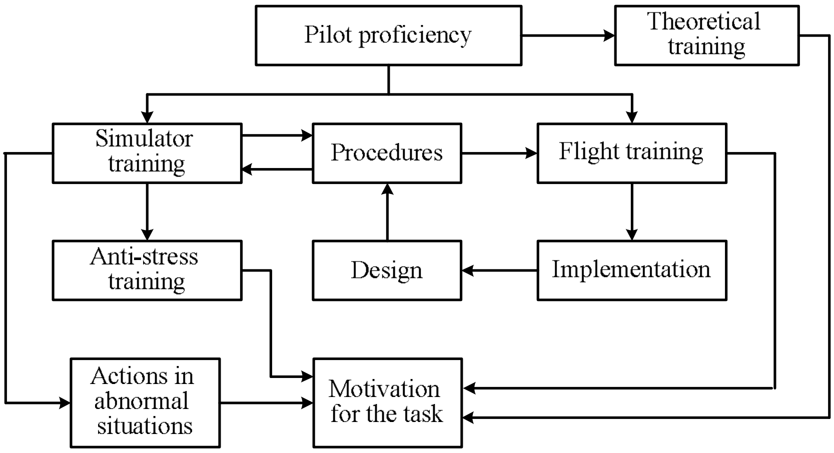


Fig. 6. Pilot training scheme

For example, during the "whipping" of the discrepancy and you can judge the quality of piloting technology, because with a strong bell, an experienced pilot does not allow strong deviations of parameters, although the expense of the steering wheel and the elephant is large. Using trend algorithms and a program of processing on a computer, according to the number of printing, the specific comparison data for flights is obtained

$$\Delta\Delta\grave{A}_{\gamma,\psi,J}=\sqrt{\Delta\grave{A}_{\gamma}^{2}+\Delta\grave{A}_{\psi}^{2}+\Delta\grave{A}_{J}^{2}}.$$

With factor overlays and without them. During the flight pilots can not always avoid the appearance of false actions.

This method can be used to determine the trend of loss of spatial targeting by pilots during the flight [8].

The most common mistakes in piloting technology with the influence of negative factors are: not holding the glide path and not keeping the speed on the glide path planning, not keeping the course, correcting it is not in the right side, not keeping the vertical speed and. etc. Moreover, after the pilot begins to correct the error, there is an amplification of the dynamic stereotype at amplitude and frequency, fixed by means of flight registration. In the existing literary sources there is a diametrically opposite idea – when the actions of factor loads there is no amplification, but so-called "breaking" of the dynamic stereotype of action. Experiments on simulator and statistics do not confirm this. Particularly good discrepancy is visible in oscillograms according to the angle of the roll parameter. Checking this provision is important for the design of new training programs, as well as for issuing practical pilot recommendations for improving its piloting skills.

Erroneous and allogic actions during the flight, connected in the first place, with changes in mental processes, loss of spatial orientation from the action of factor loads. By obtaining the spatial signals from the action of factor loads with a sufficient number of them, the pilot may fall into the zone of reflected motion, but spatial.

The suppression of temporary mapping of movements by pilots is a good indicator. According to such data, the degree of counteracting the factor load can be detemined.

Ideally, it is necessary to give such refusals that do not affect aerodynamics of an airplane. For example: the failure of the aviation horizon, the deterioration of the transparency of the atmosphere, etc.

It is also advisable to use trend algorithms to build correlation fields for dependencies of flight parameters. [8]. For example, the dependence of the angle of attack (α) from instrument speed ($V$) can be defined as following:

$$\Delta V=(V_i-V_{i+1})/K_{\min V},\quad \Delta\alpha=(\alpha_i-\alpha_{i+1})/\,K_{\min\alpha},$$

where $K_{\min V}$ and $K_{\min\alpha}$ minimum values of relevant parameters are allowed, $i = 1, 2, 3, \ldots N$.

The use of these algorithms is also useful for preventing the consequences of sharp movements by the pilot's wheel when moving to the second circle in the steering mode [9].

Let's estimate the probability of deviation of the aircraft from a given point of the flight path $O(x,y,z)$ (Fig. 7) in flight, it will be limited to two spheres with the corresponding radius $r$ and $R$.

The value of $r$ will be determined by the permissible deviation from the point $O$, which depends on the accuracy of the airborne equipment of the aircraft.

Value $r$ is the optimal point of the glide path entry, $R$ – deviation from $r$.

The value $R$ depends on the limitations of the aircraft that is on the airway, that are the width and the echelon. Thus, any point $A(x,y,z)$ of the deviation from the given point $O(x,y,z)$ will be in the volume of the sphere between the radii *R* and *r*. The magnitude of deviation probability:

$$P(V)=\frac{\frac{4}{3}\pi R^3-\frac{4}{3}\pi r^3}{\frac{4}{3}\pi R^3}=\frac{R^3-r^3}{R^3}=1-\frac{r^3}{R^3}.$$

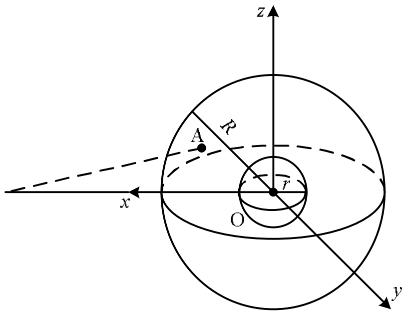


Fig. 7. Geometric interpretation of determining the probability of a plane deviation from a given point

## V. ADJUSTING THE RELIABILITY OF THE ERGATIC CONTROL SYSTEM

The reliability of the changeable system depends on the ability to perform the required functions of both the technician and the operator in the process of operating aviation equipment (Fig. 8).

The suggestion to transfer the recalculation of the mean time to failure in the design bureaus (MTTF) was proposed. Methods of recalculations are obtained on the basis of an exponential model ($\text{MTTF}_{\text{EXP}}$), using the distribution density of the work before the failure of the elements and systems that differ in physical nature, and do not contradict the two-parameter diffusion models of failures and glitches of the avionics systems ($\text{MTTF}_{\text{DN}}$). Graphs of reliability evaluation are obtained in $\text{MTTF}_{\text{EXP}}$ and $\text{MTTF}_{\text{DN}}$, also errors of λ-method, as well as dependences of methodological errors λ-method from the complexity of the technical system are obtained [10].

Comparisonofamplitudevalueisnecessaryintheanalysisof flights of the same pilot without failure and with introduced failures. Thus, by this difference, we can determine the amplitude gain that occurs under the influence of factor loads, which are imitated on aviation simulators by complex failures. Preliminary calculations on the roll showed that for 80% of pilots, this leads to amplitude strengthening of the dynamic stereotype, increasing the probability of pilot's mistakes.

To summarise it is necessary to increase the reliability of avionics systems as well as the quality of crew training according to the above-mentioned methods.

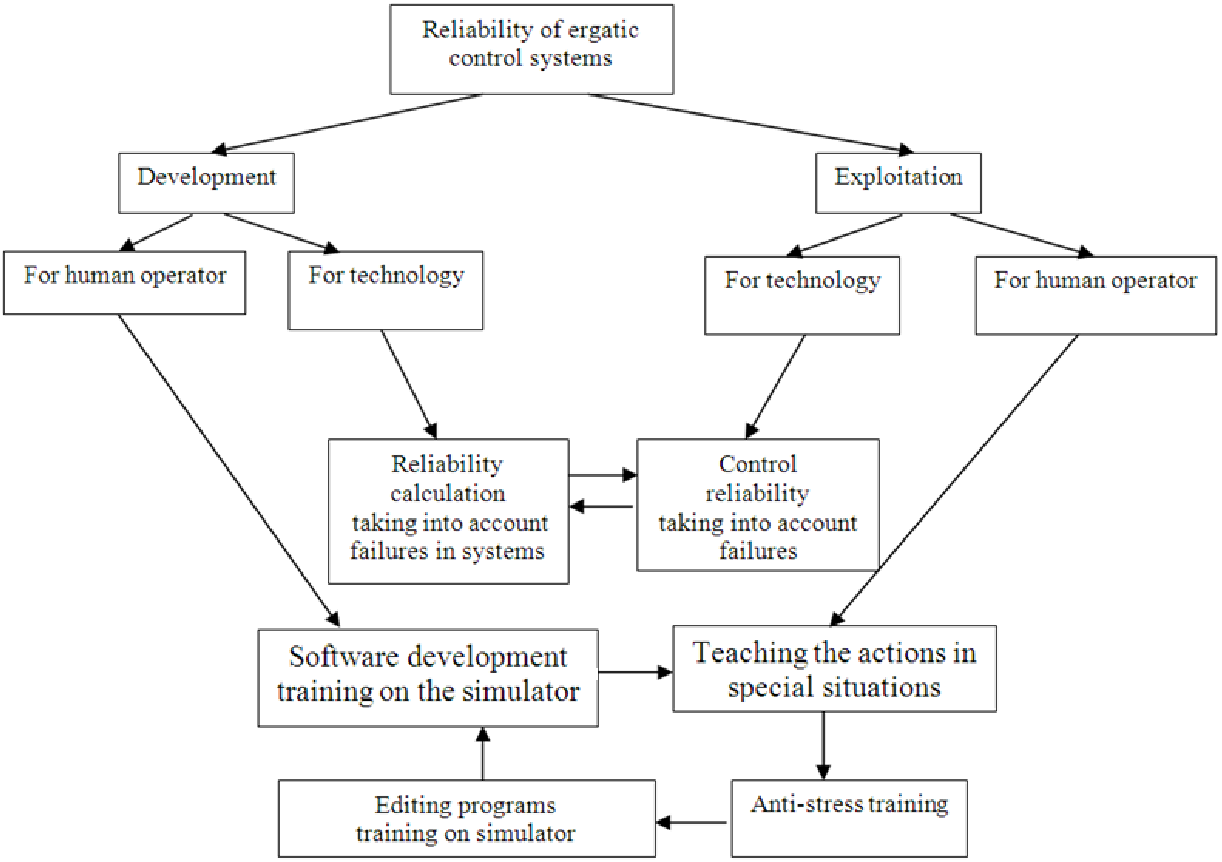


Fig. 8. The scheme corresponds to the reliability of the ergatic control system

## V. CONCLUSIONS

The formula for determining the acceptable limits of theglide path entrance in a three-dimensional space with a lateral deviation y and a vertical deviation z is developed. The plot of the dependence $f$ $(y, z)$ is constructed.

The geometric interpretation of the probability of deviation from a given point duing the glide path entrance is presented.

A scheme of methods for increasing the reliability of the erratic control system is developed.

As the result the methods for determining the poly-parametric boundaries of amplification of an integro-differentiated dynamics stereotype during the glide path entering were presented. They can be useful for developing alarm systems of flight quality as well as for decoding of flight information.

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**Ю. В. Грищенко, В. Г. Романенко, Д. М. Піпа. Пропозиції щодо методів оцінки якості входу в глісаду**

Розглянуто питання, пов'язані з оцінкою якості пілотування літальних апаратів. Проаналізовано фактори, що впливають на техніку пілотування екіпажу в аварійних ситуаціях під час польоту. В результаті запропоновано спеціальну антистресову підготовку для пілотів. Запропоновано метод визначення якості польоту відповідно до встановлених обмежень в просторі. Цей метод розглядався на прикладі етапу заходу на посадку літака з урахуванням розрахункової точності входу в глісаду в тривимірній системі координат.

**Ключові слова:** шлях польоту; ковзання; людський фактор; амплітуда параметра.

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**Ю. В. Грищенко, В. Г. Романенко, Д. М. Пипа. Предложения к методам оценки качества входа в глиссаду**

Рассмотрены вопросы, связанные с оценкой качества пилотирования летательных аппаратов. Также проанализированы факторы, влияющие на технику пилотирования экипажей в аварийных ситуациях в полете. В результате была предложена специальная антистрессовая подготовка для пилотов. Предложен метод определения качества полета в соответствии с установленными ограничениями в пространстве. Этот метод рассматривался на примере этапа захода на посадку самолета с учетом расчетной точности входа в глиссаду в трехмерной системе координат.

**Ключевые слова:** путь полета; скольжение; человеческий фактор; амплитуда параметра.

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