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SYMBAD – INSTRUMENT IN THE COURSE OF AIRCRAFT FLIGHT TEST PLANNING

Mirosław Zieja, Włodzimierz Kosiński, Joanna Wójcik

Air Force Institute of Technology, Warsaw, Poland
Księcia Bolesława Street 6, 01-494 Warsaw, Poland
tel.: +48 22 6851302, fax: +48 22 8364471
e-mail: miroslaw.zieja@itwl.pl, wlodzimierz.kosinski@itwl.pl, joanna.wojcik@itwl.pl

Abstract

Any flight test programme is essentially based on a flight test plan, i.e. a document agreed upon and accepted by all the parties interested in the tests, and authorised by the superior body/authorities responsible for the execution of the tests. The flight test plan determines the number of flights and flight hours indispensable to verify whether a given aircraft satisfies specified requirements. Many and various external factors may have significant and adverse effect on the execution of the flight test program according to the earlier agreed schedule. The identification of areas hazardous to the project is a very interesting and it depend of the experience of researchers. The flight test program in addition to the requirements for the equipment under test must take into account the available infrastructure, time and cost SYMBAD is the structure of artificial neural network (ANN) developed on the basis of experimentally gained data from the military aircraft testing. These tests were done in Aircraft Institute of Technology for the many years and for the different type of aircrafts. Potential usage of this programme for the managing of aircraft prototypes testing has been formulated as well. This case is presented in this article. Presented the program will be improved based on the knowledge of researchers. The Sindbad's structure can be easily adjusted depending on the type of test equipment, e.g. for unmanned air systems.

***Keywords**: aircraft, flight-test planning, flight test schedule, artificial neural networks*

1. Introduction

The aircraft flight-testing is usually carried out for a new-designed and -developed aircraft as well as for an upgraded one, for those in production, and for the aircraft equipment/systems built in the aircraft.

The primary objective of flight tests is to validate the aircraft conformity with requirements listed in technical specifications, rules and regulations on aircraft building, standards, and Customer's requirements.

Apart from the compliance with the aircraft specification, any flight test (FT) programme for new structures should ensure that the risk of threats to arise in the course of test flights is minimized.

The accuracy of the FT programmes and proper execution thereof strongly affects the capability to keep to the required safety levels while operating the aircraft.

The output documents produced in the course of the planning include the flight test (FT) programme together with the flight test (FT) schedule and methodology. These substantive and organisational documents form the basis for the execution of flight trials.

The FT schedule, which is a plan of flight trials execution over a specific period of time, is an integral part of the FT programme. Account is taken of the availability of labour and resources, climatic conditions and other factors that may affect the execution of the trials, such as predispositions of flight test team members, their proficiency, etc., with flight test safety taken into consideration.

With the FT programme and the FT schedule as the basis, determined are: the number of flights, the number of flight hours, the time necessary to evaluate the aircraft at the assumption that all factors which might have had some effect upon the flight-test execution do not have any adverse effect on the work [1-3].

Prior to the initiation of the FT programme development, analysed are capabilities to develop the programme allowing of the execution of the required scope of flight tests at a specified location, over a specified period of time/by a specified closing date, and with available resources.

A person in authority, i.e. responsible for the FT programme, usually the flight test programme manager, specifies the architecture of the programme and decomposes the object of configuration in order to determine capabilities of developing the programme [4, 5].

With analyses of particular objects of configuration as the basis, the flight test programme manager determines the minimum number of flights, time and resources indispensable to provide for the execution of the scope of flight tests specified by the Customer. He/she verifies what resources are required and what resources the contracting party has declared. The analysis results in the identification of areas hazardous to the project [6] and how they can affect the execution of this project.

In the paper presented programme, which used neutral network to optimally the flight test programme according to the Customer's requirements, at a proposed cost, and with safety of both the staff and the aircraft provided.

2. Simulation Program of flight tests time SYMBAD 2012/2013

The SYMBAD 2012/2013 program has been developed under the Borland C++ Builder programming environment. It uses an innovative approach to any issues of the aeronautical testing.

Knowing:

– reliability of performance of individual studies,
– distribution of flyable days in particular months,
– distribution of flyable hours in particular months,
– the number of pilots available,
– using the program, you can estimate the time to complete individual tests in a specific time and place.

Two modules can be distinguished in the SYMBAD 2012/2013 program. They are as follows:

– a module to teach the neural network,
– a module to predict time needed for aeronautical tests.

The first module consists in loading exemplary sets of tests and results thereof into the program (Fig. 1).

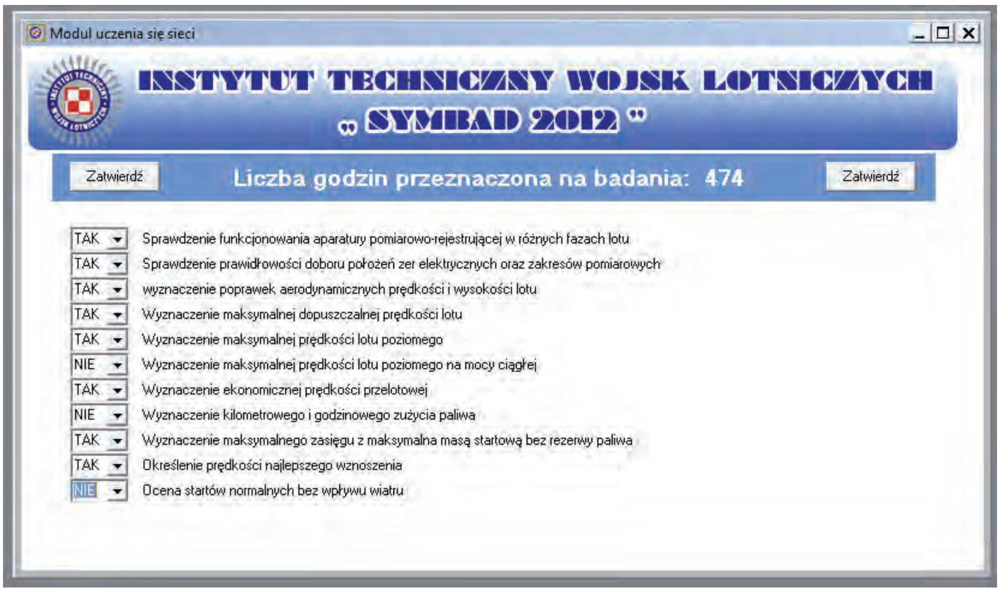

Fig. 1. A module to teach the neural network

On the basis of these results and the global settings, the program generates estimates of time needed to accomplish the selected tests.

Fig. 2. A module to predict time needed for flight tests

The program may also deliver a printout with the set of testsand read this information from the relevant data file.

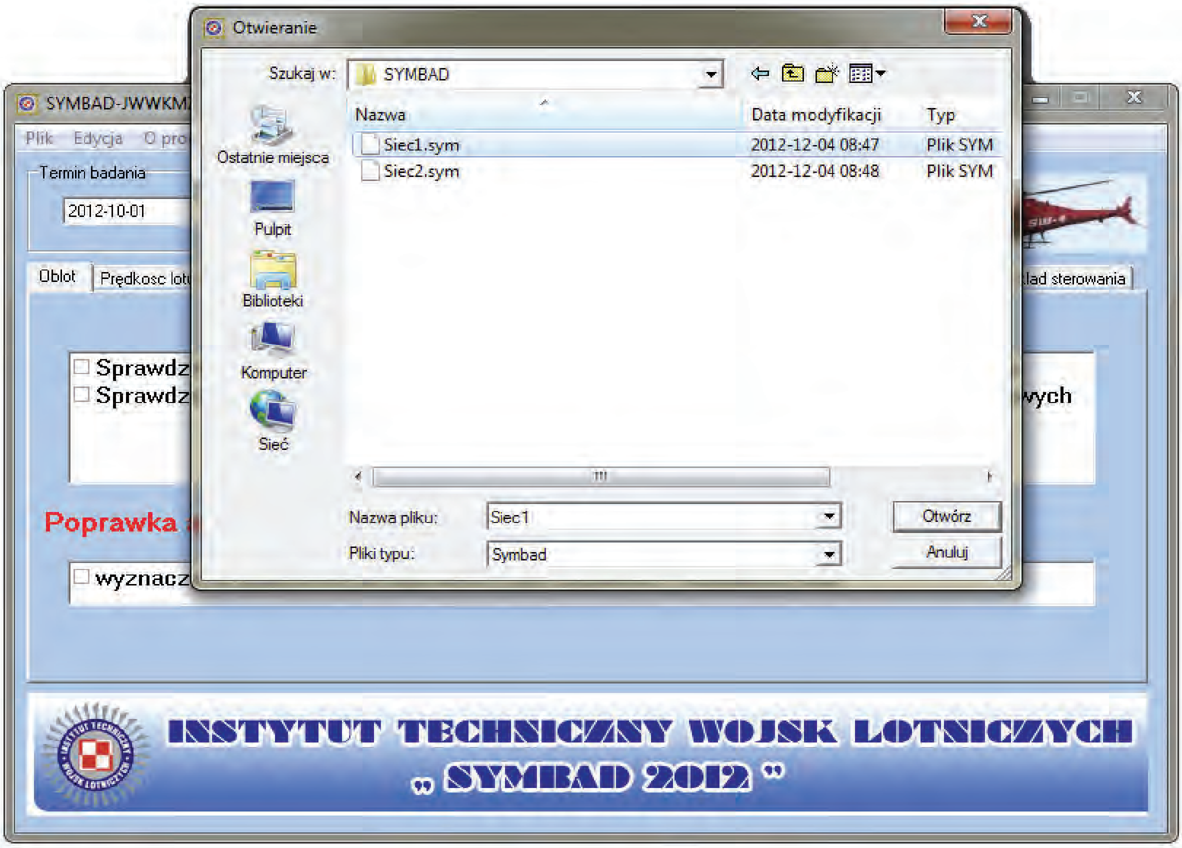

Fig. 3. Read date from menu File

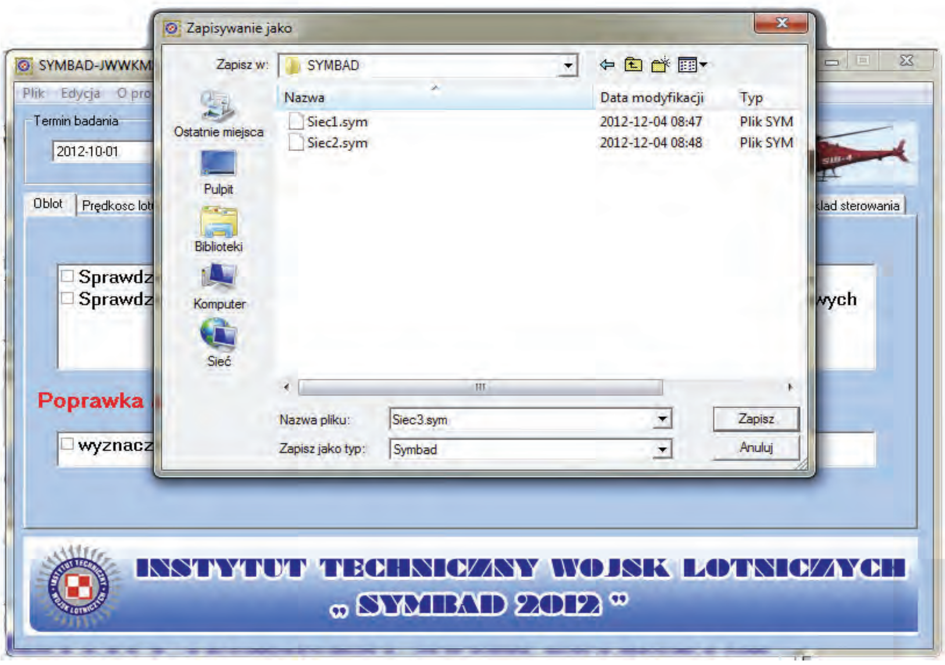

Fig. 4. Print date in menu File option

In the first stage of forecasting, however, you should configure the program based on its global settings, namely:

– refer the pilot date,
– refer flyable days in particular months,
– refer flyable hours in particular months.

The above data we get from the annual analyses carried out during the tests (Fig. 5 and 6).

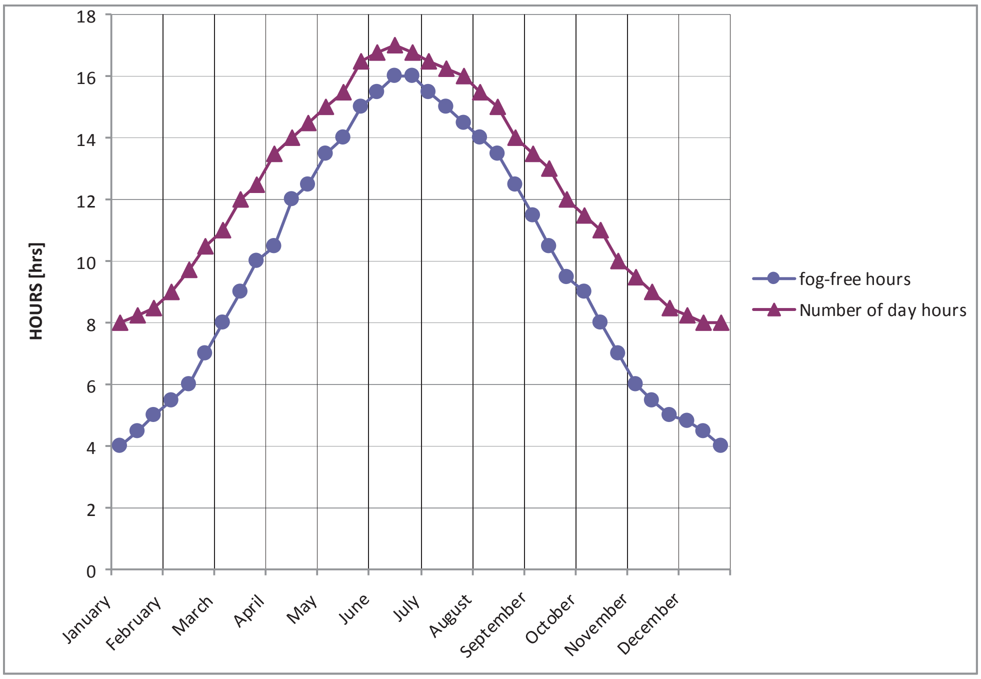

Fig. 5. Distribution of flying hours in the daytime in particular months

Then, just after their evaluation, you can enter them into the program SYMBAD. For example, the global settings of SYMBAD presented below (Fig. 7-9).

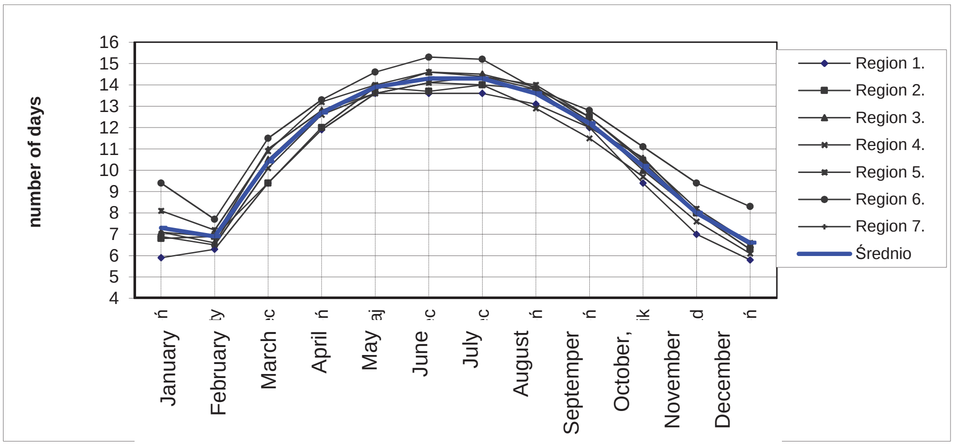

Fig. 6. The average number of days with the following weather conditions: cloud cover ≤ 6/10; visibility ≥ 6 km on military airfields in various regions of Poland

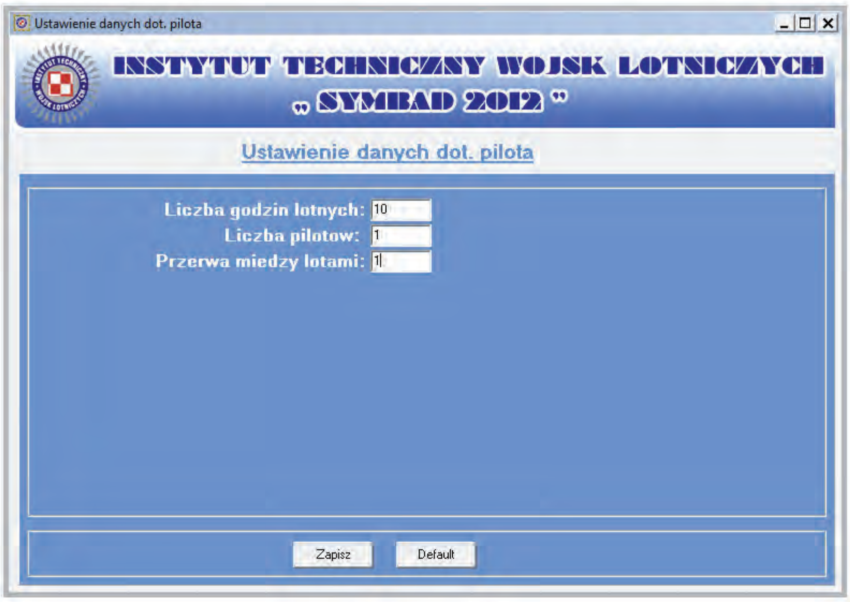

Fig. 7. Setting the remote pilot data option in the Edit menu

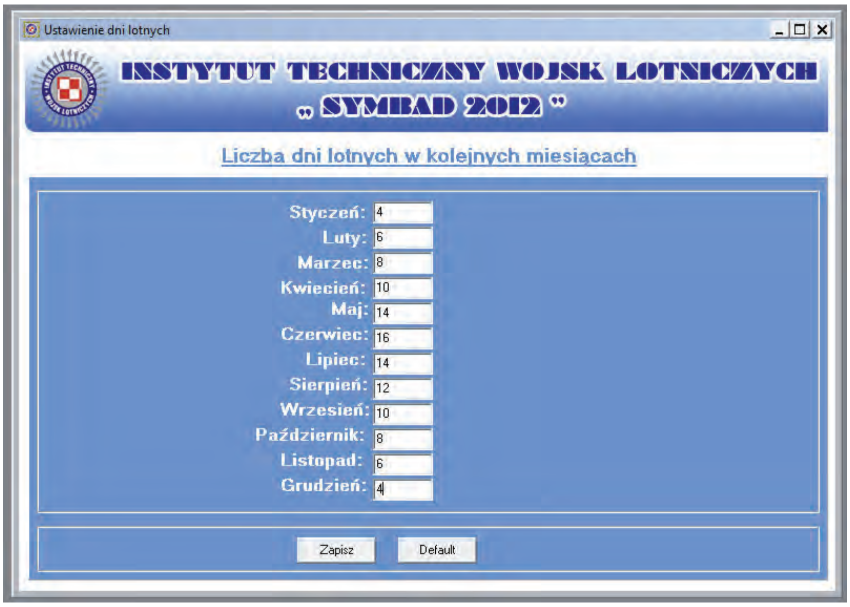

Fig. 8. The number of flyable days in particular months option on the Edit menu

Fig 9. The number of flyable hours in particular months option on the Edit menu

Only when the global settings, you must make a selection test.

Research, due to their nature, have been divided into the following menu:

- "oblot" menu,
- flight speed menu
- the flight range of the menu,
- ceiling menu,
- from the start menu,
- slots menu
- volatile properties menu,
- stability menu
- autorotation menu,
- pilotage menu
- load menu
- the control system menu.

Sample test sets are shown in the following figures (Fig. 10 and 11).

After fulfilment of the above criteria and specify the appropriate set of tests can join the process of forecasting the time to perform these tests (Fig. 2). The nucleus is adapted the algorithm of artificial neural network.

3. SSN algorithm to support management of flight-testing of prototype aircraft

Function of the intensity of the unrealised test occurrences takes the form:

$$\gamma(t) = \frac{\alpha\lambda}{1+\beta t}, \tag{1}$$

where:

α – the intensity of conducted flight tests,

t – the planned time for conducting the tests,

λ – the rate of unrealised tests,

β – the rate of learning (e.g. effectiveness of preventive treatment applied in the course of tests).

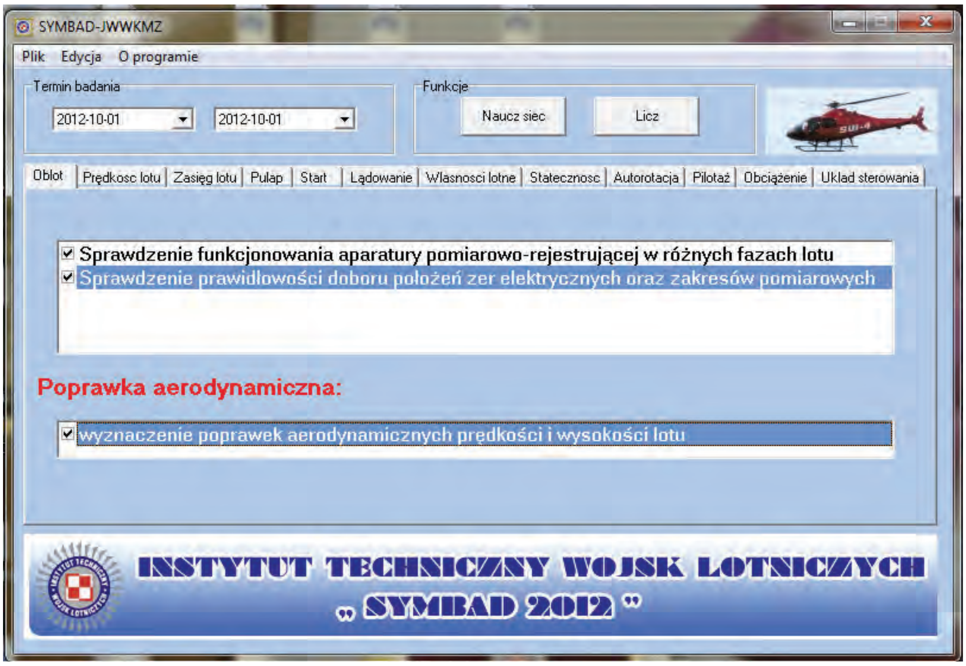

Fig. 10. Selection of research in the "Oblot" menu

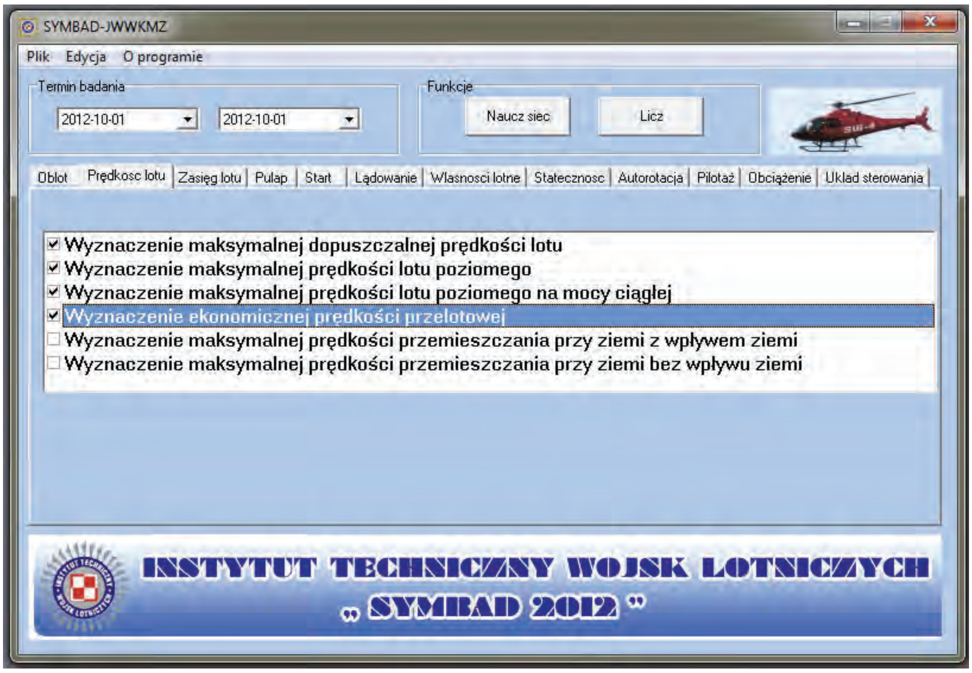

Fig. 11. Choice tests in the menu "Flight speed"

By making the relevant transformations described in the article [7] we obtain the formula for expected value unrealised air tests in the specified time.

$$B(t) = \frac{\lambda}{\beta} \ln(1 + \beta\alpha t) \ \text{ for } \ \beta \geq 1, \tag{2}$$

Having set the pointer (equation 2) you can go to build a model of the SSN.

Let set A means all executed tests. Therefore, a single set of tests we can define as a set of B:

$$B = \{B_1, B_2, ..., B_n\}, \tag{3}$$

where n is the number of tests. Naturally, a collection of B is contained in the collection A.

Then for each survey is assigned to a pointer with the result (of export) of the individual studies and the duration of the test.

$$V_{i=1}^{i=k} B_i \to \lambda_i, B_i \to t_i. \tag{4}$$

Therefore, the global character of the artificial neural network takes the following form:

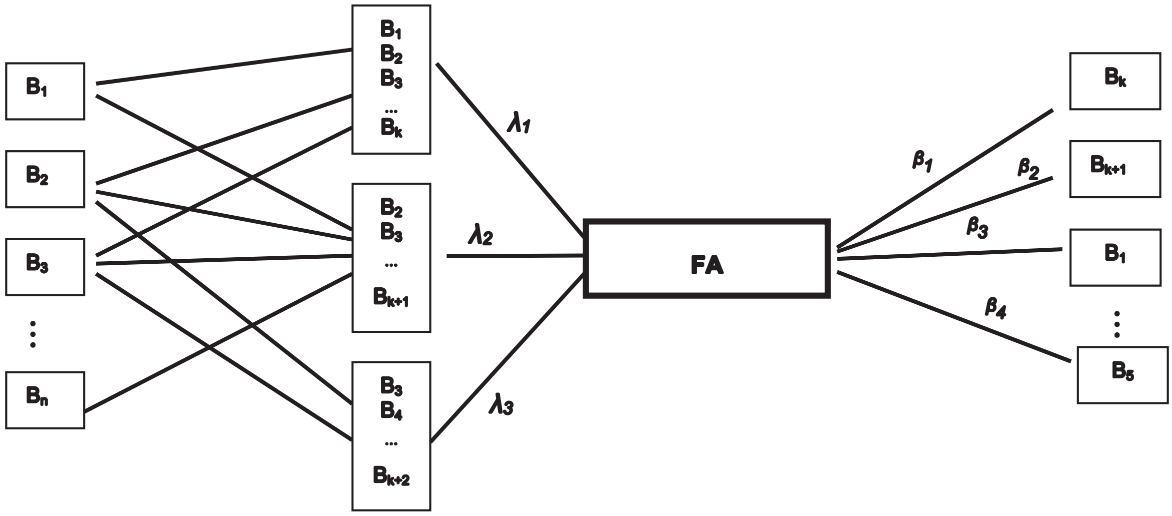

Fig. 12. ANN Model

Neurons are formed from components of the set B. A single artificial neuron is defined as a *k*-component permutation of the set B. Hence, let the set C be a set of all neurons.

$$C = \{C_1, C_2, ..., C_k\}. \tag{5}$$

What results is an estimate of time needed to complete the test. This estimate is found using equation 2.

$$V_{i\in(1,k)} C_i \to T_i\ . \tag{6}$$

The next step is to process the neurons using the activation function (AF):

$$B(t) = \frac{\lambda}{\beta} \ln(1+\beta\alpha t) FA = \min\{T_i\}\ for\ \ i \in \langle 1,k \rangle\ . \tag{7}$$

At the output, a single neuron is gained. It is composed of aeronautical tests arranged in some appropriate sequence.

The process of teaching the network consists in forming rates β (the ANN learning) for each aeronautical test in a given month.

Tab. 1. A set of the network learning rates

Number of Tests /Month	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**XI**	**XII**
A_1	$\beta_{1,1}$	$\beta_{1,2}$	$\beta_{1,3}$	$\beta_{1,4}$	$\beta_{1,5}$	$\beta_{1,6}$	$\beta_{1,7}$	$\beta_{1,8}$	$\beta_{1,9}$	$\beta_{1,10}$	$\beta_{1,11}$	$\beta_{1,12}$
A_2	$\beta_{2,1}$	$\beta_{2,2}$	$\beta_{2,3}$	$\beta_{2,4}$	$\beta_{2,5}$	$\beta_{2,6}$	$\beta_{2,7}$	$\beta_{2,8}$	$\beta_{2,9}$	$\beta_{2,10}$	$\beta_{2,11}$	$\beta_{2,12}$
$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$
A_n	$\beta_{n,1}$	$\beta_{n,2}$	$\beta_{n,3}$	$\beta_{n,4}$	$\beta_{n,5}$	$\beta_{n,6}$	$\beta_{n,7}$	$\beta_{n,8}$	$\beta_{n,9}$	$\beta_{n,10}$	$\beta_{n,11}$	$\beta_{n,12}$

The algorithm of creating the rates comprises the following stages:

- loading a ‘package’ of tests into the network (including the day/date of starting/terminating the tests) – stage I,
- selection of suitable neurons and determination of the advancement of particular components of a single neuron (this is to be done by the User with an expert method applied) – stage II,
- selection of the optimum neuron (this is also to be done by the User with an expert method applied) – stage III,
- equation (2)-based forming, by the network, of suitable rates β, in such a way as to have the time for the neuron creation shorter than that for performing a test (stage III) and with stage II proceeding.

It should be noted that under comparable conditions (i.e. with readiness of both the pilot and the aircraft) the rate *a* (intensity of aeronautical tests) takes the following value:

$$\alpha = 1.$$

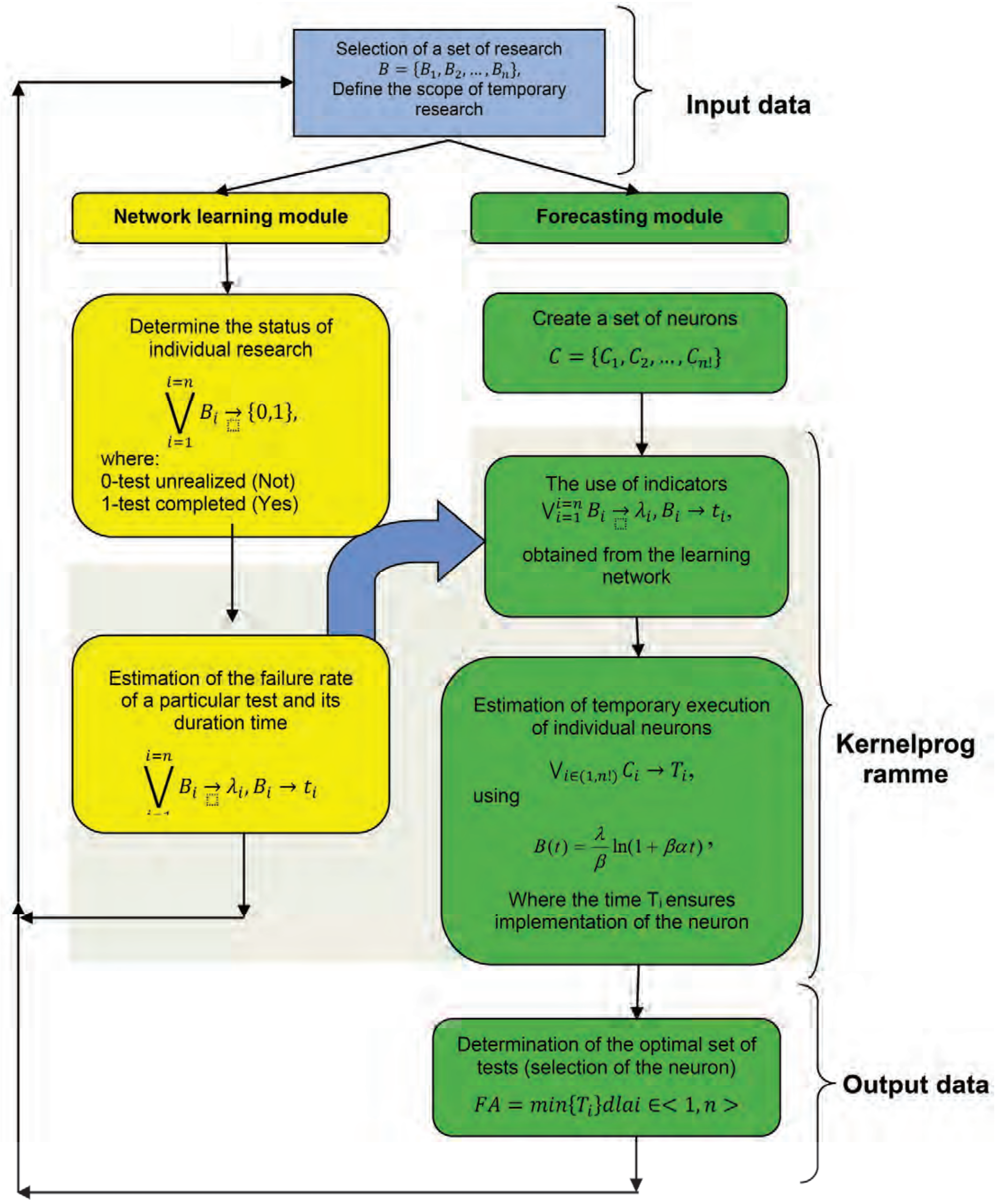

Fig. 7. SYMBAD program’s algorithm

4. Conclusions

In the paper presented is the complexity of the process of flight test planning attributable to the nature of the object to be tested, organisational principles that underlie the flight-testing practice, and the need of several flight-testing teams to collaborate.

The special nature of aircraft flight testing along with the complexity of objects put to tests, participation of many and various flight testing teams, the diversity of issues of logistics support, as well as external conditions make that the FT planning requires rich experience of all the staff responsible for that area of activity, and of the teams that collaborate on the FT programme. Ability to predict and that to assess any hazards that may occur are necessary.

The above-presented model of an artificial neural network (ANN) makes use of rich experience gained by the FT staff during the flight testing work in the course of network teaching. Programme SYMBAD is also an excellent tool to support the FT planning, and allows of the FT optimisation depending on the pre-defined time, cost, and available resources.

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