Journal of KONBiN 3(31)2014
ISSN 1895-8281
DOI 10.2478/jok-2014-0019

RESEARCH OF THE RELIABILITY OF AN AIR COMBAT MANOEUVERE – NOSEDIVE OF A JET POWERED AIRCRAFT

BADANIE NIEZAWODNOŚCI LOTNICZEGO MANEWRU BOJOWEGO – LOTU NURKOWEGO SAMOLOTU ODRZUTOWEGO

Jerzy Lewitowicz[1], Stefan Rutkowski[2]

[1]Air Force Institute of Technology, [2]Polish Air Force Academy

e-mail: lewitj@itwl.pl

Abstract: *This paper considered a problem of: the reliability of performance of a nosedive of a jet powered aircraft in the context of the ability of pilots trained on a simulator to reliably accomplish a combat mission. For research purposes, the manoeuvre of attack of a target with the nosedive, which is most commonly used by the pilots performing flights on different types of modern aircrafts, and the basic manoeuvre during aircrew training, both basic and advanced were assumed. The research was conducted on a flight simulator.*

Keywords: *manoeuvre, nosedive, aircrew training, flight simulator*

Streszczenie: *W pracy rozpatrzono problem: niezawodności wykonania lotu nurkowego samolotu odrzutowego w kontekście zdolność pilotów szkolonych na symulatorze do niezawodnego wykonania misji bojowej. Do celów badawczych przyjęto manewr atakowania celu z lotu nurkowego, który to manewr jest najczęściej stosowany przez pilotów wykonujących loty na różnych typach współczesnych samolotów oraz podstawowym manewrem podczas szkolenia lotniczego, zarówno podstawowego jak również zaawansowanego. Badania przeprowadzono na symulatorze lotu.*

Słowa kluczowe: *manewr, lot nurkowy, szkolenie lotnicze, symulator lotu.*

1. Introduction

Aircraft engineers apply ergonomic principles of the pilot's cabin design, which allows to create a more pilot-friendly working (fighting) environment enabling to complete a military operation – flight mission (FM). Common digitisation requires from a pilot greater knowledge related to the opportunities for action of all aircraft's systems, so that he/she is able to independently enact even the most complicated tactical scenarios. At the same time, the modern battlefield has been dominated by the latest computerisation's achievements, which additionally requires necessary knowledge and preparation from the pilot, so that he/she is able to, on one hand, accomplish the operation – flight mission, and, on the other hand, to survive in extremely demanding environment, which is the modern battlefield.
The pilot's perception in the pilot – aircraft arrangement is related with receiving signals, recognising events in the environment and instruments' indications, as well as commands and tips from other people, e.g. an instructor. The reliability of the accomplished operation depends from these factors. The pilot's reaction time to the received signals about the condition of the aircraft and its position is one of the basic criteria of his/her perception and psychomotor function. This time allows to assess the speed of information processing, as well as the speed of decision making. Research on reaction times is possible during flights in simulators [1, 3, 6]. The pilot's reaction to different stimuli can be properly trained, and the most effective devices for this type of trainings are flight simulators, which, on the one hand, allow for the safe training of performed manoeuvres, the acquisition of the desired habits and skills, enabling an assessment of the reliability of the manoeuvres performed by pilot, and, on the other hand, allow to reduce training costs through limiting the number of flights performed in a real aircraft. In destruction ground targets, specialised attack aircrafts or multi-role combat aircrafts, which, through a wide range of weapons possible to hang up – air combat measures (ACM) – can effectively interact with different types of strike objects on the battlefield [8,9]. Possible variants of multi-role combat aircraft's weapons for accomplishment of the air-to-ground flight mission is shown in Figure 1.
During an attack on the objects on the surface with the use of a nosedive manoeuvre, it is necessary to maintain a minimum distance from the aircraft to the target in order to continuously track its location. This requires performance of complex manoeuvres with direction, altitude and airspeed, with very dynamic changes of these parameters and piloting precision, as well as targeting in a relatively short time in order to develop the necessary location and flight conditions to use weapons. The dynamics of these manoeuvres, on one hand, must not to exceed the operating limits of the aircraft or pilot's endurance, and, on the other hand, it should allow for the shortest time of staying in the range of any air defence measures of the object. The aircraft's departure from the splinters' danger zone of the used combat measure is also a part of the deliberations in this paper. Example attack manoeuvres of various above-ground targets with different manoeuvres are shown in Figure 2.

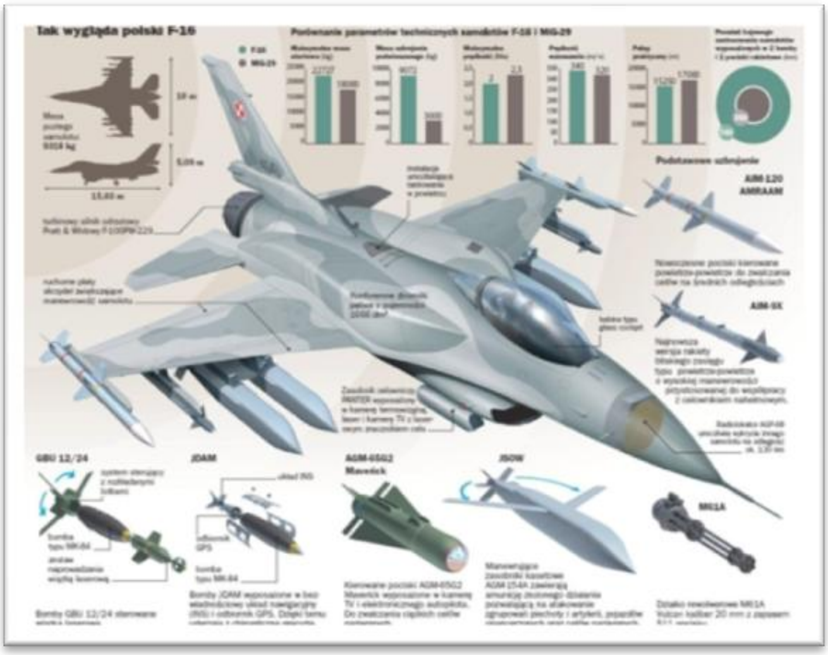

Fig. 1 Variants of the multi-role combat aircraft's weapons for destruction of above-ground/surface targets [2].

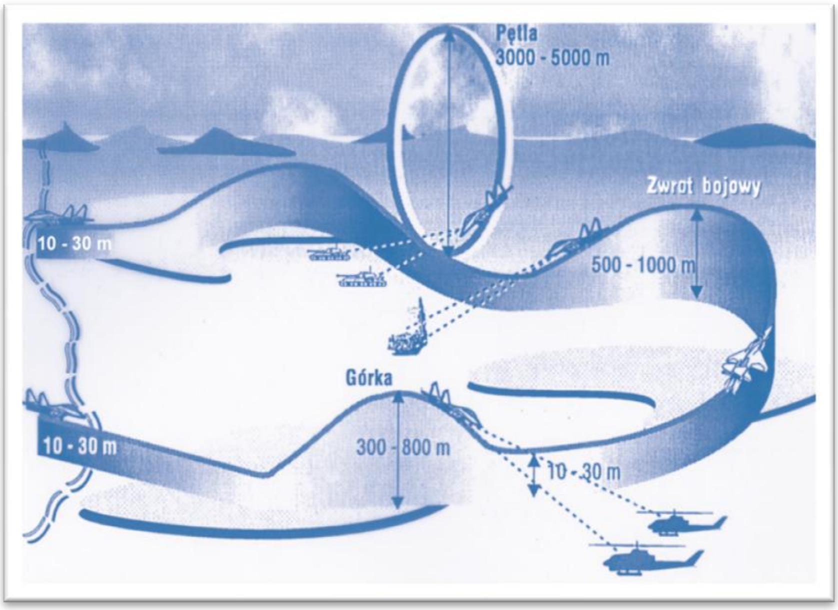

Fig. 2 Expected manoeuvres performed by the multi-role combat aircraft, accomplishing the air-to-ground flight mission

2. Characteristics of a nosedive

Introduction to the nosedive can take place from horizontal flight, the bend with tilting up to 90°, the bend with titling above 90°, and wing over. Introduction to the nosedive depends largely on the applied tactics and the type of weapons that will be used to combat the above-ground targets. The nosedive is characterized by increase of airspeed and simultaneous reduction of altitude. The larger the angle of the nosedive, the greater the increase in airspeed, and at the same time the faster the decrease in altitude . The nosedive's angle has a direct impact on pulling out of the nosedive. The greater the nosedive angle, the greater the angle of attack, and, thus, the greater overload will accompany the pilot at the time of pulling out with the simultaneous greater loss of altitude. Analysing the presented manoeuvres and their parameters, times of performance of manoeuvres attacking the above-ground target from the nosedive were specified for the three main nosedive angles. For the purposes of the research, the nosedive angles of 30° from the altitude of 1000 meters and 20° from the altitude of 600 meters, as well as the time *t*1, as the pilot's reaction time between the point of recognition (notice) of the object of attack until firing a projectile/missiles were adopted, but it does not change the fact that the destruction of the target, which translates into the success of the mission's accomplishment, as well as the flight safety is affected by the correctness of performance of the manoeuvre of attacking the above-ground target, in particular the maintenance of input parameters, such as airspeed and altitude, as well as a proper nosedive/aiming angle. The manoeuvre of attacking the above-ground target with a nosedive from its detection to pulling out the aircraft from the nosedive in order to omit the zone of splinters of the used ACM [7] is shown in Figure 3.

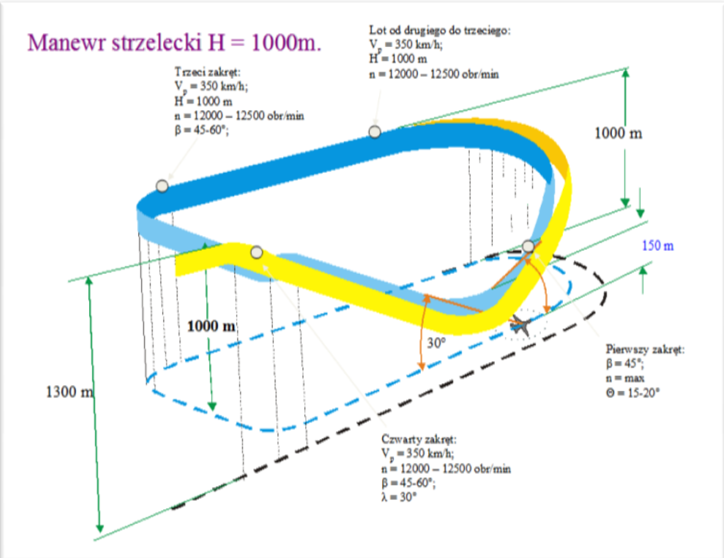

Fig. 3 Manoeuvre of attacking the above-ground target from the altitude of 1000 m

3. Likelihood of flight mission's accomplishment

Attacking the above-ground target from the nosedive requires skilful pulling out from the zone of splinters' dispersion. Therefore, two parameters characterizing the pilot's nosedive attack skills were adopted: the time to introduce into the nosedive *t*1 (from the time of notice of the target to the use of weapons) and the time of pulling out the aircraft of the nosedive *t*2. Two variants of exercises on the simulator for the three indicated groups of pilots were developed. The research was conducted on groups of pilots of different flight experience; from the group of the most experienced pilots, whose flying time is even over 3000 hours spent in the air (the A pilots group), through the pilots who have completed a flight training in the Polish Air Force Academy (the B pilots group), to the pilots of the flying time of 50-100 hours (the C pilots group), who have just acquired the basic flight habits. The choice of such a manoeuvre is purposeful.

Destruction of the above-ground target takes place during flight missions. Two flight mission's reliability models were adopted: serial and mixed one for the case, when *n* combat measures are used (Fig. 4) [4, 5]. The example of a serial mission (Fig. 4a) illustrates the classic nosedive attack of destruction, where: s_1 symbolises the performance of manoeuvre of introduction into the nosedive and targeting

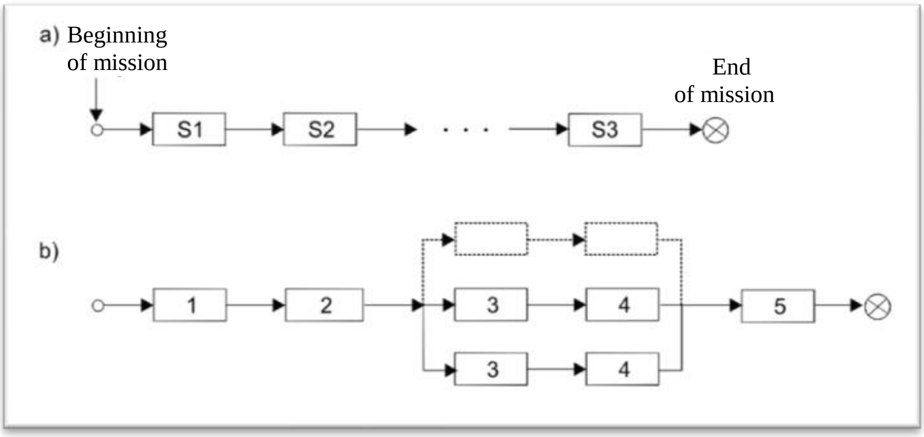

Fig. 4 Examples of operational structures of flight missions
a – serial structure; b – mixed structure

with P_N probability, which characterises the pilot's skills, which is realised in the *t*1 time; s_2 – means the efficiency (dispersion) of the missile with P_p probability and s_3 – pulling out of the attack (a nosedive) at the *t*2 time. The P_S effectiveness of the attack – the destruction of the target – describes the following expression for the series consisting of *n* missiles:

$$P_S = P_N[1-(1-P_p)^n] \quad (1)$$

The theoretical distribution of the P_s probability of success for the number of missiles $n = 4$ is shown in Figure 5.

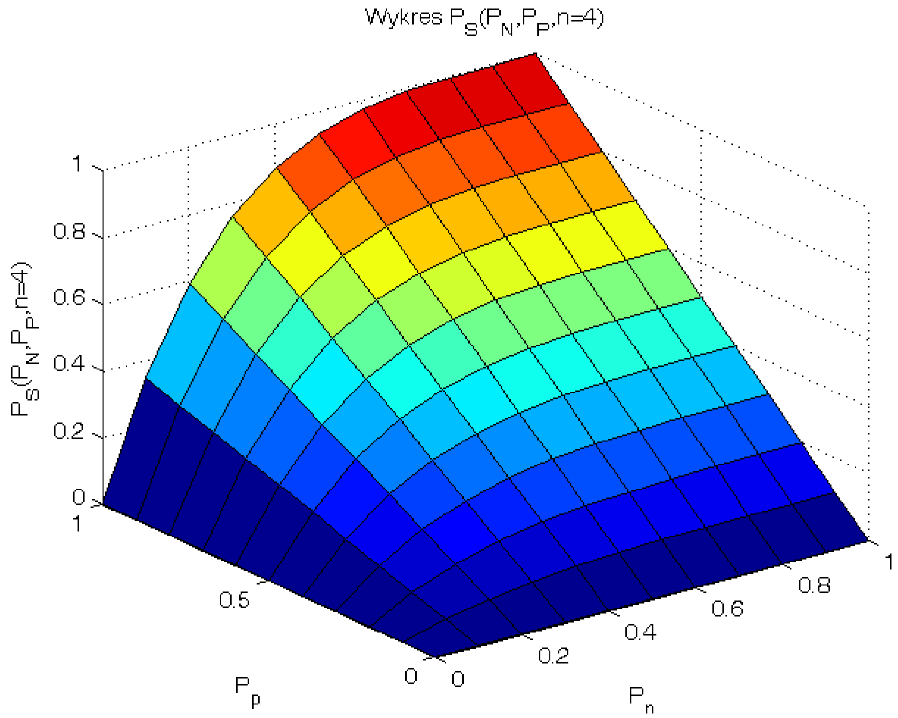

Fig. 5 The $P_S(P_N, P_p, n)$ probability of success

For random variables $t_1(m_1,\sigma_1)$, $t_3(m_3, \sigma_3)$, the equation for the probability of the destruction of the above-ground target P_S and the success of the mission $P_{mission}$, in which the destruction of the target in the t_1 time and leaving the splinters zone without loss of own aircraft in t_2 matter, which is measured by time $t3 = t1 + t2$. For the attack with one ACM:

$$P_S = P_N(t_1)[1-(1-P_p)] \tag{2}$$

$$P_{mission} = P_N(t_3)[1-(1-P_p)] \tag{3}$$

and for the series consisting of n ACMs:

$$P_S = P_N(t_1)[1-(1-P_p)^n] \tag{4}$$

$$P_{mission} = P_N(t_3)[1-(1-P_p)^n] \tag{5}$$

Probability $P_N(t_1)$ and $P_{mission}(t_3)$ is calculated with the following formulas:

$$P(t_1) = \int_x^\infty \frac{\sqrt{2/\pi}}{\sigma_1[1+\text{erf}\,(\frac{m_1}{\sqrt{2\sigma_1}})]} \exp\left[-\frac{(x-m_1)^2}{2\sigma_1{}^2}\right] dx \qquad (6)$$

$$P(t_3) = \int_x^\infty \frac{\sqrt{2/\pi}}{\sigma_3[1+\text{erf}\,(\frac{m_3}{\sqrt{2\sigma_3}})]} \exp\left[-\frac{(x-m_3)^2}{2\sigma_3{}^2}\right] dx \qquad (7)$$

In Figures 6 and 7, example measurement results of the times $t1$ and $t2$ for one of the researched pilots' groups and histograms allowing to determine the parameters of the normal distribution are illustrated.

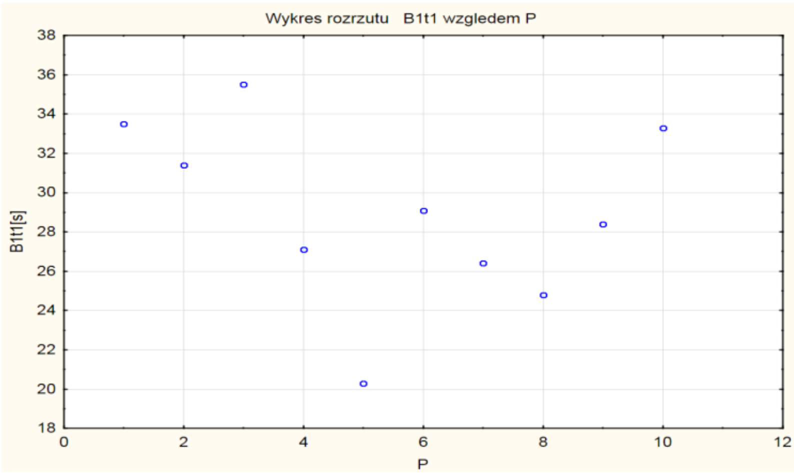

Fig. 6 Reaction time t1 of the B1 pilots group

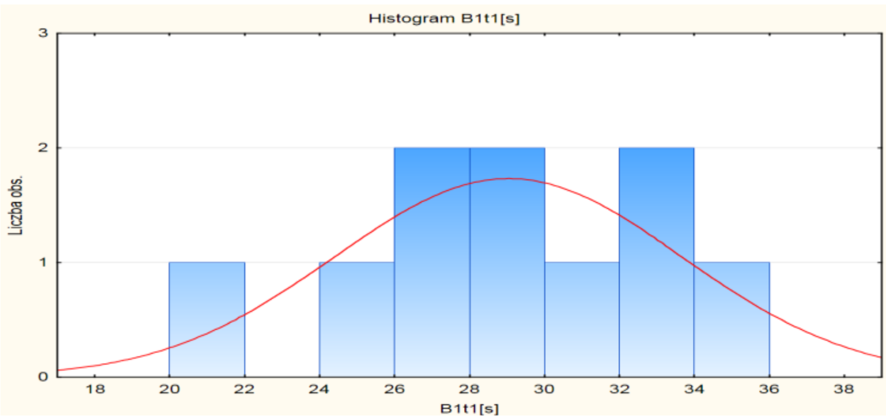

Fig. 7 Histogram and density function of reaction time t1 of the B1 pilots group

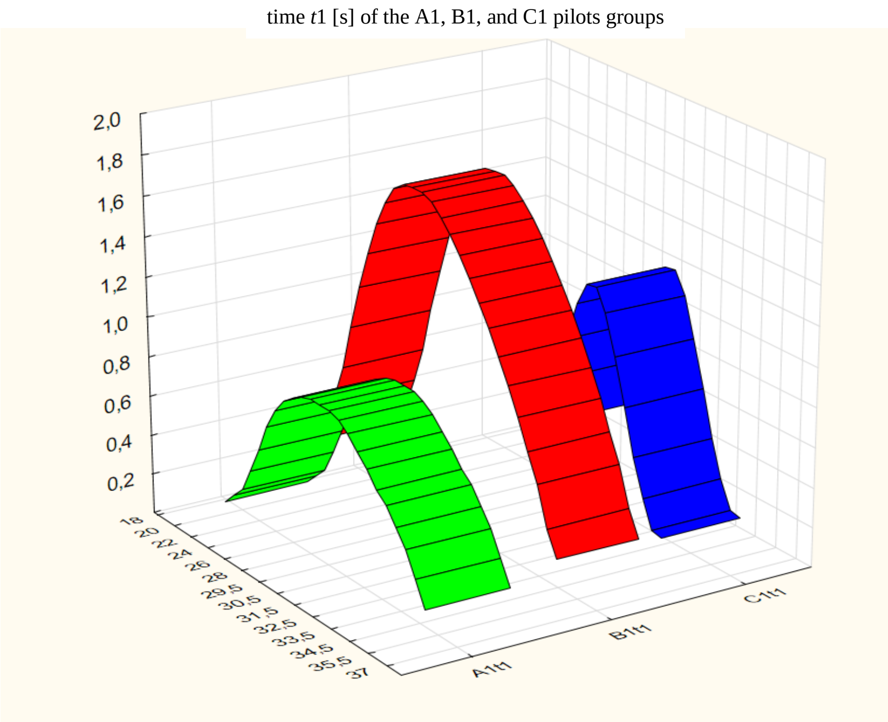

Fig. 8 Comparison of the density function of the reaction time t1 of the A1, B1, and C1 pilots groups (H 1000 m)

4. Conclusion

The pilot's reaction time is one of the basic criteria of the pilot's psychomotor function. It allows to evaluate the speed of information processing of the pilot, the speed of decision-making, and motor function of each pilot. The conducted analysis included comparison of the reaction times of the mentioned three groups of pilots according to the assumed manoeuvres of two heights, which in turn allowed to develop an algorithm of the minimum number of exercises on the simulator for the pilot for the assumed probability of destruction of the above-ground target from the nosedive of the jet powered aircraft.

5. Bibliography

[1] Allerton D.: *Principles of Flight Simulation.* American Institute of Aeronautics and Astronautics, USA 2009/

[2] Bondaruk A.: *Badanie wpływu uszkodzeń i niesprawności samolotu wielozadaniowego na bezpieczeństwo lotów*. Wydawnictwo ITWL, Warszawa 2011. *[Study on the influence of multi-role combat aircraft damage and malfunction on flight safety]*

[3] Lee A. T.: *Flight simulation, virtual environments in aviation.* ASHGATE, USA 2005.

[4] Lewitowicz J.: *Podstawy eksploatacji Statków Powietrznych. T.2, Własności i właściwości eksploatacyjne statku powietrznego*. Wydawnictwo ITWL, Warszawa 2003. *[Basics of aircraft operation. Vol.2, Operational characteristics and properties of an aircraft]*

[5] Przemieniecki J. S.: *Introduction to mathematical methods in defense analyses*. Air Force Institute of Technology, Washington D.C. 2002.

[6] Rutherford S., Thomson D, G.: *Helicopter Inverse Simulation incorporating an Individual Blade Rotor Model.* Journal of Aircraft, vol. 34, no.5, 1997.

[7] Stasiewicz S.: *Bezpieczeństwo atakowania celów naziemnych z uwzględnieniem strefy rozlotu odłamków.* R.8 [w] Problemy badań i eksploatacji techniki lotniczej, red. J. Lewitowicz, J. Borgoń, W. Ząbkowicz. Wyd. ITWL, Warszawa 1994. *[Safety of above-ground target attack considering the zone of splinters' dispersion. Ch.8 [in] Problems in aircraft technology tests and operation]*

[8] Żyluk A.: *Modelowanie i badania symulacyjne lotniczych środków bojowych*. Wydawnictwo ITWL, Warszawa 2013. *[Modelling and simulation tests of air combat measures]*

[9] Żyluk A.: *Uzbrojenie lotnicze. Badania*. Wydawnictwo ITWL, Warszawa 2013. *[Aircraft weaponry. Tests]*

Gen. bryg. (rez.) prof. dr hab. inż. Jerzy Lewitowicz. *Absolwent Wojskowej Akademii Technicznej i Uniwersytetu Warszawskiego. Główne zainteresowania: rozwój najnowszej techniki wojskowej, w tym lotniczej, budowa i eksploatacja samolotów i śmigłowców ze szczególnym uwzględnieniem diagnostyki. Posiada ponad 50. letni staż naukowy i dydaktyczny w Instytucie Technicznym Wojsk Lotniczych i na Politechnice Warszawskiej. Jest członkiem SIMP, AIAA, ICAS. Wieloletni członek trzech komitetów Polskiej Akademii Nauk: Fizyki, Budowy Maszyn, Badań Kosmicznych i Satelitarnych. Autor licznych publikacji naukowych (ponad 400). Autor i współautor 23 książek naukowych z dziedziny eksploatacji statków powietrznych, tribologii, diagnostyki, bezpieczeństwa lotów, licznych patentów oraz wzorów użytkowych. Jest pracownikiem naukowym Instytutu Technicznego Wojsk Lotniczych.*

Gen. bryg. (rez.) mgr inż. pil. Stefan Rutkowski, profesor wizytujący *w Katedrze Awioniki i Systemów Sterowania Wyższej Szkole Oficerskiej Sił Powietrznych w Dęblinie. Ukończył Wydział Wojsk Lotniczych i Obrony Powietrznej Akademii Obrony Narodowej. Ukończył studia dowódczo-sztabowe w Air University (Maxwell-USA). Jest pilotem klasy mistrzowskiej o łącznym nalocie 2800 godzin.*