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Statistics of Aviation Accidents and Preconditions for Aviation Accidents in Czechoslovak and Czech Military Jet Aircraft: Fire

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Abstract:

The article deals with the statistics of aviation accidents and preconditions for aviation accidents focusing on fires in military jet fighter, trainer-fighter and trainer aircraft in the service of Czechoslovakia and the Czech Republic from 1948 until the end of 2015. It presents a unique, previously unpublished, comprehensive overview of air disasters, crashes, damage and preconditions for aviation accidents broken down by aircraft types, as well as a complete list of military regulations containing classifications of such emergency occurrences in Czechoslovak and Czech military aviation over the past 70 years. The overviews are accompanied by explanations on the context and development trends in Czechoslovak and Czech military aviation flight safety and with a unique overview of still available reference and information sources on the subject.

Keywords:

Army of the Czech Republic, Czechoslovak Army, Czechoslovak People's Army, aviation accident, fire, jet fighter, statistics

1. Introduction

Mathematical statistics is part of mathematical sciences concerned with mathematical expression of mass phenomena, creating probabilistic models, model-data correspondence verification, hypotheses testing, data variability analyses and evaluation of their relationship [1].

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It applies a wide range of mathematical tools that can be used in various fields of human activity. The principal question is always what type of information needs to be or can be obtained in the considered case.

Having said that, it is right to ask the following question: Why to deal with statistics in military aviation? Why and for whom could such an abstract be beneficial? Let us answer the question now.

The analysis of the statistics should be aimed at the positive development in the field, systematization of past experience, formulation of development trends and their reasons, tracing system errors and failures and activation of processes to enhance error prevention. Military aviation is no exception; the identification and elimination of errors and failures result in higher safety level for all air traffic participants and in better national defence in particular. Therefore, such statistical overviews and analyses are intended not only for military pilots, but also for military aviation command and specialized bodies that can look for inspiration for streamlining their work and strengthening the enforcement of safety rules at all levels of management and in flight training.

This prompts another question: how can experience from long ago, such as the 1950s or 1960s, contribute to the current military aviation?

To trace the developments and roots of major failures and successes, the "jet era" in the military aviation should be seen and evaluated in its entirety. After all, current flight safety rules have been built on the experience of pilots of that time and as such they provide the best arguments for their observance today.

2. Scope and Available Information Sources

This study deals with the statistics of aviation accidents (hereinafter "AA") and preconditions for aviation accidents (hereinafter "PAA") focusing on fires in military jet fighters in Czechoslovakia and the Czech Republic over the past 67 years, that is from 1948 to 2015.

No precise definition of fire in relation to aviation accidents is given in currently effective military aviation regulations of the Czech Republic Air Forces; therefore, for the study, the definition given in fire protection technical standards ISO 8421-1 [2] and ISO 13943 [3] was used.

Fire is a process of combustion characterized by the emission of heat accompanied by smoke or flame or both, spreading uncontrolled in time and space [2-3].

A separate problem is false fire alarms due to malfunction of or damage to the warning segment of the aircraft firefighting system. Only events recorded in military statistics of AAs and PAAs as fires and false fire alarms were included in this study.

The information sources used for the compilation of the overviews can be broken down to three groups by the time periods they cover.

The first group of information sources covers the period 1948-1960 approximately. It includes aviation non-fiction books and personal correspondence by Mr. Miroslav Irra [4-9] and Mr. Libor Režňák [11-12] based on expert interpretation of sources from the Military Central Archives in Prague [13].

The second group of information sources covers the period 1960-1984. It includes five-volume staff manual for the Czechoslovak People's Army Air Forces compiled by Col. Stanislav Slavík, a senior flight safety inspector in the 10th Air Force in Hradec Králové airbase from 1960s to 1980s [14-18]. They offer a comprehensive overview of AAs and PAAs for the periods concerned accompanied by explanations, reflections and

statistical analyses. They were crucial classified internal materials of the then Czechoslovak People's Army to reinforce the prevention of aviation accidents.

The third group of information sources covers the period 1985-2015 (present). The data is saved in the database of the military Information System for Logistics [19] which allows searching and filtering events by selected criteria.

The information was complemented by numerous consultations with military experts from both former and current flight and non-flight staff. Generally, information on aviation accidents that took place in the late 1940s and early 1950s was the most difficult to acquire.

3. Classification of Aviation Accidents and Other Emergency Occurrences in Aviation

In order to correctly understand and interpret the following tabular overviews of AAs and PAAs, it is convenient to get acquainted with the contents and basic definitions presented in aviation regulations according to which the AAs and PAAs were classified at the time.

From 1946 through 2015, thirteen regulations were issued successively for the use of the Czechoslovak and later Czech Air Force to classify AAs and PAAs. The first regulation was the Aviation Accidents [20] directive issued in 1946. It was followed by the Let-I-5 (or Let-1-5) regulation, first issued in 1950 [21] and amended in 1953 [22], 1955 [23], 1960 [24], 1962 [25], 1968 [26], 1972 [27], 1974 [28], 1979 [29], 1991 [30] and 2000 [31]. The last (2000) Let-1-5 regulation was replaced in 2006 by the Všeob-P-10 Flight Safety [32] regulation.

4. Statistical Overviews

The statistical overviews below present an enumeration of disasters (see Fig. 1), air crashes (see Fig. 2), damage (see Fig. 3), preconditions for aviation accidents (see Fig. 4 and Fig. 5) and disaster victims (see Fig. 6), respectively, from 1948 to 2015. The overviews are drawn up on a timeline, broken down by aircraft types and supplemented by sum totals for each aircraft type and year. There is the AA or PAA sum for given type shown at lower left. Numbers in parenthesis indicate the number of AAs or PAAs whose causes were related to a fire in a part of the aircraft or with a false fire alarm (see Fig. 5).

It should be noted that not all information sources according to which these statistics were compiled used the AA and PAA classifications valid when the occurrences actually took place. For example, the staff manuals by Col. Stanislav Slavík [14-18] issued in 1979-1989 were drawn up according to the classifications in force when they were issued, not when the occurrences took place. This is evidenced, for example, by the fact that PAAs are already given in the first book of the staff manual for 1961 [14] although the official definition of PAAs was not introduced until the Let-1-5 regulation in 1972 [27].

However, this small anomaly does not significantly change the importance of the presented statistical overviews. Complete unification of the aviation emergency occurrences classification for the past 67 years by one single regulation would probably be impossible nowadays as some AA and PAA investigation records were lost.

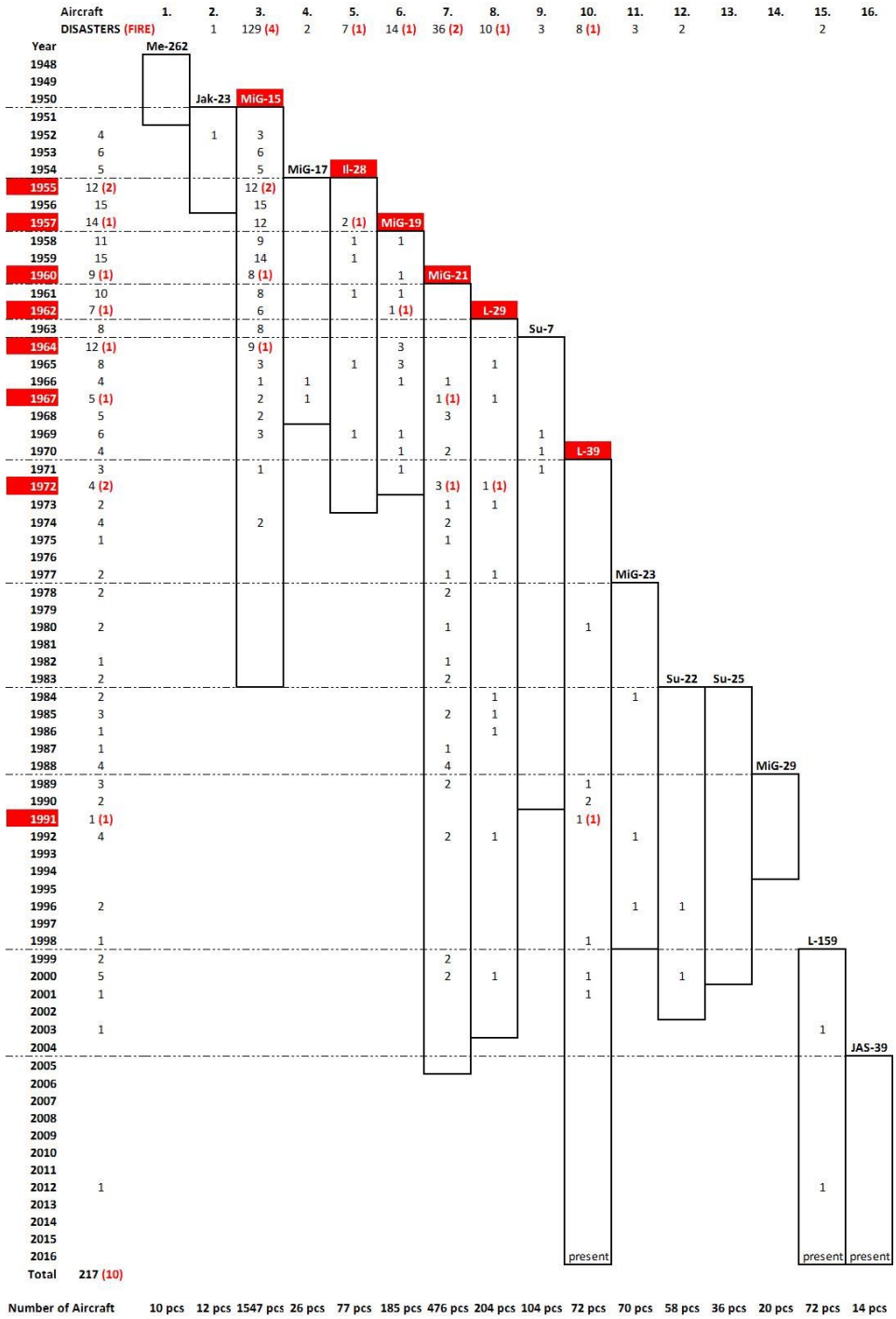


Fig. 1 Disasters (fire-related disasters) in 1948-2015

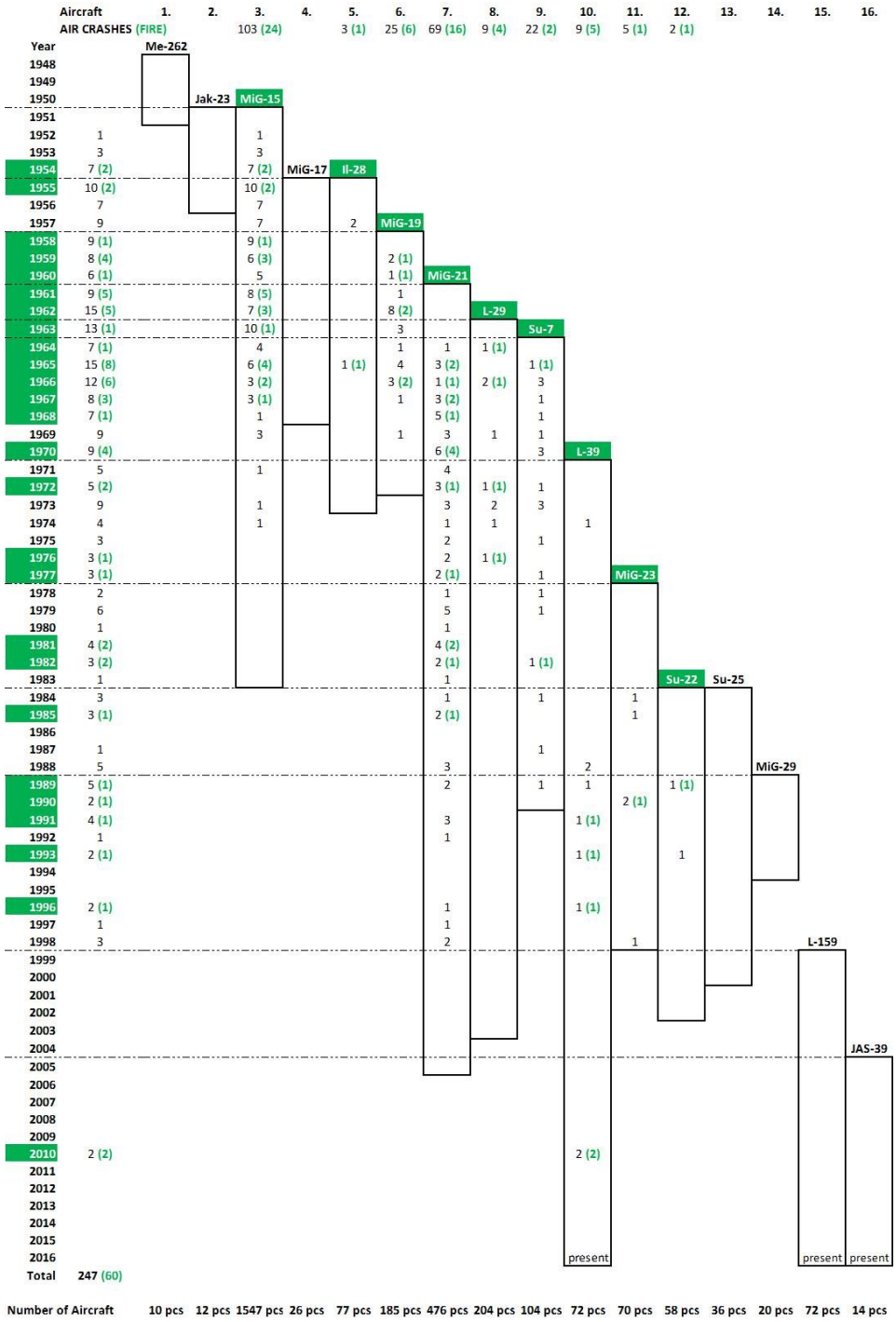


Fig. 2 Air crashes (fire-related air crashes) in 1948-2015

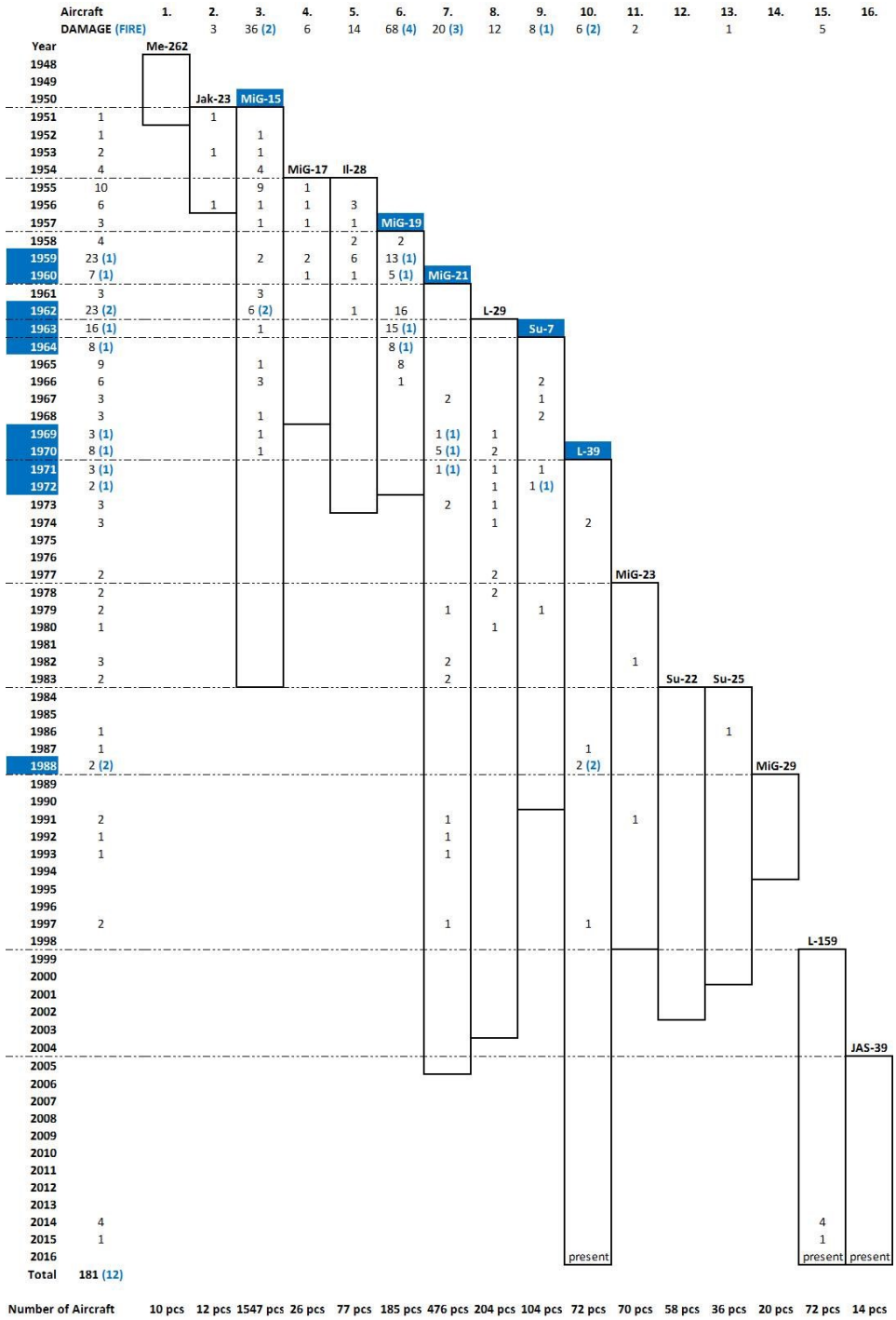
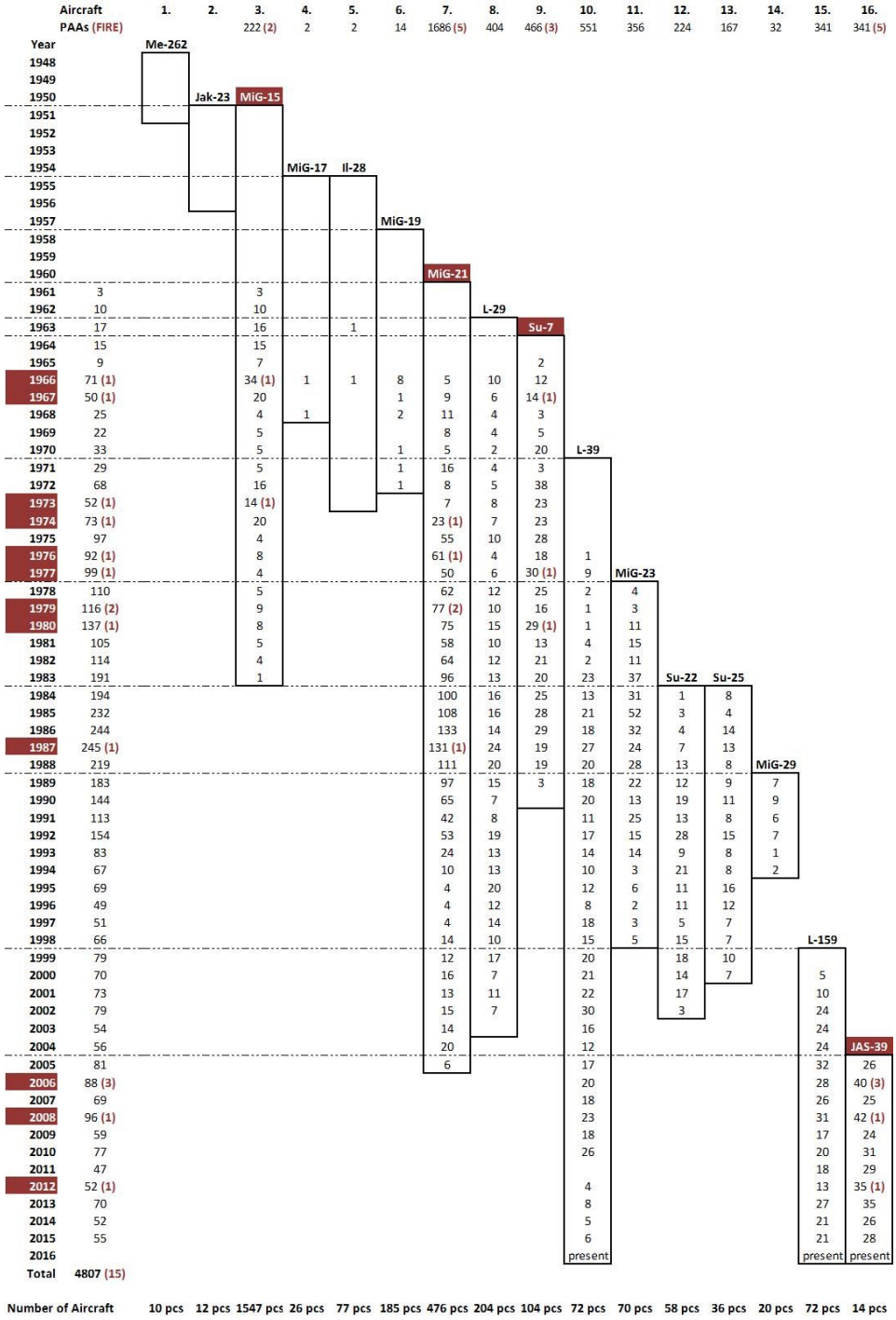


Fig. 3 Damage (fire-related damage) in 1948-2015



Aircraft	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.
PAAs (FIRE)			222 (2)	2	2	14	1686 (5)	404	466 (3)	551	356	224	167	32	341	341 (5)
Year	Me-262	Jak-23	MiG-15	MiG-17	Il-28	MiG-19	MiG-21	L-29	Su-7	L-39	MiG-23	Su-22	Su-25	MiG-29	L-159	JAS-39
1948																
1949																
1950																
1951																
1952																
1953																
1954																
1955																
1956																
1957																
1958																
1959																
1960																
1961	3		3													
1962	10		10													
1963	17		16		1											
1964	15		15													
1965	9		7						2							
1966	71 (1)		34 (1)	1	1	8	5	10	12							
1967	50 (1)		20			1	9	6	14 (1)							
1968	25		4	1		2	11	4	3							
1969	22		5				8	4	5							
1970	33		5			1	5	2	20							
1971	29		5			1	16	4	3							
1972	68		16			1	8	5	38							
1973	52 (1)		14 (1)				7	8	23							
1974	73 (1)		20				23 (1)	7	23							
1975	97		4				55	10	28							
1976	92 (1)		8				61 (1)	4	18	1						
1977	99 (1)		4				50	6	30 (1)	9						
1978	110		5				62	12	25	2	4					
1979	116 (2)		9				77 (2)	10	16	1	3					
1980	137 (1)		8				75	15	29 (1)	1	11					
1981	105		5				58	10	13	4	15					
1982	114		4				64	12	21	2	11					
1983	191		1				96	13	20	23	37					
1984	194						100	16	25	13	31	1	8			
1985	232						108	16	28	21	52	3	4			
1986	244						133	14	29	18	32	4	14			
1987	245 (1)						131 (1)	24	19	27	24	7	13			
1988	219						111	20	19	20	28	13	8			
1989	183						97	15	3	18	22	12	9	7		
1990	144						65	7		20	13	19	11	9		
1991	113						42	8		11	25	13	8	6		
1992	154						53	19		17	15	28	15	7		
1993	83						24	13		14	14	9	8	1		
1994	67						10	13		10	3	21	8	2		
1995	69						4	20		12	6	11	16			
1996	49						4	12		8	2	11	12			
1997	51						4	14		18	3	5	7			
1998	66						14	10		15	5	15	7			
1999	79						12	17		20		18	10			
2000	70						16	7		21		14	7		5	
2001	73						13	11		22		17			10	
2002	79						15	7		30		3			24	
2003	54						14			16					24	
2004	56						20			12					24	
2005	81						6			17					32	26
2006	88 (3)									20					28	40 (3)
2007	69									18					26	25
2008	96 (1)									23					31	42 (1)
2009	59									18					17	24
2010	77									26					20	31
2011	47														18	29
2012	52 (1)									4					13	35 (1)
2013	70									8					27	35
2014	52									5					21	26
2015	55									6					21	28
2016										present					present	present
Total	4807 (15)															
Number of Aircraft	10 pcs	12 pcs	1547 pcs	26 pcs	77 pcs	185 pcs	476 pcs	204 pcs	104 pcs	72 pcs	70 pcs	58 pcs	36 pcs	20 pcs	72 pcs	14 pcs

Fig. 4 PAAs (fire-related PAAs) in 1948-2015

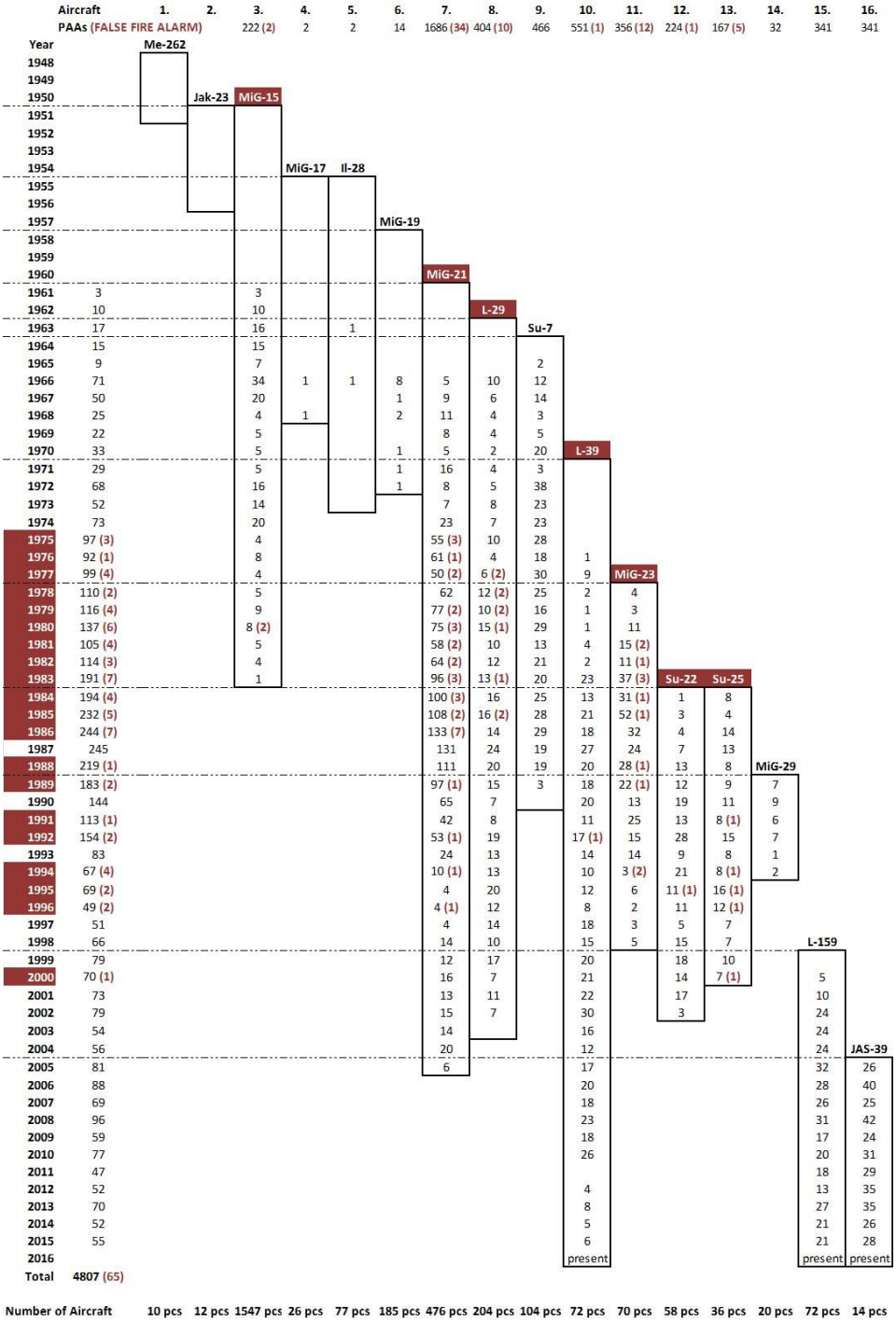


Fig. 5 PAAs (false fire alarm related PAAs) in 1948-2015

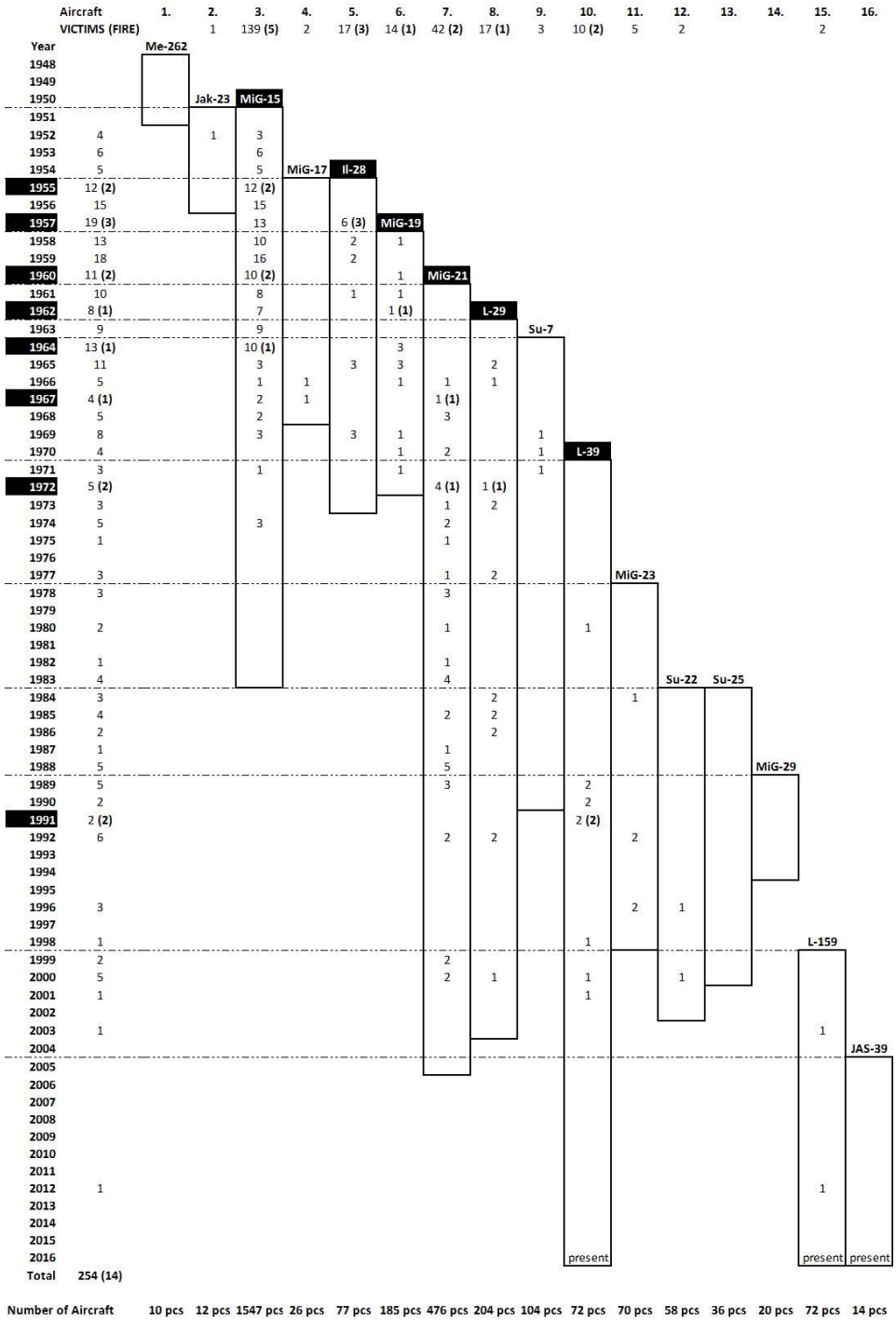


Fig. 6 Number of disaster victims from among the flight staff (number of victims of fire-related disasters) in 1948-2015

5. Interesting Facts, Contexts and Development Trends

The tabular overviews (see Fig. 1 to Fig. 6) show that, for the purpose of this study, a total of 5 452 reported AA or PAA aviation emergency occurrences were traced within 67 years. The list, however, may not be complete. We face at least three problems:

1. Different information sources describing AAs or PAAs in different historical periods used different scales and definitions for the classification of AAs and PAAs according to regulations in force at that time. Many information sources used AA and PAA classification scales valid when the historical overviews were drawn up, not when the events occurred. The staff manuals by Col. Stanislav Slavík [14-18] may serve as a typical example. Therefore, there is a slight distortion in the numerical overviews which unfortunately nowadays cannot be avoided as many AA investigation records that could reveal the original classification are not available any more. This applies particularly to AAs that took place in the 1950s.
2. Human error, inventiveness and inconsistency are unpredictable at any time. Many accounts provided by old time witnesses revealed that a lot of emergency occurrences that nowadays could be regarded as damage or at least PAA had not been recorded and many times, for they could have posed a threat to the professional growth, not even reported. In this way, we miss additional information that will probably be lost forever.
3. Also, many information sources are slowly disappearing. Even archives cannot keep all records forever. For example, many archival documents of the Military Central Archives in Prague were lost in the floods in 1997. Many old time witnesses in advanced age pass away and often they are the only people who know the real meaning of many archival materials and can be asked about them.

We do not mention these problems to diminish the value of the analytical analyses we present but, on the contrary, to enable the readers to perceive the reality in a comprehensive, contextual and fully authentic way with all positives and negatives involved. Despite the mentioned problems and inaccuracies, the AA and PAA statistical overviews still have a significant information value and clearly show the principal development trends in the former Czechoslovak and Czech military aviation safety concepts.

The following development trends based on the AA and PAA statistics were broken down by AA and PAA types with regard to the historical period and type of the aircraft technology.

5.1. AA and PAA Development Trends – General

For the formulation of general AA and PAA development trends over time, the tabular overviews (see Fig. 1 to Fig. 6) provide the following facts.

The number of AAs recorded as disasters decreased over time (see Fig. 1). The greatest number of disasters was recorded from the mid-1950s to mid-1960s. The most critical years were 1956 (15 disasters) and 1959 (15 disasters).

The number of AAs recorded as air crashes also decreased over time (see Fig. 2). The greatest number of air crashes was also recorded from the mid-1950s to mid-1960s. The most critical years were 1962 (15 air crashes) and 1965 (15 air crashes).

The gradual decrease in the number of air disasters and air crashes was mainly due to the gradual reduction in number of flight hours, reduction in the number of aircraft in active military service, improvements in pilot training and, of course, due to higher reliability of aircraft safety and rescue systems. The relatively high number of air crashes

in the 1950s and 1960s was also influenced by the fact that this classification included events that would be classified as "ground accidents" since 2000 (see the Let-1-5 regulation issued in 2000 [31]), i.e., events that did not take place in flight, but occurred, for instance, during engine tests at aircraft stands on ground.

The ratio between the number of disasters and air crashes was also changing over time. It illustrates how the opportunities of self-rescue for the aircraft crew members changed, as well as how these opportunities could be seized in practice, that is, it gives evidence on the level of experience and training of the crew members. In the 1950s, the number of disasters prevailed over, or at most corresponded to the number of air crashes, which shows that the aircraft rescue systems were not yet much developed and the level of experience and training of the crew members was low. In the 1960s, the air crashes began to prevail over the disasters and they do until present days. It was due to the gradual increase in technical capabilities and reliability of aircraft rescue systems (especially ejection seats), developments of systems for the identification and indication of dangerous flight regimes, as well as the continuous increase in preparedness of pilots for in-flight emergencies. Also, the importance of military flight simulators in flight training has been growing ever since.

The greatest and continuing threats in aviation include the unpredictability of weather conditions and only limited knowledge of human performance limits (human factors) to which extensive scientific research has long been devoted.

The number of AAs recorded as damage occurrences also decreased over time (see Fig. 3), but it was heavily influenced by frequent and substantial changes in definitions given in the regulations for the classification of AAs. The introduction of "aviation emergency occurrence with favourable ending" in 1962 (see the 1962 Let-1-5 regulation [25]) affected the damage definition most prominently together with the introduction of "minor accidents" in 1968 (see the 1968 Let-1-5 regulation [26]) followed up by PAAs in 1972 (see the 1972 Let-1-5 regulation [27]). Some of the original damage occurrences were reclassified as one of the above mentioned and thus disappeared from the summaries. The definition for damage as known and used at present stabilized only in the 1991 Let-1-5 regulation [30] in the early 1990s. Similar to disasters and air crashes, the greatest number of damage occurrences was recorded from the mid-1950s to mid-1960s. The most critical years were 1959 (23 damage occurrences) and 1962 (23 damage occurrences).

Unlike all types of AAs, the number of PAAs varied over time. In 1972-1987 it grew and then in 1988-1992 it slightly declined falling in 1993 to about a half compared to 1992. Since 1993, it has maintained at approximately the same level with minor fluctuations with the exception of 2005-2008 when the number of PAAs temporarily increased.

Although in the first book of the staff manual by Col. Stanislav Slavík [14] the records of PAAs for 1960-1971 were presented, they were records for emergency occurrences that were evidently reclassified at that time for the purpose of compiling the summaries.

In the historical, political and technical development contexts, each fluctuation in the PAA statistics had its own reason. For example, the gradual increase after 1972 was caused by the fact that in 1972 the classification of PAAs was officially introduced and was developing later. Once closer to 1989 when "Velvet Revolution" took place in former Czechoslovakia, the number of errors, deficiencies and inconsistencies was increasing. The maximum number of PAAs was recorded in 1987 exceeding several times the long-term average counts. The situation calmed down and stabilized after the

Velvet Revolution, but still the number of PAAs was well-above the long-term average over the previous years. The 1993 saw another turning point as in January 1st, 1993, Czechoslovakia split into the Czech and Slovak Republics and the statistics divided in halves approximately. The numbers of AAs, i.e. disasters, air crashes and damage, remained largely unaffected as the AAs were already very sporadic. The fluctuation in the number of PAAs in 2005 is inextricably linked to the introduction of Saab JAS-39 Gripen into the service of the Czech Republic Air Forces.

It is now quite difficult to assess which of the combat aircraft types used were statistically safe or unsafe for the crew in their time. For a complete and authoritative statistical overview, at least three numerical values would have to be put into a ratio: the total number of flight hours for a given aircraft type in a given year, number of aircraft of a given type in active service in a given year and the number of relevant AAs and PAAs for a given aircraft type in a given year. Hereby, we would obtain the number of hours flown between individual AAs and PAAs in different types of aircraft for the year concerned. If such a calculation were performed for all years in chronological order, we would get a basis for a tabular or graphical processing of accurate flight safety trends across aircraft types and time periods in accordance with then applicable regulations for the classification of AAs and PAAs. It should be noted that such a hypothetical evaluation would be influenced by the unpredictability of weather conditions and human factors that make most of the AAs almost unique. Such a detailed analysis is, however, beyond the scope of this study.

For a given moment, one can choose one arbitrary criterion and make at least an indicative overview. For the purpose of this study, the criterion chosen was the total number of individual AA and PAA types.

As for the total number of AAs recorded as disasters, the MiG-15 ranked first with the total of 129 recorded disasters – mostly in the basic MiG-15 version (47 disasters) and the MiG-15bis version (46 disasters). The MiG-21 ranked second with the total of 36 disasters – mostly in the MiG-21 F-13 (12 disasters) and the MiG-21MF (8 disasters) versions. The MiG-19 ranked third with the total of 14 disasters – mostly in the MiG-19S (7 disasters) and the MiG-19PM (4 disasters) versions.

As for the total number of AAs recorded as air crashes, the MiG-15 ranked first with the total of 103 recorded air crashes – mostly in the basic MiG-15 version (42 crashes) and the MiG-15bis version (27 crashes). The MiG-21 ranked second with the total of 69 air crashes – mostly in the MiG-21 F-13 (29 crashes) and the MiG-21MF (10 crashes) versions. The MiG-19 ranked third with the total of 25 air crashes – mostly in the MiG-19S (17 crashes) and the MiG-19PM (6 crashes) versions.

As for the total number of victims of AAs from among the flight staff, the MiG-15 ranked first with the total of 139 victims – mostly in the basic MiG-15 version (47 victims) and the MiG-15bis version (46 victims). The MiG-21 ranked second with the total of 42 victims – mostly in the MiG-21 F-13 (12 victims) and the MiG-21MF (8 victims) versions. Surprisingly, the Il-28 and L-29 share the third position, both with the total of 17 victims – mostly in their basic versions the Il-28 (8 victims) and L-29 (13 victims) and the Il-28R (6 victims) and L-29R (4 victims) versions.

Despite these facts, the number of AA victims decreased over time in relation to the number of disasters (see above). In terms of the number of AA victims, the most critical period was the late 1950s, namely 1957 (19 victims) and 1959 (18 victims).

5.2. AA and PAA Development Trends – Fires and False Fire Alarms

For the formulation AA and PAA development trends over time in relation to fires and false fire alarms, the tabular overviews (see Fig. 1 to Fig. 6) provide the following facts.

AAs recorded as disasters caused by a fire on board an aircraft accounted for 4.6 % of all recorded disasters and their number decreased over time (see Fig. 1). The greatest number of such disasters was recorded in the late 1950s. The most critical year was 1955 (2 disasters). The last disaster of this kind was recorded in 1991.

AAs recorded as air crashes caused by a fire on board an aircraft accounted for 24.3 % of all recorded air crashes and their number varied over time (see Fig. 2). In the 1950s it increased, in the 1960s stagnated and since 1970s it has been gradually reducing as the time gap between the emergency events has been increasing. The greatest number of these events was recorded in 1959-1967. The most critical year was 1965 (8 air crashes). The last air crash of this kind was recorded in 2010.

The proportion of disasters (10 disasters) and air crashes (60 crashes) caused by a fire shows that, in terms of total numbers, crashes strongly dominated and the ratio was 6:1. This can be explained by the fact that fire is a type of an in-flight emergency with often fatal consequences for the aircraft but the crew is usually given sufficient time to make a decision for problem solving or self-rescuing. Again, we face the problem with the level of training and experience of the crew members as well as the reliability and technical capabilities of aircraft rescue systems.

AAs recorded as damage caused by a fire on board an aircraft accounted for 6.6 % of all recorded damage occurrences and their number decreased over time (see Fig. 3). The greatest number of these events was recorded in 1959–1964 and in 1969-1972. The most critical year was 1962 (2 damage). The last damage of this kind was recorded in 1988. This criterion, however, should be viewed only as indicative due to significant changes to the definitions of damage as discussed above (see Section 5.1).

PAAs caused by a fire on board an aircraft accounted for 0.3 % of all recorded PAAs and their distribution in time was rather random (see Fig. 4). The greatest number of these events was recorded in 1973-1980 and in 2006-2012. The most critical year was 2006 (3 PAAs). They were recorded in the MiG-15, MiG-21, Su-7 and JAS-39. The last PAA of this kind was recorded in 2012.

PAAs caused by a false fire alarm on board an aircraft accounted for 1.4 % of all recorded PAAs and their distribution in time varied (see Fig. 5). In 1975-1980 their number increased, in 1980-1986 stagnated and in 1987-1996 gradually decreased in a continuous course. The greatest number of these events was recorded in 1977-1986. The most critical years were 1983 (7 PAAs) and 1986 (7 PAAs). Most of them were recorded in the MiG-21, MiG-23 and L-29. The last PAA of this kind was recorded in 2000.

Choosing again the total number of individual AA and PAA types caused by a fire for the criterion gave us the following score.

As for the total number of AAs recorded as disasters caused by a fire, the MiG-15 ranked first with the total of 4 recorded disasters in the basic (1 disaster), bis (1 disaster), bis SB (1 disaster) and UTI (1 disaster) versions. The MiG-21 ranked second with the total of 2 disasters in the F-13 (1 disaster) and MF (1 disaster) versions. The third position was shared by the Il-28 (basic version – 1 disaster), MiG-19 (S version – 1 disaster), the L-29 (basic version – 1 disaster) and the L-39 (ZA version – 1 disaster).

As for the total number of AAs recorded as air crashes caused by a fire, the MiG-15 ranked first again with the total of 24 recorded air crashes – mostly in the MiG-15bis (9 crashes) and the basic MiG-15 (7 crashes) versions. The MiG-21 ranked second with

the total of 16 air crashes – mostly in the F-13 (9 crashes), PF (2 crashes), MA (2 crashes) and MF (2 crashes) versions. The MiG-19 ranked third with the total of 6 air crashes – mostly in the S (4 crashes) version.

As for the total number of flight staff victims of AAs caused by a fire (see Fig. 6), the MiG-15 (basic version – 2 victims, UTI version – 2 victims) ranked first and Il-28 (basic version – 3 victims) ranked second. The third position was shared by the L-39 (ZA version – 2 victims).

Finally, the number of victims of AAs caused by a fire, fortunately, also decreased over time. The most critical period was the late 1950s, namely 1957 (3 victims).

6. Conclusion

The above mentioned overviews clearly show that the aviation accident rate in the Czechoslovak and Czech military aviation was by no means random. It was largely conditioned by the factors that can be influenced by humans and, therefore, it is worth looking back and learning a lesson from the successes and mistakes of past generations. The purpose of these activities is focused not only on the improvement of the safety in the military aviation, but it is also aimed at the recognition of the work and often the highest sacrifice of the specialists in this area whose mistakes can be a valuable source of our learning a lesson. This opportunity should not be missed because failing to learn from mistakes leads to repeating them which in this case may have serious if not fatal consequences.

The authors would like to thank all who do or did participate in the development of the Czechoslovak and Czech military aviation safety and pay tribute to those who gave their lives for it even in peaceful times. We believe that their work and sacrifice were not in vain and will never be forgotten.

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References

[1] BRADNOVÁ, H. et al. *Encyclopaedic Dictionary* (in Czech). Prague: Odeon, 1993. Klub čtenářů (Odeon). ISBN 80-207-0438-8.

[2] ISO 8421-1:1987, *Fire protection – Vocabulary – Part 1: General terms and phenomena of fire*.

[3] ISO 13943:2008, *Fire safety – Vocabulary*.

[4] IRRA, M. *Aero Avia S/CS-92*. (in Czech). 1st ed. Nevojice: Jakab Publishing, 2014. ISBN 978-80-87350-17-1.

[5] IRRA, M. *MiG-15: Vol. 3.* (Bi-lingual English/Czech publication). 1st ed. Nevojice: Jakab Publishing, 2007, p. 96, ISBN 978-80-87161-01-2.

[6] IRRA, M. *MiG-17: The "Seventeen"* (Bi-lingual English/Czech publication). 1st ed. Nevojice: Jakab Publishing, 2012, p. 128, ISBN 978-80-87350-10-2.

[7] IRRA, M. *Ilyushin Il-28: The Ilyushin Il-28 in Czechoslovak Air Force* (Bi-lingual English/Czech publication). 1st ed. Nevojice: Jakab Publishing, 2013, p. 128, ISBN 978-80-87350-12-6.

[8] IRRA, M. *The Mikoyan-Gurevich MiG-19 in Czechoslovak Air Force* (in Czech). 1st ed. Nevojice: Jakab Publishing, 2014, p. 128, ISBN 978-80-87350-15-7.

[9] IRRA, M. *The "Twenty-one": The MiG-21 in Czechoslovak and Czech Air Force 1962–2005: Vol. 2.* (Bi-lingual English/Czech publication). 1st ed. Nevojice: Jakab Publishing, 2008, p. 112, ISBN 978-80-87161-04-3.

[10] IRRA, M. *Aero L-29 "Dolphin": Vol. 2*. 1st ed. Nevojice: Jakab Publishing, 2016, ISBN 978-80-87350-34-8.

[11] REŽŇÁK, L. *The Silver Jet MiG-15: Jet Beginnings of the Czechoslovak Air Force 1950–1957* (in Czech). 1st ed. Cheb: Svět křídel, 2012, p. 567, ISBN 978-80-87567-14-2.

[12] REŽŇÁK, Libor. *The Steel Stallion MiG-19 and the Czechoslovak Air Force 1958–1972* (in Czech). 1st ed. Cheb: Svět křídel, 2008, p. 582, ISBN 978-80-86808-45-1.

[13] Military Central Archives: Homepage. *Military Central Archives: Homepage* [online]. Praha, 2010 [cited 2016-05-10]. Available from: <http://www.vuapraha.cz/>

[14] SLAVÍK, S. *Overview of Aviation Accidents, Serious Preconditions and Preventive Experience (Book 1)* (in Czech). 1st ed. Hradec Králové, 1979.

[15] SLAVÍK, S. *Overview of Aviation Accidents, Serious Preconditions and Preventive Experience (Book 2)* (in Czech). 1st ed. Hradec Králové, 1979.

[16] SLAVÍK, S. *Overview of Aviation Accidents, Serious Preconditions and Preventive Experience (Book 3)* (in Czech). 1st ed. Hradec Králové, 1981.

[17] SLAVÍK, S. *Overview of Aviation Accidents, Preconditions and Preventive Experience 1981–1982* (in Czech). 1st ed. Hradec Králové, 1986.

[18] SLAVÍK, S. *Overview of Aviation Accidents, Preconditions, Deficiencies and Preventive Experience 1983–84* (in Czech). 1st ed. Hradec Králové, 1989.

[19] AURA, s.r.o. *Information System for Logistics of Ministry of Defence and the Army of the Czech Republic (ISL)* [software]. [accessed 2016-01-21].

[20] *Aviation Accidents* [directive, K čj. 12.416/let. – 1946] (in Czech). 1st ed. Prague: Ministry of National Defence, 1946 [Military Central Archives in Prague].

[21] *Aviation Accident* [regulation Let-I-5] (in Czech). 1st ed. Prague: Ministry of National Defence, 1950 [Military Central Archives in Prague].

[22] *Aviation Occurrences and Procedure for Their Investigation* [regulation Let-I-5] (in Czech). 1st ed. Prague: Ministry of National Defence, 1953 [Administrative Archives of the Armed Forces of the Czech Republic in Olomouc].

[23] *Classification, Investigation and Prevention of Aviation* [regulation Let-I-5] (in Czech). 1st ed. Prague: Ministry of National Defence, 1955 [Administrative Archives of the Armed Forces of the Czech Republic in Olomouc].

[24] *Classification and Method of Investigation of Aviation Emergency Occurrences* [regulation Let-1-5] (in Czech). 1st ed. Prague: Ministry of National Defence, 1960. NV-0031413/60 [Administrative Archives of the Armed Forces of the Czech Republic in Olomouc].

[25] *Classification and Investigation of Aviation Emergency Occurrences* [regulation Let-1-5] (in Czech). 1st ed. Prague: Ministry of National Defence, 1962. T PVOSL-261-62 [Administrative Archives of the Armed Forces of the Czech Republic in Olomouc].

[26] *Classification and Investigation of Aviation Accidents* [regulation Let-1-5] (in Czech). 1st ed. Prague: Ministry of National Defence, 1968. T MNO-40-62-68 [Administrative Archives of the Armed Forces of the Czech Republic in Olomouc].

[27] *Classification, Investigation, Record-keeping and Prevention of Aviation Accidents and Their Preconditions* [regulation Let-1-5] (in Czech). 1st ed. Prague: Ministry of National Defence, 1972. T MNO-40-176-71 [Administrative Archives of the Armed Forces of the Czech Republic in Olomouc].

[28] *Classification, Investigation, Record-keeping and Prevention of Aviation Accidents and Their Preconditions* [regulation Let-1-5] (in Czech). 1st ed. Prague: Ministry of National Defence, 1974. T MNO-40-175-74 [Administrative Archives of the Armed Forces of the Czech Republic in Olomouc].

[29] *Classification, Investigation, Record-keeping and Prevention of Aviation Accidents and Their Preconditions* [regulation Let-1-5] (in Czech). 1st ed. Prague: Ministry of National Defence, 1979.

[30] *Flight Safety* [regulation Let-1-5] (in Czech). 1st ed. Stará Boleslav: Federal Ministry of Defence, 1991 [Administrative Archives of the Armed Forces of the Czech Republic in Olomouc].

[31] *Flight Safety* [regulation Let-1-5] (in Czech). 1st ed. Prague: Ministry of Defence, 2000 [Administrative Archives of the Armed Forces of the Czech Republic in Olomouc].

[32] *Flight Safety* [regulation Všeob-P-10] (in Czech). 1st ed. Prague: Ministry of Defence, 2006.