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Ejection Causes in Military Jet Aircraft in Czechoslovakia and the Czech Republic

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Abstract:

The article deals with the causes of ejections of crew members in military jet fighter, fighter-trainer and trainer aircraft in the service of Czechoslovakia and the Czech Republic from 1948 until the end of 2016. It presents a list of ejection causes by aircraft types on a timeline as well as historical and technical contexts, facts and development trends of these causes. Importantly, the role of the human factor in the causes of aircraft emergency events associated with ejections is analyzed. The study is accompanied by a unique overview of reference and still accessible information sources on the subject.

Keywords:

Army of the Czech Republic, ejection, aviation accident, human factor, jet aircraft, cause, statistics

1. Introduction

Ejection is a procedure of an emergency exit of the aircraft by the crew using the ejection seat in an emergency situation that cannot be dealt with in other manner and in which the life of the crew is threatened.

For the "jet era" of military aviation in the former Czechoslovakia and the present Czech Republic, a total of 209 aviation accidents (hereinafter "AA") associated with crew ejection could be tracked back. A total of 227 flight staff and 1 non-flight staff members ejected. Of this number, a total of 37 flight staff members did not survive the ejection [1-17].

This study aims to give answers to at least three questions: "What were the main factors of the AA causes leading to ejections of crew members?" "Under what circumstances and weather conditions did these AAs occur?" and "Which scenarios or

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factors of such scenarios may be timeless, i.e. may present a risk even today, despite technical advances in military aviation?"

The authors will try to answer these and other questions in the following paragraphs.

2. Classification of Aviation Accidents and Their Causes

The classification of AAs used in the study is based on the contents of the Všeob-P-10 Flight Safety regulation [18], which was in force between 2006 and June 2016, being replaced by the Order of the Minister of Defence No. 13/2016 Journal – Flight Safety of 15th June 2016 [19]. In this Order of the Minister of Defence, however, substantial changes in definitions, terminology and classification of emergency occurrences in military aviation were made. Therefore, in order to effectively synchronize data from AAs for different periods, the authors of this study chose to use the classification system based on the previous Všeob-P-10 Flight Safety regulation. Most of available technical literature and archival records are based on the contents of this Všeob-P-10 Flight Safety regulation, including the information base from the Information System for Logistics [16], a part of which has been used by the Air Forces of the Czech Armed Forces (hereinafter "AF ACR") to keep records of emergency occurrences since 1985 to the present day.

In conformity with the Všeob-P-10 Flight Safety regulation, AAs are divided into disasters (see Section 3.1), air crashes (see Section 3.2) and damage (see Section 3.3). If the Order of the Minister of Defence No. 13/2016 Journal – Flight Safety [19] classification were used, the three types of occurrences would be categorized uniformly as aviation accidents, which would be detrimental to the clarity of the results interpreted in the study.

The causes of all AAs are primarily classified under one of four factors of the event's main cause: technical factor (hereinafter "TF"), human factor (hereinafter "HF"), environmental factor (hereinafter "EF") and not found (hereinafter "N"). The human factor can be further subdivided into human factor – flight personnel (hereinafter "HF-fp") and human factor – non-flight personnel (hereinafter "HF-np").

The technical factor includes operational degradation, design and manufacturing defects and 'other causes' that encompass premature destructions of suspension live ammunition (spontaneous destructions of bombs on suspension lugs or premature destructions of missiles near to the aircraft shortly after being launched).

The human factor–flight personnel includes errors in command and organization (by in-flight personnel, i.e. pilots), errors in navigation (incorrect navigation calculations, calculations of fuel consumption, etc.), piloting (failure in mastering advanced piloting technique), using aviation equipment (unintentional errors in the use of aviation equipment), noncompliance with rules by crew (recklessness in flight), in-flight personnel errors (airborne collisions when pilot was hit without his fault by another aircraft) and, rarely, health reasons (such as eating errors or lifestyle), or other causes (such as aircraft destructions in real combats – downing, clashes with airspace violators).

The human factor–non-flight personnel includes errors in command and organization (by non-flight personnel, i.e. air traffic controllers, meteorologists and others), errors in the military unit's aviation engineering services (deficiencies in aircraft operational maintenance, servicing and repairs) and poor quality of service work in manufacturing or repair plants (e.g. deficiencies in overhauls).

The environmental factors include weather conditions (atmospheric anomalies, such as lightning strikes) and foreign object ingestion with no fault of the unit's aviation engineering services (e.g., ingestion of a part of a target for live air target practice).

The group of unknown main factors of AA causes includes all cases not conclusively clarified and evidenced.

Also, the stage of flight in which the emergency situation was first detected is observed: before take-off ("1"), take-off ("2"), climb ("3"), flight task ("4"), arrival ("5"), approach maneuvering ("6"), landing ("7"), after landing ("8") and unknown ("9").

3. Causes, Interesting Facts, Contexts and Development Trends

A total of 209 AAs of various types (38 disaster AAs, 168 crash AAs and 3 damage AAs) were tracked down and analyzed for this study. The causes and links between those aviation accidents are dealt with in the following paragraphs (see Sections 3.1 to 3.4).

3.1. Ejection Causes – Disaster AAs

A total of 38 AAs recorded as disasters (see Fig. 1 for an example) associated with the ejection of one or two crew members were tracked down (see Tab. 1). A total of 45 crew members were involved, out of which 41 attempted to eject (4 successfully and survived, 37 unsuccessfully and were killed). The remaining 4 crew members never even attempted to eject and were killed in the cockpit.

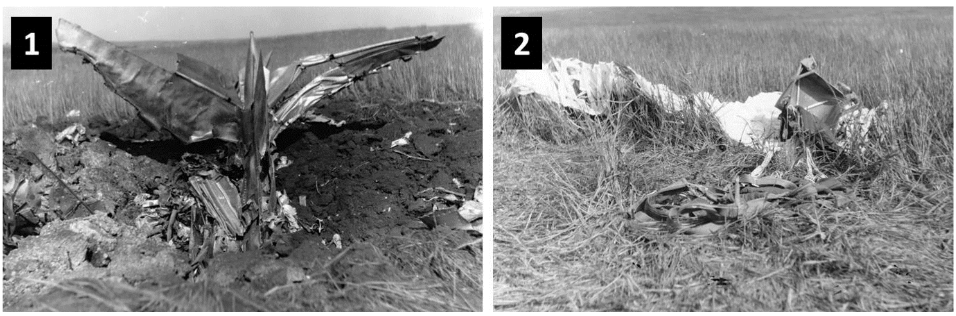

Fig. 1 The MiG-15 disaster – June 16th, 1958: (1) tailplane debris, (2) KK-1 type ejection seat [17]

The average age of the 37 crew members killed in the ejection or its aftermath was 31. The youngest pilot was 19, the oldest one was 42. The average number of flight hours for those 37 pilots was approximately 850 with the minimum corresponding to 30 flight hours and the maximum corresponding to 2 360 flight hours.

Among the unsuccessfully ejected pilots (37 pilots – 100 %), there were 12 pilots with no skill class (32.4 %), 3 pilots of skill class 3 (8.1 %), 2 pilots of skill class 2 (5.4 %), 16 pilots of skill class 1 (43.2 %) and 4 pilots with no identification of pilot skill class (10.8 %). Pilot skill classes were introduced in the Czechoslovak Air Forces drawing on the example of the Soviet Union only in 1954. The average number of

Tab. 1 Factors of the main causes of disaster AAs associated with ejection of one or two crew members in 1948–2016 and meteorological conditions under which the AAs occurred (by aircraft type and number of AAs) [1-17]

Aircraft type and version	**Main cause of the AA (ejection)**					**Meteorological conditions in the AA**			
	TF	**HF-fp**	**HF-np**	**EF**	**N**	**NWCD***	**DWCD***	**NWCN***	**DWCN***
MiG-15									
MiG-15	4	17	0	0	2	18	3	2	0
MiG-15 bis	1	9	2	0	3	10	3	2	0
MiG-15 SB	2	1	0	0	0	1	2	0	0
MiG-15 bis SB	1	0	1	0	0	2	0	0	0
MiG-15 bis R	1	4	2	0	0	4	2	1	0
UTI MiG-15	4	1	0	0	2	4	2	0	1
Total for type (57 = 100 %)	**13 (22.8 %)**	**32 (56.1 %)**	**5 (8.8 %)**	**0 (0 %)**	**7 (12.3 %)**	**39 (68.4 %)**	**12 (21 %)**	**5 (8.8 %)**	**1 (1.8 %)**
MiG-21									
MiG-21 F-13	10	6	3	0	2	16	4	1	0
MiG-21 PF	4	0	0	0	3	4	2	0	1
MiG-21 PFM	1	2	2	2	0	3	3	0	1
MiG-21 R	1	1	0	0	1	2	0	1	0
MiG-21 MA	3	2	0	0	0	5	0	0	0
MiG-21 MF	3	6	0	0	0	3	3	1	2
MiG-21 UM	0	1	1	0	0	1	1	0	0
Total for type (54 = 100 %)	**22 (40.8 %)**	**18 (33.3 %)**	**6 (11.1 %)**	**2 (3.7 %)**	**6 (11.1 %)**	**34 (63 %)**	**13 (24.1 %)**	**3 (5.5 %)**	**4 (7.4 %)**
Su-7									
Su-7 BM	7	2	1	0	4	12	0	1	1
Su-7 BKL	2	2	0	0	3	5	0	1	1
Su-7 U	0	0	0	0	1	0	1	0	0
Total for type (22 = 100 %)	**9 (40.9 %)**	**4 (18.2 %)**	**1 (4.5 %)**	**0 (0 %)**	**8 (36.4 %)**	**17 (77.3 %)**	**1 (4.5 %)**	**2 (9.1 %)**	**2 (9.1 %)**
MiG-19									
MiG-19 S	2	3	1	0	5	6	0	2	3
MiG-19 P	1	0	0	0	0	0	0	1	0
MiG-19 PM	2	2	0	0	1	1	2	0	2
Total for type (17 = 100 %)	**5 (29.4 %)**	**5 (29.4 %)**	**1 (5.9 %)**	**0 (0 %)**	**6 (35.3 %)**	**7 (41.2 %)**	**2 (11.8 %)**	**3 (17.6 %)**	**5 (29.4 %)**
L-39									
L-39 C	4	0	0	0	1	3	0	2	0
L-39 ZA	2	0	0	0	0	2	0	0	0
Total for type (7 = 100 %)	**6 (85.7 %)**	**0 (0 %)**	**0 (0 %)**	**0 (0 %)**	**1 (14.3 %)**	**5 (71.4 %)**	**0 (0 %)**	**2 (28.6 %)**	**0 (0 %)**
MiG-23									
MiG-23 BN	1	1	0	0	1	2	1	0	0
MiG-23 MF	0	0	0	0	1	1	0	0	0
MiG-23 U	0	1	0	0	0	1	0	0	0
Total for type (5 = 100 %)	**1 (20 %)**	**2 (40 %)**	**0 (0 %)**	**0 (0 %)**	**2 (40 %)**	**4 (80 %)**	**1 (20 %)**	**0 (0 %)**	**0 (0 %)**
L-29									
L-29	0	2	1	0	1	4	0	0	0
Total for type (4 = 100 %)	**0 (0 %)**	**2 (50 %)**	**1 (25 %)**	**0 (0 %)**	**1 (25 %)**	**4 (100 %)**	**0 (0 %)**	**0 (0 %)**	**0 (0 %)**
Su-22									
Su-22 M-4	1	1	0	0	0	2	0	0	0
Total for type (2 = 100 %)	**1 (50 %)**	**1 (50 %)**	**0 (0 %)**	**0 (0 %)**	**0 (0 %)**	**2 (100 %)**	**0 (0 %)**	**0 (0 %)**	**0 (0 %)**
Total for all (168 = 100 %)	**57 (33.9 %)**	**64 (38.1 %)**	**14 (8.3 %)**	**2 (1.2 %)**	**31 (18.5 %)**	**112 (66.7 %)**	**27 (16.1 %)**	**17 (10.1 %)**	**12 (7.1 %)**

*Note: NWCD - Normal Weather Condition during the Day; DWCD - Difficult Weather Condition during the Day; NWCN - Normal Weather Condition during the Night; DWCN - Difficult Weather Condition during the Night flight hours for these 4 pilots with no identification of skill class was approximately 290. It can be assumed, therefore, that according to the later classification, they would rank approximately as pilots of skill class 3.

The most frequent stages of flight in which the situation leading to a disaster AA associated with ejection occurred were: flight task – stage of flight “4” (21 cases – 55.3 %), approach maneuvering – stage of flight “6” (8 cases – 21.0 %) and climb – stage of flight “3” (5 cases – 13.2 %).

Most of disaster AAs occurred under NWCD – 32 cases (84.2 %), the rest under DWCD – 4 cases (10.5 %) and DWCN – 2 cases (5.3 %). No-one was killed in the ejection or its aftermath under NWCN.

The main causes of this type of aviation disasters include human factors (27 cases – 71 %) and technical factors (9 cases – 23.7 %); in two cases (5.3 %) the causes were not found. Regarding the human factor, flight personnel error (20 cases – 52.6 %) prevails over non-flight personnel error (7 cases – 18.4 %).

The most critical time of the year appears to be June (11 disasters) and April (6 disasters). Other months of the year when the other disasters of this type took place over the course of 47 years (between 1955 and 2000 when disasters of this type were recorded) include March, May, July, August, September, October and November.

The following overview of specific causes of disaster AAs is complemented by number and percentage of cases of the total of 38 events (100 %).

Specific causes falling under “TF” included: operational degradation (7 cases – 18.4 %) and design and manufacturing defects (2 cases – 5.3 %) involving various failures in aircraft fuel and hydraulic equipment, fire, destructions to engine components and failure of the on-board rescue system (ejection seat).

Specific causes falling under “HF-fp” included: piloting (13 cases – 34.2 %), in-flight personnel (2 cases – 5.3 %), noncompliance (3 cases – 7.9 %), command and organization (1 case – 2.6 %) and use of aviation equipment (1 case – 2.6 %). Most frequent were airborne collisions and failure in mastering advanced piloting technique.

Specific causes falling under “HF-np” included: flight control (3 cases 7.9 %), unit’s aviation engineering services (2 cases – 5.3 %) and poor quality of work in manufacturing or repair plants (2 cases – 5.3 %). The most frequent were: air traffic control errors, defective aircraft maintenance or, for example, improper fuel storage affecting adversely its quality (presence of water in the fuel resulting in engine failure in flight).

3.2. Ejection Causes – Air Crash AAs

A total of 168 AAs recorded as air crashes (see Fig. 2 for an example) were associated with ejection of one or two crew members (see Tab. 2). After deduction of 5 cases in which pilots ejected two times, we have found out that a total of 179 crew members were involved (178 flight personnel members and 1 non-flight personnel member, an aircraft technician). All 179 crew members successfully ejected and survived.

The average age of the 178 flight personnel members was 32. The youngest pilot was 19, the oldest one was 53. The average number of flight hours for those 178 pilots was approximately 920 with the minimum corresponding to 50 flight hours and the maximum corresponding to 4 201 flight hours.

Among the successfully ejected pilots, there were 24 pilots with no skill class, 16 pilots of skill class 3 (8.7 %), 22 pilots of skill class 2 (12.0 %), 112 pilots of skill class 1 (61.3 %) and 9 pilots with no identification of pilot skill class (4.9 %). The percentages were calculated from a total of 183 pilots (100 %), because the double-ejected pilots had a different pilot skill classes in each of their ejections. The average number of flight hours for the 9 pilots with no identification of skill class was approximately 400. It can be assumed, therefore, that according to the later classification, they would rank approximately as pilots of skill class 3 or 2.

The most frequent stages of flight in which the situation leading to an air crash AA associated with ejection occurred were: flight task – stage of flight "4" (105 cases – 62.5 %), approach maneuvering – stage of flight "6" (24 cases – 14.3 %) and climb – stage of flight "3" (22 cases – 13.1 %).

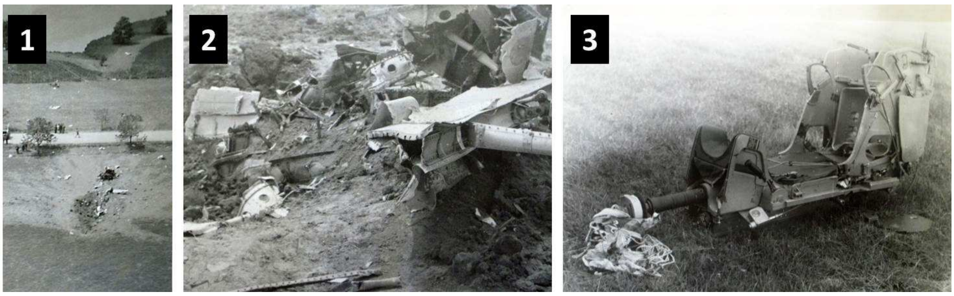

Fig. 2 The Su-7 BM air crash – June 1st, 1966: (1) aerial view of the crash site, (2) fuselage and wing debris, (3) KS-3 type ejection seat [17]

Most of the air crashes occurred under NWCD – 112 cases (66.7 %), the rest under DWCD – 27 cases (16.1 %), NWCN – 17 cases (10.1 %) and DWCN – 12 cases (7.1 %).

The main causes of this type of air crashes include human factors (78 cases – 46.4 %) and technical factors (57 cases – 33.9 %); environmental factors were the main causes in two cases (1.2 %) and in 31 cases (18.5 %) the causes were not found. Regarding the human factor, flight personnel error (64 cases – 38.1 %) prevails over non-flight personnel error (14 cases – 8.3 %).

The following overview of specific causes of air crash AAs is complemented by numbers and percentage of cases of the total of 168 events (100 %).

Specific causes falling under "TF" included: operational degradation (34 cases – 20.2 %), design and manufacturing defects (20 cases – 11.9 %) and other causes (3 cases – 1.8 %) involving various failures in aircraft fuel and hydraulic equipment, fire, destructions to engine components, mechanical failures in aircraft control systems, explosion of aircraft main batteries or premature explosion of ammunition (missiles) near the aircraft.

Specific causes falling under "HF-fp" included: piloting (33 cases – 19.6 %), noncompliance (9 cases – 5.3 %), use of aviation equipment (7 cases – 4.2 %), in-flight personnel (7 cases – 4.2 %), other causes (3 cases – 1.8 %), navigation (2 cases – 1.2 %), medical care (2 cases – 1.2 %) and command and organization (1 case – 0.6 %). The most frequent were: airborne collisions, failure in mastering advanced piloting technique, fuel exhaustion, errors in aircraft operation procedures or, in two cases, unintended downing by another aircraft.

Specific causes falling under "HF-np" included: military unit's aviation engineering services (9 cases – 5.3 %), flight control (3 cases – 1.8 %), command and organization (1 case – 0.6 %) and poor quality of work in manufacturing or repair plants (1 case – 0.6 %). The most frequent were: air traffic control errors, defective aircraft maintenance or improper fuel storage affecting adversely its quality (as in disasters above).

Tab. 2 Factors of main causes of air crash AAs associated with ejection of one or two crew members in 1948–2016 and meteorological conditions under which the AAs occurred (by aircraft type and number of AAs) [1-17]

Aircraft type and version	**Main cause of the AA (ejection)**					**Meteorological conditions in the AA**			
	TF	**HF-fp**	**HF-np**	**EF**	**N**	**NWCD**	**DWCD**	**NWCN**	**DWCN**
MiG-15									
MiG-15	4	17	0	0	2	18	3	2	0
MiG-15 bis	1	9	2	0	3	10	3	2	0
MiG-15 SB	2	1	0	0	0	1	2	0	0
MiG-15 bis SB	1	0	1	0	0	2	0	0	0
MiG-15 bis R	1	4	2	0	0	4	2	1	0
UTI MiG-15	4	1	0	0	2	4	2	0	1
Total for type (57 = 100 %)	**13 (22.8 %)**	**32 (56.1 %)**	**5 (8.8 %)**	**0 (0 %)**	**7 (12.3 %)**	**39 (68.4 %)**	**12 (21 %)**	**5 (8.8 %)**	**1 (1.8 %)**
MiG-21									
MiG-21 F-13	10	6	3	0	2	16	4	1	0
MiG-21 PF	4	0	0	0	3	4	2	0	1
MiG-21 PFM	1	2	2	2	0	3	3	0	1
MiG-21 R	1	1	0	0	1	2	0	1	0
MiG-21 MA	3	2	0	0	0	5	0	0	0
MiG-21 MF	3	6	0	0	0	3	3	1	2
MiG-21 UM	0	1	1	0	0	1	1	0	0
Total for type (54 = 100 %)	**22 (40.8 %)**	**18 (33.3 %)**	**6 (11.1 %)**	**2 (3.7 %)**	**6 (11.1 %)**	**34 (63 %)**	**13 (24.1 %)**	**3 (5.5 %)**	**4 (7.4 %)**
Su-7									
Su-7 BM	7	2	1	0	4	12	0	1	1
Su-7 BKL	2	2	0	0	3	5	0	1	1
Su-7 U	0	0	0	0	1	0	1	0	0
Total for type (22 = 100 %)	**9 (40.9 %)**	**4 (18.2 %)**	**1 (4.5 %)**	**0 (0 %)**	**8 (36.4 %)**	**17 (77.3 %)**	**1 (4.5 %)**	**2 (9.1 %)**	**2 (9.1 %)**
MiG-19									
MiG-19 S	2	3	1	0	5	6	0	2	3
MiG-19 P	1	0	0	0	0	0	0	1	0
MiG-19 PM	2	2	0	0	1	1	2	0	2
Total for type (17 = 100 %)	**5 (29.4 %)**	**5 (29.4 %)**	**1 (5.9 %)**	**0 (0 %)**	**6 (35.3 %)**	**7 (41.2 %)**	**2 (11.8 %)**	**3 (17.6 %)**	**5 (29.4 %)**
L-39									
L-39 C	4	0	0	0	1	3	0	2	0
L-39 ZA	2	0	0	0	0	2	0	0	0
Total for type (7 = 100 %)	**6 (85.7 %)**	**0 (0 %)**	**0 (0 %)**	**0 (0 %)**	**1 (14.3 %)**	**5 (71.4 %)**	**0 (0 %)**	**2 (28.6 %)**	**0 (0 %)**
MiG-23									
MiG-23 BN	1	1	0	0	1	2	1	0	0
MiG-23 MF	0	0	0	0	1	1	0	0	0
MiG-23 U	0	1	0	0	0	1	0	0	0
Total for type (5 = 100 %)	**1 (20 %)**	**2 (40 %)**	**0 (0 %)**	**0 (0 %)**	**2 (40 %)**	**4 (80 %)**	**1 (20 %)**	**0 (0 %)**	**0 (0 %)**
L-29									
L-29	0	2	1	0	1	4	0	0	0
Total for type (4 = 100 %)	**0 (0 %)**	**2 (50 %)**	**1 (25 %)**	**0 (0 %)**	**1 (25 %)**	**4 (100 %)**	**0 (0 %)**	**0 (0 %)**	**0 (0 %)**
Su-22									
Su-22 M-4	1	1	0	0	0	2	0	0	0
Total for type (2 = 100 %)	**1 (50 %)**	**1 (50 %)**	**0 (0 %)**	**0 (0 %)**	**0 (0 %)**	**2 (100 %)**	**0 (0 %)**	**0 (0 %)**	**0 (0 %)**
Total for all (168 = 100 %)	**57 (33.9 %)**	**64 (38.1 %)**	**14 (8.3 %)**	**2 (1.2 %)**	**31 (18.5 %)**	**112 (66.7 %)**	**27 (16.1 %)**	**17 (10.1 %)**	**12 (7.1 %)**

Specific causes falling under "FP" included: foreign object ingestion with no fault of the unit's aviation engineering services (1 case – 0.6 %) and weather conditions (1 case – 0.6 %). In the first case, a pilot chute from an aerial fighter-practice target parachute system was sucked into the engine compressor; in the second case the aircraft was struck by lightning in flight.

3.3. Ejection Causes – Damage AAs

A total of 3 AAs recorded as damage (see Fig. 3 for an example) associated with a crew member ejection (see Tab. 3). A total of 6 crew members were involved (6 flight personnel members). Three crew members successfully ejected and three crew members did not attempt to eject, but successfully completed the flight with damaged aircraft.

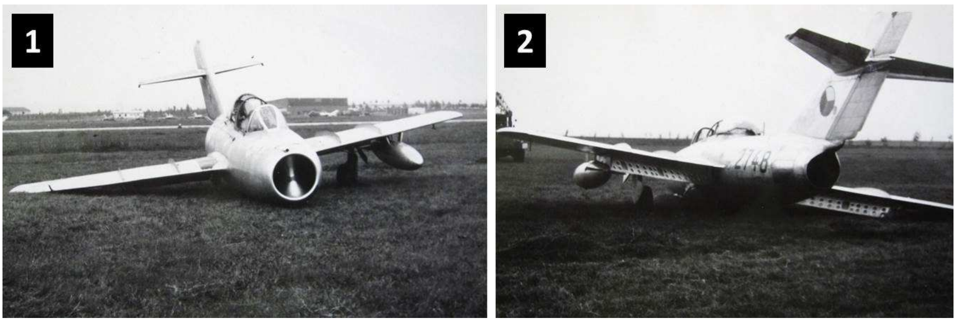

Fig. 3 The UTI MiG-15 damage AA – September 23rd, 1963: (1) front view, (2) view from the rear [17]

The average age of the 3 crew members that survived the ejection was 32. The youngest pilot was 24, the oldest one was 33. The average number of flight hours for these 3 pilots was approximately 1 000 with the minimum corresponding to 294 flight hours and the maximum corresponding to 2 075 flight hours.

Among the successfully ejected pilots (3 pilots – 100 %), there was 1 pilot of skill class 3 (33.3 %) and 2 pilots of skill class 1 (66.7 %).

The only stage of the flight in which the situation leading to a damage AA associated with ejection occurred was the flight task – stage of flight "4" (all 3 cases – 100 %). Also, all damage AAs occurred under NWCD – 3 cases (100 %).

The main cause of this type of damage AAs was the human factor (2 cases – 66.7 %); in 1 case (33.3 %) the cause was not found. Regarding the human factor, in both cases it was an error of the flight personnel.

The following overview of specific causes of damage AAs is complemented by numbers and percentage of cases of the total of 3 events (100 %).

Specific causes falling under "HF-fp" included: piloting (1 case – 33.3 %) and noncompliance (1 case – 33.3 %). In the first case it was a failure in mastering advanced piloting technique (recovery from an intentional spin); in the second case the instructor unintentionally induced a loss of consciousness in a student pilot by a high-G maneuver (the student pilot, disoriented after regaining consciousness, instinctively ejected).

Tab. 3 Factors of main causes of damage AAs associated with ejection of one or two crew members in 1948–2016 and meteorological conditions under which the AAs occurred (by aircraft type and number of AAs) [1-17]

Aircraft type and version	Main cause of the AA (ejection)					Meteorological conditions in the AA			
	TF	**HF-fp**	**HF-np**	**EF**	**N**	**NWCD**	**DWCD**	**NWCN**	**DWCN**
MiG-15									
UTI MiG-15	0	2	0	0	0	2	0	0	0
Total for type (2 = 100 %)	**0 (0 %)**	**2 (100 %)**	**0 (0 %)**	**0 (0 %)**	**0 (0 %)**	**2 (100 %)**	**0 (0 %)**	**0 (0 %)**	**0 (0 %)**
L-39									
L-39 C	0	0	0	0	1	1	0	0	0
Total for type (1 = 100 %)	**0 (0 %)**	**0 (0 %)**	**0 (0 %)**	**0 (0 %)**	**1 (100 %)**	**1 (100 %)**	**0 (0 %)**	**0 (0 %)**	**0 (0 %)**
Total for all (3 = 100 %)	**0 (0 %)**	**2 (66.7 %)**	**0 (0 %)**	**0 (0 %)**	**1 (33.3 %)**	**3 (100 %)**	**0 (0 %)**	**0 (0 %)**	**0 (0 %)**

3.4. Analysis of Types and Causes of Aircraft Crew Response in Relation to Ejections

The ejected pilots can be divided into five groups:

1. Pilots who did not respond to the critical situation.
2. Pilots who responded to the critical situation too late.
3. Pilots who responded in time and correctly to the critical situation:
   a. The on-board rescue system worked properly – they survived.
   b. The on-board rescue system did not work properly – they were killed.
4. Pilots who responded in time, but incorrectly to the critical situation.
5. Pilots who responded unnecessarily (inappropriately) to the critical situation.

There were instances where pilots did not respond to the critical situation (see Group 1 above), but still survived. That can be the case where in two-seaters the instructor (commander) responds to the critical situation by ejecting both pilots in time or by giving instructions to eject when there is a risk that the student pilot will respond late or will not respond at all.

The crash of the L-39 C in February 1996 during a night piloting training may serve as an example. Fire (titanium fire) started during a maneuver causing an engine unit to fail. The instructor ordered the ejection of both crew members (instructor first, student second) because there was a real danger that the student would not respond to the situation in a timely manner. Two years later (in February 1998), that former student pilot was killed in the same type of aircraft.

Pilot’s zero response to the emergency situation can be due to insufficient training, low respect for flying (noncompliance with rules and regulations), fear of reprisal, or unpredictability of psycho-physiological response.

Pilots who responded to the critical situation too late were usually killed as they failed to use the on-board rescue system within the limits in which it is safe to use; that is, they ejected at a too low altitude or at a high airspeed in combination with a low altitude.

An example of this can be found in practically any disaster associated with ejection except for three cases. In two out of these three cases, the pilots were killed due to a proven failure of the on-board rescue system (ejection seat) – see Group 3 below. In the third case, the pilot himself voluntarily decided for late ejection for altruistic reasons.

It was the MiG-21 PF disaster in November 1974 when aerial target attack under difficult weather conditions at night was trained. When arriving to the airfield at a low altitude, the engine failed and fire started. Given the situation, it was impossible to attempt the in-flight restart as the aircraft was flying over a congested city area. Due to difficult weather conditions and rapid drift-down, the pilot decided to keep the aircraft aloft so as to pass safely past the last inhabited house. As a result of this decision, he ejected at a low altitude and was killed. The aircraft hit the ground some 150 meters from the nearest building.

Pilot's delayed response to the emergency situation can be due to insufficient training, low respect for flying, fear of reprisal, unpredictability of psycho-physiological response patterns, or altruistic action.

Pilots who responded to the critical situation in time (see Group 3a above), i.e. within the limits of a safe use of the on-board rescue systems, usually survived, with the exception of very scarce cases where the on-board rescue systems (ejection seats) did not work properly (see Group 3b above). Only two cases with this characteristic are known to the authors of this study.

The first one was the MiG-15 T disaster in May 1964. The flight task was towing glide targets. When returning from the flight action, the engine failed due to the presence of water in the fuel (inappropriate fuel storage) and the pilot responded to the situation by ejecting. As a result of a technical failure, the seat did not detach from the pilot after being launched from the aircraft and thus prevented the main parachute from being deployed. The pilot was killed after hitting the ground seated in the ejection seat.

The second case was the Su-7 BM disaster in November 1969 during ground target shooting practice. After the third circle turn of the shooting range the aircraft suddenly nosed into a dive and the pilot ejected. The technical cause of the event was never fully explained due to the level of destruction of the aircraft wreck, but it is highly probable that in the critical phase of the maneuver, the aircraft controls locked as a result of a mechanical failure that appeared from time to time in this type and version of the aircraft. Not all failures of this type resulted in a disaster. In this case, the pilot was not killed during the ejection process, but decidedly in its aftermath. The ejection took place at a sufficient altitude of 800 m. One of the ejection seat pyrocartridges, however, did not burn out properly preventing the drogue from being deployed. Moreover, the pilot also manually intervened into the automatic procedure. As a result, the parachute canopy got snagged on the seat flying near, failed to fully open and the pilot's fall was only slightly slowed down. Branches of trees and terrain probably further slowed the fall because the pilot was still alive after hitting the ground. Due to post-traumatic shock (resulting either from a blow of some kind or from a psychological distress suffered after surviving a situation that normally would lead to death) the pilot took off his flight suit, lay down on the bare earth and died from hypothermia in the evening. He was found the following day, because the disaster occurred at dusk and with growing darkness the search and rescue operation was called off. At that time, there were no Search and Rescue Teams and the unit commander decided to call off the search and rescue operation in accordance with the regulations in force which, unfortunately, did not have any provisions for such occurrences. It is highly probable that if the on-board rescue system had worked properly, this highly experienced pilot would have survived. This event continues to be a memento in the history of Czechoslovak military aviation.

Pilots who responded to the critical situation in time, but incorrectly (see Group 4 above), were usually killed. Only one case with this characteristic is known to the authors of this study.

It was the MiG-15 disaster in August 1960 at a high-altitude formation flying training. During the training, a smoke appeared in the cockpit and the pilot responded to the situation by ejecting. However, he assumed incorrect position for ejection in the ejection seat and his parachute harness was incorrectly fastened. For these reasons the pilot died in spite of the fact that the decision to eject was made in time and at more than enough altitude. Such a scenario is easily repeatable and relevant even today.

Pilot's incorrect response to the emergency situation can be due to insufficient training or low respect for flying.

Pilots who responded to the critical situation unnecessarily (see Group 5 above) are those who ejected before exhausting all other options to address the situation. Three different cases (examples) with this characteristic are known to the authors of this study.

The first one is the MiG-15 crash in October 1965 when advanced piloting techniques at stratospheric altitudes were trained. For unknown reasons, an engine unit failed in flight. The pilot attempted to restart the engine in flight, but he performed the procedure too quickly and the residual fuel caught fire in the engine discharge nozzle for a short moment. The pilot evaluated the situation as fire and ejected.

The second one is the MiG-21 F crash in April 1979 during a navigation flight under difficult weather conditions during the day at a high altitude. In the course of the flight the pilot experienced an acute nausea and subjectively felt he was no longer capable of maintaining control of the aircraft and thus he ejected. Investigations of the air crash showed that the pilot's ill health was caused by a previous eating error and the situation could be probably resolved with a breathing technique. Such a scenario is easily repeatable and relevant even today.

The third one is the UTI MiG-15 damage in September 1963 during a piloting technique check flight during the day when the instructor was demonstrating a double combat turn to the student pilot. The student pilot lost consciousness due to excessive g-force and while he was regaining consciousness in the final phase of the turn, he subconsciously evaluated the situation as emergency and ejected from the cockpit's front seat. According to the aviation accident investigation report, the student pilot lost consciousness because he had assumed incorrect position for the high-G maneuver and had performed ejection in a sub-vigil state when he was unable to properly perceive or evaluate the situation. This scenario is also easily repeatable and still relevant.

By summarizing the causes of pilots' zero, late, or incorrect responses to emergency situations, the following list of causes emerges:

A. insufficient training,
B. low respect for flying (noncompliance with rules and regulations),
C. fear of reprisal,
D. altruism,
E. unpredictability of psycho-physical responses.

Insufficient training (see cause A above) does not involve only low standard of pilot training, but also inexperience with a given type of emergency situation, etc. Developments in standards, complexity and technical capabilities of equipment available for pilot training make this cause of AAs less relevant than before. Flight simulators play a substantial role in raising preparedness of pilots for in-flight emergencies.

Low respect or noncompliance with rules and regulations (see cause B above) involve failing to adhere to healthy lifestyle or mental hygiene principles (tiredness, fatigue, burnout, etc.), indiscipline, inadequate pre-flight preparation, etc. Unfortunately, this phenomenon is very subjective and still relevant. In general, the level of respect for and approach to the pilot profession changes with age in military fighter pilots. Over time, a fascinated and proud student pilot (aged 20-25) becomes a combatively competitive professional (age 30-35) and then a respectable restrained professional (over 40). Combativeness and readiness for risk-taking recede being superseded by respect and often extensive experience. The analysis of statistics and causes of AAs shows that response time and success rate in resolving in-flight emergency situations increase in pilots with their age and flight hours. The pilot's experience accelerates his response by up to seconds. Also, staff grading has an important effect on pilot performance and rapidity of response. Over the last 30 years, career advancement rate has significantly accelerated due to organizational changes in the army. Formerly, pilots would be appointed to senior positions at around 40 years of age (when their combativeness in a direct action was already on decline); now they are appointed at the age of 33 to 35 when they are in the best physical and mental shape. The more non-flight is the pilot's career bracket, the more impaired is his ability and response in in-flight emergencies. Work on a systematic solution to the problem is still ongoing in the Air Forces of the Czech Armed Forces.

Fear of reprisal (see cause C above) involves fear of disciplinary action in the military unit, social harm, and criminal penalties including material liability. This broad issue has been with the Czechoslovak and Czech military aviation since the end of the Second World War. From 1950s to 1990s, pilot's thorough interrogation was the first step in the AA investigation and if his fault, however minimal, was proven, he would be made an example of. If a criminal act (infringement of military regulations) was established, the pilot would be prosecuted by a military prosecutor's office and sanctioned. There were also cases where the content of pilots' testimonies contradicted the conclusions set out in investigation reports, for example, the MIG-21 MF crash of January 17th, 1979 or the MiG-21 MA crash of April 15th, 1988. Both pilots described the emergency situations as results of technical failures, but officially they were convicted of committing an error. At the time of those events, emergency flight recorders were not at a level that would allow pilots to disprove the allegations or, on the contrary, confirm investigation findings. After the Velvet Revolution (1989), military prosecutor's offices were replaced by public prosecution authorities in 1994 and military investigators of air accidents gradually began to move towards a system of investigation that offered somewhat more protection to the pilots. This process intensified after 1999 when the Czech Republic joined the North Atlantic Treaty Organization (NATO). Personal data of pilots began to disappear from public AA overviews and only AA scenarios and causes started to be discussed publicly. These steps granted at least some anonymity to those involved in AAs and mitigated the psychological impact on them. However, the problem has not yet been fully resolved as public prosecution authorities assess including military cases according to civil law which does not take into account military-specific conditions. Therefore, there are cases of imposing criminal penalties or material liability on members of military who did not commit any error in terms of military regulations or duties. Fear of reprisal, whether rightful or not, is still an issue in the Air Forces of the Czech Armed Forces which has yet to be resolved and is one of the main stress factors for aircraft crew members in emergency situations.

Altruism (see cause D above) or “unselfish love for others” lies in efforts not to cause harm to anybody in a situation that entails harm to other persons (e.g., when there is a risk of aircraft crash in residential area). Late ejections were recorded in several AAs, but not always they ended up as disasters. In former Czechoslovakia and now in the Czech Republic, where the density of the settlement is high, pilots were often having moral dilemmas: “Where to fly the falling aircraft?” or “ When to bail out to make sure I will not hit people’s homes?” Often the thought that occurred to pilots parachuting down after ejecting was “For God’s sake, I hope it won’t hit and kill anyone!” This first thought was frequent in pilots who ejected at night or under difficult weather conditions when they could not see the earth. Again, this issue remains highly topical today.

Unpredictability of psycho-physiological responses (see cause E above) is based on the ability of the human body, under certain conditions, to respond subconsciously or involuntarily to specific stimuli from the environment. On a physiological level, there are individual responses of the body to pressure and gravity changes. On a psychological level, stress and burn-out syndrome play important roles. This, too, is part of human factor, still under-researched and difficult to measure.

In sum, at least four out of five causes as defined above are still relevant and topical and are sure to be of interest in the field of air safety in the future.

4. Conclusion

Despite technical advancements in military aviation, ejection remains the last resort for aircrew to save their lives in emergency situations. The analyses of statistics and causes of AAs associated with ejections clearly show that ejection is not, by any means, a phenomenon of the past. Even in present days, pilots must be ready to make use of the ejection while taking into account all specific circumstances and consequences that go along with that.

Let us try to answer the three key questions made in the introduction of the study (see Section 1 above).

The factors of the main cause of AAs associated with ejections were, for the most part, “HF-fp (41.1 % of all AAs)” and “TF” (31.6 % of all AAs). “HF-np” (10 % of all AAs) and “EF“(1 % of all AAs) played minor role in the occurrence of the events. Relatively high percentage of the AA causes was never explained (16.3 % of all AAs). Among specific causes linked to “HF-fp”, “piloting” (22.4 % of all AAs), “noncompliance” (6.2 % of all AAs) and “in-flight personnel” (4.3 % of all AAs) predominate (see Sections 2 and 3 for detailed specifications). Among specific causes linked to “TF”, “operational degradation” (19.7 % of all AAs) and “design and manufacturing defects (10.5 % of all AAs) prevailed (see Sections 2 and 3 for detailed specifications).

In many cases, weather conditions and flight stage played a key role in making decision on how to address the emergency situation; nevertheless, the large majority of AAs associated with ejections occurred under “NWCD” (70.4 % of all AAs). Other weather conditions were represented to a lesser extent: “DWCD” (14.8 % of all AAs), “NWCN” (8.1 % of all AAs) and “DWCN” (6.7 % of all AAs). Regarding the flight stage, the emergency situation occurred most frequently during “flight task” (61.8 %

of all AAs), followed by “approach maneuvering” (15.3 % of all AAs), “climb” (12.9 % of all AAs), “arrival” (8.1 % of all AAs), “take-off” (1.4 % of all AAs) and “landing” (0.5 % of all AAs). The crew consisted mainly of pilots of skill class 1 (56.7 % of all crew members) and pilots with no skill class (15.7 % of all crew members). The average age of all ejected crew members was 31.

It is very difficult to decide whether some AA scenarios may be of timeless character. It cannot be said that some AAs could never repeat in a given way. Of course, they could, but with much less probability than in the past. With improved maintenance systems, technical inspections and aircraft operation, the probability of occurrence of technical failures in flight has dramatically decreased. Better weather monitoring forecasting systems help to significantly reduce the likelihood of being confronted in flight with unexpected weather conditions. Only confrontations with atmospheric anomalies (such as lightning) or collisions with animals (mostly birds) remain unpredictable. The highest risks are, however, still associated with a human factor. In principle, the performance of flight crews cannot be objectively quantified and therefore measured. There are methods that can estimate, but not guarantee, the human factor’s potential. There are also rules of conduct that can increase or decrease the probability of human factor performance, but never guarantee it. Response to stress remains an unmeasurable individual issue in all persons. The only thing that is ever improving in terms of human factor is the system and quality of flight training. Other important factors that have a great influence on rapidity and quality of emergency response, such as emotions, fear, altruism, character, or life habits cannot be controlled in aircraft crew members.

However, there are situations that can be prepared for mentally by awareness, as well as there are sources of stress for pilots that can be eliminated overtime, thus eliminating the likelihood of their negative effects.

To summarize the greatest possible amount of the most important findings and experiences with the causes of ejections for future prevention of AAs is the main objective of this study.

The authors would like to thank all ejected crew members who were willing to speak and share their often very specific experience with ejections. Their perspective with the hindsight, as well as details in description of emergency situations, often open up the possibility to fill out the gaps in AA investigation reports and understand the context of the events. These experiences are invaluable for the safety of flying of future generations of pilots.

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