DCIEM NO 98-TM-06

A Review of Push-pull Effect in Canadian Forces Aircraft Accidents: 1976 - 1995

EXECUTIVE SUMMARY

1. Push-pull effect has been defined as decreased +Gz tolerance resulting from preceding relative -Gz. It has been identified in laboratory and in-flight studies, but little is known about the operational incidence of push-pull effect within the Canadian Forces (CF). In order to enhance our knowledge, a review of CF Boards Of Inquiry (BOIs), Aircraft Accident Incident Reports (AAIR) and Flight Safety Summary Investigations (FSII) was initiated to determine if push-pull effect was causal in any previous aircraft accidents.

2. A total of 284 CF jet and trainer accidents were reviewed of which 95 were "A" category. Eighteen were selected for detailed review (all "A" category), from which five accidents were identified as involving, or possibly involving, push-pull effect. The results of this study suggest that that push-pull effect was a probable or possible cause factor in at least five CF aircraft accidents and two CF aircraft incidents over 20 years from 1976 to 1996. Research into methods to protect against the push-pull effect is continuing at DCIEM. This report is being circulated in accordance with a recommendation from the accident that occurred in July 1995 in Cold Lake, which was to promote education of the CF Fighter community on the hazards and insidious nature of the push-pull effect. The results of this study should be made widely available in order to continue that effort.

Background

3. The existence and potential importance of a phenomenon in which G tolerance is reduced by a period of relative negative G_z (defined as less than one G_z) followed by positive G_z was recognized many years ago (Referred to hence as push-pull effect) (Ref A). Little is known however, about the historical incidence of push-pull effect within the CF. Study in this area began in earnest recently (Ref B,E and F) and the issue has recently gained prominence within the Canadian Forces (CF), partially because of an accident in 1995. Indications are that there is widespread interest in many other countries.

4. A review of CF Boards Of Inquiry (BOIs) was requested (Ref C) to determine if push-pull effect was causal in any previous aircraft accidents. Understanding the mechanism of push-pull effect and developing protection strategies are separate issues

being addressed by DCIEM in an extensive research program and are not within the scope of this study.

Objective

5. The main objective of this investigation was to determine if push-pull effect may have been a contributing factor in CF high performance and trainer aircraft accidents since 1976. A secondary objective was to compile available pilot's physiological and flying time data from these accidents.

Method

6. BOIs from as far back as 1976 were reviewed. BOIs prior to 1976 were not studied due to a limited availability of information and wider variance in the content contained in the BOIs. Only jet and trainer aircraft BOIs were examined. Helicopter accidents were not studied due to the limited flight envelope and transport aircraft accidents were not studied due to the nature of the flying operation. A total of 284 CF jet and trainer accident BOIs were reviewed of which 95 were "A" category, meaning the aircraft was a write off and/or there were serious or fatal injuries. Aircraft types included the CF100 Canuck (limited number), CF101 VooDoo, CF104 Starfighter, CF116 Freedom Fighter, CF188 Hornet, CT124 Musketeer, CT114 Tutor, and CT133 Silver Star (T-Bird). The main areas of interest were pilot incapacitation and flight profile (particularly G-time history). Special attention was paid to accidents for which cause factors were undetermined. In addition, available physiological and flying time data for those accidents that may have involved push-pull was compiled.

7. The accident summary and several of the first witness testimonies of each BOI were read initially, and any accident considered to be potentially influenced by the push-pull effect were then reviewed more thoroughly.

Results and Discussion

8. Of the 284 BOIs reviewed, eighteen were selected for detailed review (all "A" category), from which five accidents were identified as involving, or possibly involving, push-pull effect. Although CF aircraft incidents were not an explicit part of this study, two incidents that likely involved push pull effect were identified; one was discussed in an accident BOI, and another occurred during the course of this study. Table 1 shows applicable information for the five accidents and two incidents. BOIs are not generally available for review, however narratives for the accidents and incidents are included at Annex A. The method and procedures for preparation are contained in Reference D. Three other BOIs in which push pull effect could not be ruled out are excluded from the results. Although each one may have involved pilot incapacitation, the

available evidence was insufficient to identify the probable cause and/or to support a period of relative negative G_z prior to the accident.

9. All cases included the main factors indicating push-pull effect was involved. Each had the potential for pilot incapacitation, a period of relative negative G_z and a subsequent positive G_z manouever. For incapacitation, the cases can be summarized as follows:

i). Three of the cases involved a probable GLOC.

ii). Three more involved a possible GLOC.

iii). The final case remained undetermined; however, the flight profile was consistent with a push-pull profile, which incapacitated the pilot.

The negative flight profiles flown were initiated by flying a bunting profile in two cases, by an unloaded barrel roll in two cases, by a descent head-on to a target in two cases, and with a jink-out followed by an extension in one case. The positive flight profiles flown were initiated by a slicing manouever in four cases, by a pullout after a dive in two cases, and with a level turn in one case.

Table 1: Information of Accidents and Incidents Involving Push - Pull Effect as a Factor

Aircraft #	Probable Cause	Occurrence of Incapacitation	Flight Profile (manouever)	G Time History
CT114138 Accident Non Fatal	Disorientation	Possible *	Push-over to gain airspeed Turning pull out	-1 G_z bunt High + G_z (> +5) Rapid Onset (RO)
CF104649 Accident Fatal x2	Undetermined	Unknown A/C entered steep descent. Attempted pull-up was unsuccessful	Jink-out Extension Slice-back	-2 G_z <1 G_z approx +4 G_z
CF116726 Incident No Injury	GLOC	Yes	Unloaded Barrel Roll Nose -down high G_z slice	0.5 G_z bunt + 6 - 7 G_z RO
CF116735 Accident Fatal	Undetermined Possible GLOC	Likely Steep descent impacted near vertical at Mach	Probable unloaded Barrel Roll Nose- down slice	>1 G_z High + G_z RO
CF104744 Accident Fatal	Undetermined Possible GLOC	Likely Steep descent impacted near vertical at Mach	Level 210 ° turn at approx 4.8 G_z	Possible <1 G_z Sustained +4.8 G_z
CF188714 Accident Fatal	GLOC	Likely Steep descent impacted near vertical at Mach	Descent head-on to target +5.5 G_z slice	10 s <1 G_z +5.5 G_z for 6s RO
CF188707 Incident No Injury	GLOC	Yes	30 ° Nose-down dive to rocket delivery +5.5 G_z pullout	10 Sec <1 G_z +5.5 G_z for 6s RO

*The instructor pilot could not recall having GLOC'd but was disoriented prior to ejection. Disorientation is a common phenomena after a GLOC episode and the student pilot in this case did suffer a GLOC during the manouever flown.

10. Table 2 shows six types of available data collected for the pilots, for information purposes. Such parameters may influence push-pull effect, but the data is insufficient to support trends or draw conclusions.

Table 2: Pilot Experience and Physiological Data

Aircraft #	Crew Position	Age	Height (Cm)	Weight (Kg)	Total Flying Time (Hours)	Total Flying Time on Type (Hrs)
CT114138	Instructor Pilot	23	178	68	610	500
CT114138	Student Pilot	24	178	72	80	55
CF104649	Instructor Pilot	30	188	79	2650	1155
CF104649	Student Pilot	28	180	74	1808	46
CF116735	Solo Pilot	28	172	63	513	281
CF104744	Solo Pilot	24	170	73	953	580
CF188714	Solo Pilot	30	194	110	742	191
CF116726	Solo Pilot	30	176	90	2130	325
CF188707	Solo Pilot	27	178	75	1070	162

Conclusion

11. The results of this study present evidence that push-pull effect was a probable or possible cause factor in at least five CF aircraft accidents and two CF aircraft incidents over 20 years from 1976 to 1996. This indicates the potential operational relevance of the push-pull effect and stresses the need for continued research into better protection from the Life Support Equipment available to aircrew. Continued education of aircrew leading to an increased awareness of the potential hazards of the push-pull effect in relation to G time history is essential. Also, the information included in this study may support other, more extensive studies regarding parameters that influence the push-pull effect.

References: A. von Beckh HJ. Human Reactions During Flight to Acceleration Preceded by or Followed by Weightlessness, Aerospace Medicine June 1959; 30:391-409

B. Banks RD, Grissett JD, Turnipseed GT, Saunders PL, Rupert AH. The Push-Pull Effect, Aviation, Space & Environmental Medicine 1994; 65:699-704.

C. Tasking Directive - Push-Pull Effect Review, Head/Aviation Life Support Sector May 1996. DCIEM.

D. A-GA-135-001/AA-002 Aircraft Accident Investigation Report. Canadian Forces Publication.

E. Banks RD and Goodman, LS. Neurological Influence in Push-Pull Effect. (in) Neurological limitations of aircraft operations: Human performance implications. AGARD Conference Proceedings CP 579, April 1996, 1-1N 1-10.

F. Davidson RA, Beevis D, Buick F, Donati ALM, Kantor L, Bannister SHR, Brook EA, Rochefort JAP, Turner JR. Human Factors in the CF-18 Pilot Environment,Toronto: Defence and Civil Institure of Environmental Medicine 1991; DCIEM Report No 91-11.

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Annex A - Narratives to CF Accidents/Incidents Involving Push-Pull Effect From 1976-1995

September 1976- CT114138 - On recovery from Slow Flying the instructor pilot took control of the aircraft and initiated a smooth push over (-1 G_z bunt, time unknown) to set up for a vertical eight manouever. Airspeed increased faster than anticipated and the pilot began a pull out and gradually applied some G_z. Speed brakes were selected and G_z rapidly built up until student GLOC'd. Pilot recalls continuing to attempt to recover with no effect. As the aircraft passed through 5-7000' pilot ordered ejection, about the time student recovered from GLOC. Both pilots ejected safely. Witnesses on the ground stated the ejections occurred with wings level in a level attitude. Aircraft trim found in the 100-105 kt range indicating it was probably not trimmed out from the slow flying. It is probable that during attempted pull out the instructor pilot GLOC'd. He was disoriented during recovery and elected to eject from the aircraft.

November 1977 - CF104649 - The accident aircraft was one of two CF104s on an air combat maneuver (ACM) training mission. The student pilot occupied the rear seat of a CF104D, which was the normal procedure for ACM training. After the set-up at 25,000 ft, the student pilot initiated a planned - G_z defensive maneuver, the second of the sortie. As planned, the aircraft executed the -2 G_z jink-out maneuver for several seconds, then extended at relative - G_z for several more seconds. The aircraft then flew a slice-back to about +4 G_z. During that maneuver, the aircraft entered a descent with approximately 135^0 bank and 60^0 nose down pitch. When the aircraft entered cloud at approximately 4000 ft, the dive had decreased to $20\text{-}30^0$ nose down and 45^0 bank. Although a radio call to "knock-it-off" was made as the accident aircraft passed 16,000 ft, there were no radio transmissions heard from the mishap aircraft. On impact the wings were level, pitch attitude was slightly nose up, and speed brakes deployed. Both pilots were killed on impact.

February 1981 - CF116735 - During ACM 2 vs 1, the pilot in #2 Aircraft engaged a bogey at 16000' and 400 kts. Lead then called him off and #2 exited high and left. He was not heard from again and the accident site was located some time later. Standard Operating Procedures for #2 at time of exit was to pull off high and execute an unloaded (less than 1 G_z for a few seconds) barrel roll, then reacquire the fight and rejoin when called by lead. This would have required a high G_z loading as the bogey had initiated a high (+6 G_z) turn. Evidence presented to the BOI indicated that #2 was doing that. He was attempting to re-engage after losing visual with the formation (based on a previous radio call from 2). The aircraft had crashed at high speed in a near vertical descent.

Anecdotal note: Just prior to impact, #2 pilot was heard to transmit 3-5 seconds of " heavy breathing" stated by lead as " breathing at a regular beat, not excessive, as if he knew he had a problem and he was trying to work it out." It is possible that this

was the early stages of a recovery from GLOC, and is consistent with observed reactions in the DCIEM centrifuge.

May 1983 - CF104744 - During a air-to-air gunnery mission the incident pilot accomplished a head on pass to engage a target dart being towed by a CT133. Set up was at 2-3000' above the tow aircraft and after the pass the pilot initiated a slicing nose down turn with an estimated 4.8 g in afterburner. The IP in the back seat of the CT133 observed the aircraft at approximately 10-20 deg nose down with 110 deg bank. After about 10 sec, the aircraft was observed to ease off the turn rate (relax the G_z) and steepen descent to >70 deg. No recovery was attempted and afterburner remained on until ground impact.

Note: Although a period of relative neg G_z could not be confirmed, it is consistent with this type of manouever that during the set up the pilot was at <1 G_z to maintain visual with the dart.

5 - July 1995 - CF 188714 - This accident occurred during an ACM mission at Cold Lake. The accident pilot experienced relative negative G_z for approximately 8 seconds during a head-on pass with the second aircraft. He then commenced a nose-down slicing manouever prior to G_z loading to a plateau of +5.6. After about 5 sec, the pilot began to ease off the turn rate (relax the G_z), continue the roll and increased the angle of descent to >70 deg. The pilot initiated a recovery attempt at extremely low altitude with insufficient time to pull out. The aircraft impacted the ground at Mach. The pilot did not attempt to eject and was killed.

In addition to these accidents, there are also at least two incidents of note.

1976 - CF116726 - This incident was discovered from Case #3 (it was included in the BOI) and occurred on a CF5 aircraft that was engaging a towed dart. The pilot had bunted for a short period of time to visually acquire the dart and then commenced an aggressive high G_z turn to engage it. During the turn, he GLOC'd (at around +7 G_z) and when he regained consciousness, the aircraft was nose down at high speed towards the ground. The pilot overstressed the aircraft on recovery and minimum pullout altitude was estimated at 200 feet.

July 1996 - CF188707 - This incident involved a CF188 on an air to ground delivery. During the dive the pilot experienced 10 - 15 seconds of <1 G_z followed by an aggressive +5.5 G_z recovery. After approximately 5 sec, the G_z was relaxed when the pilot apparently GLOC'd. He recovered and returned to base.

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