

# INVESTIGATION OF AIRCREW NOISE EXPOSURE ONBOARD THE NRC DASSAULT FALCON AIRCRAFT THROUGH FLIGHT TESTING

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## 1 Introduction

The NRC Dassault Falcon 20 is a small business jet powered by two General Electric CF700 jet engines. The Falcon serves the Flight Research Laboratory at NRC as a customizable research facility and is shown in Figure 1. Research operations such as micro-gravity parabolas, environmental measurements and aerial photography produce a variety of unique flight conditions in addition to the standard steady level flight completed by most commercial and business jets. Additionally, the NRC Falcon has a significant quantity of furnishings, cushions and aesthetic fixtures removed for research purposes. Unique flight profiles in combination with a modified aircraft interior produces a distinct noise environment compared to the original configuration. The evaluation of these noise levels is essential for the determination of aircrew noise exposure and the selection of optimal hearing protection.



Figure 1: NRC Dassault Falcon 20; Small Business Jet

## 2 Flight Test Procedure and Equipment

The objective of this flight measurement was to measure the interior cabin and cockpit noise levels throughout the standard flight conditions of the NRC Falcon 20 aircraft. The NRC Falcon was outfitted with 6 microphones at representative aircrew and pilot locations to measure the aircraft interior sound pressure levels.

### 2.1 Microphone Mounting

In accordance with ISO 5129 [1], the microphones were affixed with custom designed mounts and were located within the aircraft cabin as shown in Figure 2. Mic 1 through Mic 4 were positioned at unoccupied cabin seat locations. Mic 5 and Mic 6 were positioned 0.1 m from the ear position of the pilot and co-pilot; the mounting methods are shown in Figure 3.

The aircraft interior sound pressure levels were

measured using an NRC custom data acquisition system incorporating a certified portable Data Recording System MSSR-2010-SAR-2 made by Teletronics Technology Corporation as well as PCB Piezotronics microphones: 378B02 ICP. Post processing was completed in LMS Test.LAB and MATLAB software packages.



Figure 3: Unoccupied Seat (left) and Pilot Ear (right) Mounting Configurations

### 2.2 Flight Test Procedure

The flight measurement profile was selected to be representative of a typical NRC Falcon microgravity research flight. The measurement flight included: taxi, take-off, climb, steady level flight, acceleration, deceleration, microgravity parabolas and landing flight conditions. Each measurement condition targeted 60 seconds of steady-state flight for data acquisition. However, some flight conditions are inherently transient (parabolas, take-off etc).

Throughout the flight measurement a maximum indicated airspeed of 350 knots (414 knots ground speed), a maximum altitude of 17,210 ft and a maximum engine pressure ratio of 1.59 were recorded.

## 3 Results

The aircraft interior sound pressure levels were analyzed in narrow band and 3<sup>rd</sup> octave bands for each microphone location at each flight condition. The A-weighted Sound Pressure Levels (SPL) were analyzed in accordance with ISO 9612 [2], CSA Z107.56-06 [3] and the Canadian Aviation Occupational Health and Safety Regulations (OHSR) [4].

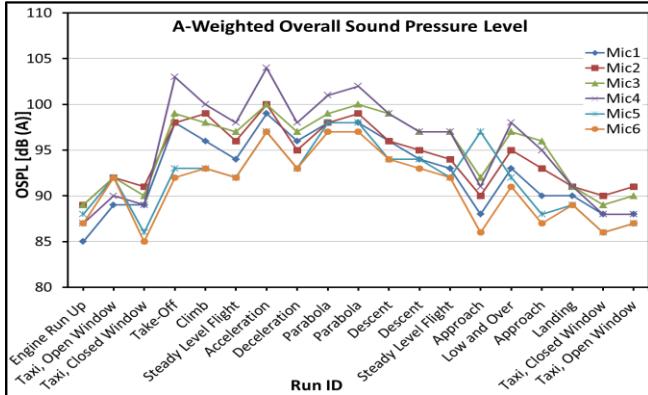
### 3.1 Overall Sound Pressure Levels

The A-weighted overall SPL are shown in Figure 4. It can be seen that the Take-Off, Acceleration and Parabola



Figure 2: Microphone Locations

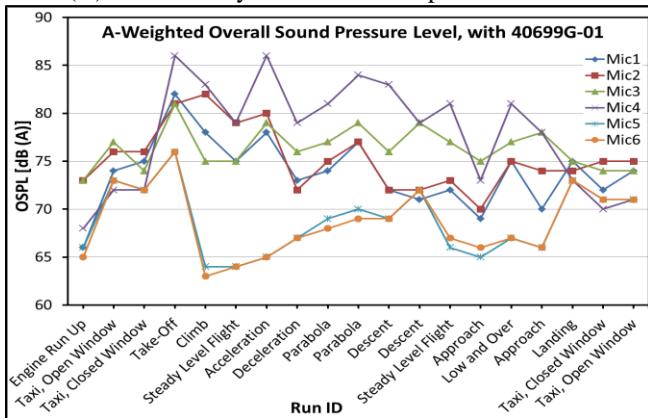
flight conditions exhibited higher SPL compared to the remaining flight conditions. The highest overall SPL was measured at the rear starboard side cabin seat (Mic 4) at 104 dB(A) during the acceleration to 300 KIAS flight condition; in accordance with the Canadian Aviation OHSR, a worker will reach their maximum noise exposure dose in 9.6 minutes when exposed to 104 dB(A) cumulatively for one 24 hour period.



**Figure 4: A-Weighted Overall Sound Pressure Levels for Individual Flight Conditions**

Various David Clark headset models are used in the NRC Falcon 20 aircraft. Among them is the 40699G-01 which was selected to calculate the aircrew hearing protected cumulative maximum noise exposure dose. Insertion loss data of the David Clark 40699G-01 headset was measured in the NRC hearing protection evaluation facility [5]. The A-weighted overall SPL for aircrew protected with the 40699G-01 headset is shown in Figure 5.

The highest overall SPL were measured at the rear starboard cabin seat (Mic 4) with 86 dB(A) for the Take-Off and Acceleration flight conditions. In accordance with the Canadian Aviation OHSR, a worker will reach the maximum noise exposure dose in 10 hours when exposed to 86 dB(A) cumulatively for one 24 hour period.



**Figure 5: A-Weighted Overall Sound Pressure Levels while Protected with the David Clark 40699G-01 Headset**

### 3.2 Example Flight Profile

To calculate the expected maximum noise exposure dose aircrew would experience when participating in a standard microgravity research flight, an example flight profile was developed as shown in Table 1.

**Table 1: Example Flight Profile: Schedule**

#	Condition	$\Delta t$	#	Condition	$\Delta t$
1	Engine Start	10	6	Parabolas	30
2	Taxi	5	7	SLF	15
3	Take-Off	1	8	Descent	5
4	Climb	5	9	Landing	1
5	SLF	10	10	Taxi	5

\*SLF = Steady Level Flight,  $\Delta t$  is the condition duration in minutes

The Canadian Aviation OHSR cumulative maximum noise exposure dose was calculated using the Octave Band Procedure as outlined in CSA Z94.2-14 [6]; the results are shown in Table 2.

**Table 2: Cumulative Maximum Noise Exposure Dose**

Dose	Mic1	Mic2	Mic3	Mic4	Mic5	Mic6
<b>Without HP</b>	131%	161%	200%	281%	111%	94%
<b>With HP</b>	1%	2%	1%	4%	0%	0%

\*HP = Hearing Protection

It is likely that the aircrew and flight crew will reach and exceed the maximum noise exposure dose within one flight if not equipped with hearing protection; while equipped with a properly fitted David Clark 40699G-01 headset, they will not have operational limitations due to noise exposure. Such high levels of cabin noise are attributed to the significant modifications of the NRC Falcon cabin including the removal of seat cushions, carpet and other sound absorbing trims. Moreover, the inclusion of research equipment racks provides additional sound sources and reflective surfaces to increase the noise level.

## 4 Conclusions

The NRC Dassault Falcon 20 aircraft cabin interior exhibited the highest overall sound pressure levels at the rear starboard side cabin location near the engines for the majority of the flight conditions. The high power engine conditions such as the take-off and acceleration conditions exhibited the highest overall sound pressure levels.

Hearing unprotected aircrew onboard the NRC Falcon aircraft are likely to reach the cumulative maximum noise exposure dose during a standard microgravity research flight. There is no operational duration limit due to noise exposure for aircrew equipped with a properly fitted David Clark 40699G-01 headset (or similar). It is likely that the removal of interior acoustic insulation and the inclusion of additional equipment significantly altered the aircraft cabin noise environment from the original manufacturer's design.

## References

- [1] International Standards Organization, "Acoustics - Measurement of Sound Pressure Levels in the Interior of Aircraft During Flight," Geneva, Switzerland, Standard ISO-5129, 2001.
- [2] International Standards Organization, "Acoustics - Determination of Occupational Noise Exposure," International Organization for Standardization, Switzerland, Standard ISO 9612:2009, 2009.
- [3] Canadian Standards Association, "Measurement of Occupational Noise," Canada, Standard CSA Z107.56-06, 2006.
- [4] "Aviation Occupational Health and Safety Regulations - Part 2: Levels of Sound," 2015. [Online]. <http://laws-lois.justice.gc.ca/PDF/SOR-2011-87.pdf>
- [5] Sebastian Ghinet, "Cabin and Exterior Noise Assessment of the RCAF CH-147F Helicopter Through Flight and Ground Testing," National Research Council, Ottawa, Laboratory Technical Report LTR-FRL-2015-0045, 2015.
- [6] Canadian Standards Association, "Hearing Protection Devices - Performance, selection, care, and use," CSA, Toronto, Ontario, Canada, Standard Z94.2-14, December 2014.