FLIGHT TEST INSTRUMENTATION OF THE PUSH-PULL EFFECT ON A CF-18 AIRCRAFT

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ABSTRACT

During high performance fighter aircraft manoeuvres, a fighter pilot may be exposed to a physiological phenomenon known as the "Push-Pull Effect" (reference (ref) [1]). This effect will alter the pilot's homeostasis whereas blood flow to the brain will be increased during low negative normal acceleration (-Gz) and suddenly decreased during positive normal acceleration (+Gz). It has been hypothesized that this effect can lessen the G-tolerance of the human body thereby making the subject more susceptible to G induced Loss of Consciousness (G-LOC) (refs [2], [3] and [4]). G-LOC is not a desirable state for a pilot in a high performance aircraft such as a CF-18.

To better understand and study the Push-Pull Effect on a fighter pilot, the Aerospace Engineering Test Establishment (AETE) and the Defence and Civil Institute of Environmental Medicine (DCIEM) produced an In-Flight Research (IFR) Program sponsored by the Canadian Forces (CF). The aim of this program was to measure the physiological response of relaxed test subjects, unprotected by a G-suit, when exposed to the Push-Pull manoeuvre in flight. This IFR would validate the centrifuge data and confirm that the Push-Pull Effect can occur in flight. This paper will present the instrumentation, design, telemetry system and installation methodology utilized to perform experimental physiological research on a high performance, ejection seat equipped fighter aircraft (CF-18). Also, preliminary results on the Push-Pull Effect, obtained through this IFR Program will be presented.

KEY WORDS

Flight Test Instrumentation, Push-Pull Effect, G-LOC and Airborne Telemetry.

INTRODUCTION

Push-Pull Effect Description: A fighter pilot is often exposed to +Gz which is highly counteracted by the utilization of a G-suit. During aerial combat manoeuvres, to gain kinetic energy i.e. airspeed, a fighter pilot will transition to very low normal acceleration (Gz), sometimes going to a low -Gz. Once airspeed has been gained, the pilot will pull high +Gz to continue with the flight. This last type of combat manoeuvre is known as "Push-Pull" since the pilot pushes and then pulls on the control stick. It has been found that such a manoeuvre may be the cause of certain aircraft crashes (ref [5]) due to the decrease in head level blood pressure, leading to G-LOC.

Push-Pull Effect Testing: Various centrifuge and simulator experiments (ref [6]) have been conducted through the years to study the effect of +Gz and even -Gz but the presence of lateral and longitudinal accelerations (Gx and Gy) from these systems have raised some concerns about the validity of the data. Therefore to fully study this effect, DCIEM proposed, in 1996, a collaborative investigation with AETE to study the Push-Pull Effect during flight. Non-intrusive biomedical measurands were installed on the chest (ElectroCardiogram (ECG)), stomach and legs (ElectroMyogram (EMG)) and head and fingers (Arterial Blood Pressure) of a test subject who was strapped in the back seat of a dual-seat CF-18 aircraft. Also, a visual cue identification and response system was designed and installed in the aircraft. This system was used to monitor tunnelling of vision symptoms during +Gz exposure. A color video camera was mounted in front of the test subject to monitor eye movement and facial expression. The aircraft utilized during this IFR program was a fully instrumented Canadian Forces CF-18 which was modified to allow in-flight acquisition and recording of all the biomedical measurands attached to the test subject. Moreover, the biomedical measurands and color video of the test subject were digitized (2 Megabits/sec (Mbps) Pulse Code Modulated Non-Return-to-Zero Level (PCM NRZ-L)), compressed and telemetered real time (S-Band) to the Flight Test Control Room (FTCR) to analyze the physiological behavior of the test subject as the flight profiles were flown. Throughout this IFR program, over 40 test missions with various flight profiles were performed with 16 test subjects in the spring of 1998.

First, a description of the flight test instrumentation on the CF-18 will be presented followed by the design and concept utilized to implement the biomedical measurands on this fighter aircraft. Afterwards, a general description of the ground and airborne telemetry system will be provided including the utilization of a video compression system. Finally, the flight test technique, profiles and preliminary results of this IFR will be presented.

CF188907 FLIGHT TEST INSTRUMENTATION SYSTEM

Baseline Instrumentation: Two of the 134 CF-18 fighter aircraft, CF188701 and CF188907, bought by the Canadian Air Force in the early 1980's, were delivered by McAir to AETE with a full Flight Test Instrumentation Package installed. In 1996 and 1998, an extensive upgrade of the instrumentation system on CF188701 and CF188907 was performed by AETE's engineers. The upgrade included replacement of all major data acquisition components with state of the art units, installation of new systems such as a Triple Deck Cockpit Video Recording System (TDCVRS), and rewiring of a large portion of the instrumentation system. The baseline instrumentation system, used during this IFR on CF188907, consists of the following major sub-systems:

(1) The TDCVRS, which uses a TEAC V-83AB-F recorder, two sill cameras and a color Head-Up Display (HUD) camera;

(2) A programmable data acquisition system, which uses the Aydin Vector PCU-816 and 808 to signal condition and encode transducer and 1553 MUX BUS signals. The signal conditioning cards in the PCUs allowed the selection of two important parameters. Primo, a pre-sample filter Cut-Off frequency (fc) using a DC coupled, unity gain, 6-pole active Butterworth Low Pass Filter (LPF) was selected by the user by plugging in a resistor network for each channel. Finally, the Sampling Frequency (fs) and filtering were selected to be able to bandlimit the signal waveform of interest, retain all of its significant features and minimize aliasing;

(3) The Primary Data Recording System (PDRS) uses the Merlin ME-981 Encoder for Pulse Code Modulation (PCM) to Video Formatting and recording is performed via the TEAC V-80AB-F HI –8 Recorder. Also, at this moment, AETE is testing the Operational Test Instrumentation System (*Otis*) which uses solid state data recording capability therefore moving away from tape recording. Another characteristic of *Otis* is the utilization of the Global Positioning System (GPS) and the aircraft's Inertial Navigation Set (INS) for Time, Space and Position Information (TSPI).

(4) The Secondary Data Recording System (SDRS) is the MARS 2000 Modular Airborne Recording System which can directly record up to 14 channels for PCM and/or analog signals on 10.5 inch reels of tape;

(5) Time Code Generator (TCG) system uses the DATUM 9150 TCG and allows for time correlation of all data streams being recorded and telemetered;

(6) The Telemetry (TM) system, uses a Loral Conic Video Compression System (VCS) 600A and two Lockheed Martin Conic CTS-905 S-Band (2362 MHz and 2372 MHz) transmitters to provide a real-time transmission of video and measurand data to the

Flight Test Control Room (FTCR) at AETE. The TM System will be described in more detail below; and

(7) Transducer installations which include accelerometers, wing strain gauges, aileron motion sensors and fuel quantity sensors.

Figure 1 shows the emplacement of the above components on the aircraft. One of the most important baseline measurands that had to be gathered during the IFR Push-Pull testing was the acceleration of the aircraft. The intent was to measure, as closely as possible, the G on the subject in the backseat. All three axes (Gx, Gy and Gz) were measured for completeness of the data and to verify the exact G vector to which the subject was exposed. On the test aircraft, CF188907, there are three sources that can provide the normal, longitudinal and /or lateral acceleration (Gz, Gx and Gy respectively). An accelerometer located near the Centre of Gravity (C of G), panel 42L on the aircraft provides normal acceleration. This transducer is located 160.5 inches aft of the rear seat (longitudinal axis). It was installed and calibrated by AETE. Normal acceleration (Gz) and the lateral acceleration (Gx) can also be obtained from a linear accelerometer located next to the Flight Control Computer A (FCCA) on CF188907. These measurands are captured from the 1553 MUX BUS using the PCU-816, recorded in the aircraft and telemetered to the FTCR as discussed below. This accelerometer, installed by McAir, provides information to the FCCA and is installed 19.0 inches (longitudinal axis) ahead of the test subject's seat. Finally, the INS provides Gz , Gx and Gy measurands. These measurands are retrieved from the 1553 MUX BUS by the PCU-816, recorded in the aircraft and telemetered to the FTCR as discussed below. The INS is located 1.12 inches (longitudinal axis) ahead of the test subject's seat.

Biomedical Instrumentation: To study the effect of Gz on the human body, the following parameters were measured during this IFR (refer to figures 1 and 2 to have an idea of the location of these measurands in the aircraft and on the test subject):

(1) **Arterial Blood Pressure (BP) - Head and Heart:** Blood pressure indicates the ability of the blood to circulate in the test subject's body against G force gradients. To adequately measure the heart and head blood pressures of the test subject sitting in the back of the aircraft, a **port**able instrument to monitor finger **a**rterial **pres**sure was utilized (PORTAPRES). This unit provides an indirect and non-invasive measurement of blood pressure in a finger using a photoplethysmograph technique (refer to [7]). Therefore like the larger bicep's version, blood pressure can be measured by using miniature finger cuffs, that fit on the end of the finger, which must be inflated and maintained at a constant pressure. To measure the heart and head blood pressure using the PORTAPRES unit, a finger cuff including a pressure transducer is placed at the measured finger and the compliant ending is placed at the reference level. In our case, the reference level was the heart; therefore the end of the pressure transducer was attached under the flying suit of the test subject at the heart level (see figure 2). For the head blood pressure measurements, the reference level sensor was attached to the helmet of the test subject at eye level. The pressure transducer and reference level sensor is a height correction system which compensates for hydrostatic level effects due to arm movement or/and changes in +Gz. To minimize any movements of the tests subject's left hand, where the two finger cuffs were attached, the test subject's hand was immobilized with an AETE designed adjustable 35° arm rest. This mechanism also minimized recording errors and allowed the two finger cuffs to be on the same plane as the heart of the test subject. Finally, two Control Units were located on the right hand side of the test subject, attached to the canopy. The test subject was required to activate a touch pad button, on the Control Units, to re-calibrate this system between different profiles as explained below. The main PORTAPRES Units were mounted on the back canopy deck (see figure 1) and connected to the PCU-808 located in the 4L Instrumentation Bay. The analog outputs of these units were digitized and formatted into a PCM NRZ-L stream to be recorded and telemetered.

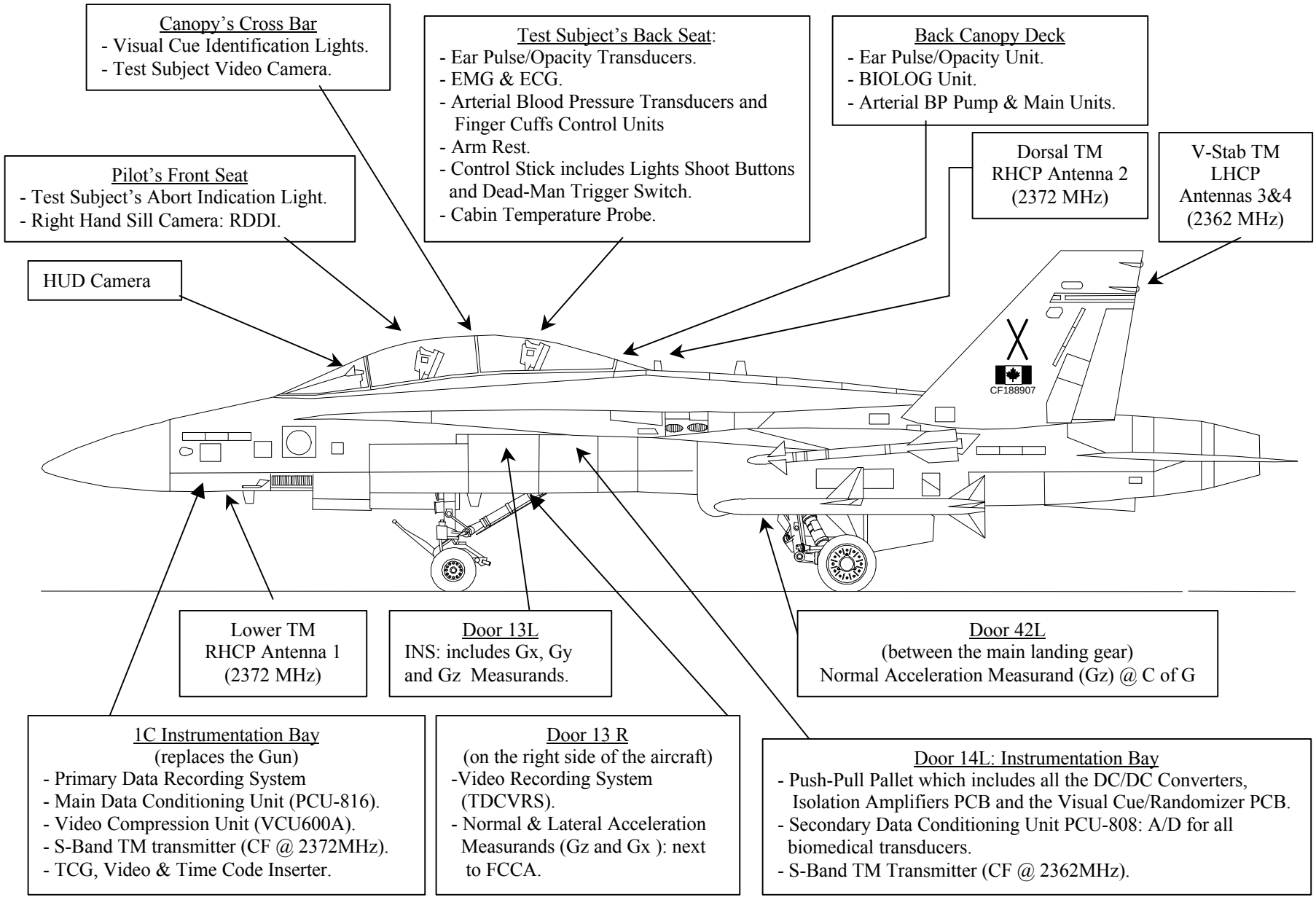

Figure 1 - CF188907 Baseline and Push-Pull Instrumentation Systems

(2) **Ear Pulse/Opacity Transducers**: These non-invasive measurands provided a qualitative indication of the amount of blood (opacity) and the blood pressure (pulse) reaching the head (at eye level) of the test subject during the Push-Pull manoeuvre. They were used in conjunction with the blood pressure measurand mentioned above and therefore helped in the prevention against inadvertent G-LOC of the test subject during flight. These measurands were utilized as the primary indicator of circulatory events leading to possible G-LOC. DCIEM designed the opacity and pulse sensor which included an integrated photodiode having an output varying from 0.1 Volt (V) for dark conditions to 3.5 V for full brightness and an Infra-Red (IR) Light Emitting Diode (LED) with a wavelength of 985 nanometers (nm). Both the photodiode and IR LED were molded in a separate silicon rubber substance and positioned in each side of the upper part of the right and left ear (pinna). Therefore as the amount of blood increased or decreased at the ear, the IR LED would transmit less or more light to the receiving photodiode on the other side of the pinna. The signal was sent to the ear pulse/opacity unit, located on the upper left hand of the test subject in the back cockpit deck, by two cables attached to the helmet of the test subject and ending at a ten (10) pin quick disconnect connector. This connector was configured to facilitate ejection and critical egress clearance. The analog output of this unit was also digitized and formatted into a PCM NRZ-L stream to be recorded and telemetered. Thus, after getting dressed, the test subject had to carry an "umbilical cord" on his left hand that contained the wires for the ear opacity/pulse unit. A major challenge with these transducers was to be able to install them adequately on both ears and afterwards place the combat helmet on the test subject. After installing the transducers and helmet on the test subject, a bench test was performed to quantify the performance of the transducers before directing the test subject to the aircraft.

(3) **ElectroCardiogram (ECG)**: This non-invasive measurand provided information on the changes of electrical potential occurring during the heartbeat of the test subject. It indicated the stability of rate and rhythm of the test subject's heart. To measure the ECG on the test subject, a BIOLOG (ref [8]) unit, which is an ambulatory data logger specifically designed for research involving biological signals and physiological phenomena, was utilized. Three electrodes were directly affixed to the skin of the test subject as described in ref [8]. All the cables attached to the electrodes were connected to a twenty six (26) pin quick disconnect connector. Therefore, the test subject would carry another umbilical cord on the right hand when boarding the aircraft. The umbilical cord would then be connected to the right hand side of the aft cockpit to a mating connector. This last connector would relay all the cables to the BIOLOG unit, located on the back cockpit deck in the right hand side above the right shoulder of the test subject (figures 1 and 2). All the data was then relayed to the PCU-808, PDRS and TM system.

(4) **ElectroMyogram (EMG)**: The EMG measures the electrical signals which accompany activation of any skeletal muscle. Since it was important to have the test subject relaxed, and therefore that no straining manoeuvre be performed, the EMG measurands were able to give us such an indication. Six (6) electrodes were connected to the leg and abdomen of the test subject and attached to the BIOLOG signal conditioning box through the twenty six (26) pin quick disconnect connector mentioned above. The electrodes were placed parallel to the long axis of the muscle fibers on the right leg and abdomen. Again, the analog output data of the BIOLOG was relayed to the PCU-808, PDRS and also telemetered to the ground for real time analysis.

(5) **Visual Cue Identification and Response System**: The visual cue identification system was used to detect and record the tunnelling of the test subject's vision when exposed to Gz. This parameter is another important indicator of Gz tolerance. This measurement of vision serves as an endpoint marker for +Gz tolerance. Three lights (one centre and two peripheral) were placed at approximately eye-level (above the aft instrument panel) facing the test subject in the rear cockpit of the instrumented test aircraft (see figure 1 and 2). The centre red light was situated directly in front of the subject while the peripheral green lights were located at approximately 25º on either side of the centre light (with respect to the test subject). The lights illuminated at random intervals between 1 and 1.5 seconds. Note that the two green lights were connected in parallel and thus illuminated simultaneously. When the test subject observed a light, he/she pressed a button corresponding to the light that illuminated (centre or peripheral). This button, which was activated with his/hers right thumb, was located on a control stick in the rear right hand console panel. Pressing the button extinguished the light and the cycle repeated. If the button was not depressed, the light remained on, and the other light continued to cycle randomly. Also, the subject was required to hold down, with his right index finger , a trigger dead-man's switch on the control stick. Releasing the switch illuminated an Abort Light on the pilot's instrument panel, possibly indicating G-LOC of the test subject. Therefore, this Abort Signal system enabled the pilot to know if the test subject wanted to terminate a test profile or if he/she experienced G-LOC. To generate the pseudo-random signals and control the operation of the centre and peripheral lights, as well as the action taken when the 'extinguish' buttons are pressed, a visual cue/randomizer circuit was designed by AETE. The randomizer circuit was based on a PIC16C84 microcontroller, running on a 4MHz crystal, giving it an instruction cycle time of 1μs. It was located in the 4L Instrumentation Bay as shown in figure 1 and was directly connected to the visual cue identification lights, the control stick and the abort indication light located in the cockpit. The randomizer circuit was also connected to the PCU-808, the PDRS and the TM system. Thus, the FTCR could monitor real time how the test subject was "shooting" the lights or if he/she released the dead man switch.

(6) **Body Core and Cabin Temperature:** An increase of the body temperature promotes vasodilatation which, in turn, can lower blood pressure in the test subject, and therefore, Gz tolerance. Thus, the test subject's oral temperature was measured twice, just after being strapped in the aircraft and again immediately after unstrapping (post flight). Also, the cabin temperature was monitored using a temperature probe and display unit located in the rear cockpit. The analog output of the unit display was also digitized (PCU-808), recorded (PDRS) and transmitted by telemetry as mentioned below.

Ground and Airborne Telemetry System: AETE's S-Band TM system can be divided in three subsystems:

(1) **Aircraft TM Subsystem**: The test aircraft CF188907, used for this IFR Push-Pull program, is equipped with two Lockheed Martin Conic CTS-905 S-Band transmitters having 2362 MHz and 2372 MHz as centre frequencies. One of the transmitters (2372 MHz) is connected to two TECOM Right Hand Circularly Polarized (RHCP) antennas located on the upper dorsal deck and lower nose of the aircraft (see figure 1). The other transmitter (centre frequency at 2362MHz) is connected to two Left Hand Circularly Polarized (LHCP) antennas located on the Vertical Stabilizers (V-Stabs) on CF188907 as shown in figure 1. Therefore this aircraft is equipped with frequency, spatial and polarization diversity for better tracking and reception. Also a Loral Conic Video Compression Unit 600A (VCU-600A) is installed in the aircraft. The VCU-600A encodes analog video (from the SILL and HUD cameras for example) and digital data (measurands from the PCU-816) in a single PCM NRZ-L signal, which is transmitted to the ground. During this IFR, a color camera was mounted in front of the test subject to monitor eye movement and facial expression for any sign of G-LOC. This camera was connected to the VCU-600A as well as a 500 kilobits/sec (kbps) biomedical and baseline instrumentation PCM NRZ-L signal encoded by the PCU-816. The overall output data rate of the VCU-600A fed to the transmitters was 2 Mbps providing a real time video image of the test subject's face and measurand data to the ground TM station. The PCM format for the biomedical and baseline measurands had the following characteristics: 1 Major Frame, 9 minor frames/ major frame, 225 words/ minor frame and 12 bits/word. Thus with a data rate of 500 kbps, the Minor Frame Rate (MiFR) and Major Frame Rate (MaFR) were respectively equal to 189.19 minor frames/sec and 20.58 major frames/sec. Over 67 measurands were part of the PCM format ranging from SubCommutated Data (SubCom) (20.58 samples per seconds (sps) especially for 1553 MUX BUS data) to Super-Commutated Data (SprCom) (rates up to 8333.33 sps for the digitized pilot/test subject voice).

(2) **Primrose Lake Evaluation Range (PLER) TM Subsystem**: The Push-Pull flight test profiles were performed at PLER which is located approximately 60 kilometers (km) north of the FTCR. PLER contains a 10 foot (ft) dish Telemetry Tracking

System (TTS) which tracks the aircraft and acquires the TM transmitted data. The TTS is connected to two receivers (Microdyne 1400-MRA), a Diversity Combiner (Microdyne 3200-PCA) and a Bit Synchronizer (Aydin Vector Model 336A). The output of the Bit Synchronizer is connected to an S-Band transmitter with a centre frequency of 2387 MHz to rebroadcast the TM data to the FTCR therefore providing real time data of the aircraft during its flight at the range.

(3) **FTCR TM Subsystem**: The TM data transmitted from PLER is acquired by a single Microdyne 1400 MRA Receiver in the FTCR. The video output of the receiver is connected to a Bit Synchronizer (Aydin Vector Model 335) to produce a synchronous signal that is fed to a Video Expansion Unit 600A (VEU 600A). The VEU 600A, working in pair with the VCU 600A, decodes the incoming PCM digital data stream back to an analog video signal and a data signal. Therefore it provides an analog video output (connected directly to a monitor) and an NRZ-L data signal (biomedical and aircraft instrumentation data) that is fed to the Loral 500 Decommutation System.

Integration of the Baseline/Biomedical and Telemetry Systems: The most difficult aspect of a medical IFR program such as this one is the integration of all the biomedical equipment in a fighter aircraft such as the CF-18. Three main considerations had to be taken into account during the integration of such instrumentation on the aircraft.

(1) **Electrical Isolation of the Test Subject:** Since the test subject's skin is in direct contact with electrodes and other biomedical sensors, there is a possibility that he/she might be exposed to electrical shock hazards. To reduce the probability of such an event, the circuit design of all the systems integrated together had to isolate the test subject from any conductive path in the aircraft. This was performed by using Isolation Amplifiers (BURR BROWN ISO120SG) and DC/DC Converters (VICOR MI-J00). Both of these systems have isolation characteristics that meet the Canadian Standard Association's (CSA) requirements for Medical Electrical Systems (ref [9]) :

a. The Isolation Amplifiers ISO120SG use a duty cycle modulation-demodulation technique to transmit a signal. The signal of interest is transmitted digitally across a 2 pF differential capacitive barrier. This capacitive barrier allows only a limited amount of leakage current to go through the test subject in case of a malfunction of the system. If we use the voltage and frequency generated by the aircraft generators i.e. V =115 volts AC and f = 400 Hz then, the typical leakage current through this isolation device would be equal to 0.58 uA:

$$I_{leakage} = V/Xc = V \times (2\pi fC)$$
$$= (115\ V) \times (2\pi\ (400Hz)(2 \times 10^{-12} F))$$
$$= 0.58uA$$

where V = aircraft AC voltage, f = aircraft frequency and C = capacitive barrier of the isolation amplifier. This leakage current is less than the 100 uA rms recommended by CSA 22-2 (ref [9]). Nine (9) isolation amplifiers were installed on a Printed Circuit Board (PCB) and were used to separate the biomedical units from the test subject to the PCU therefore eliminating any potential shock hazard coming from the PCU system as shown in figure 2.

b. Five (5) DC/DC Converters were utilized to supply power to all the Biomedical Units (i.e. Biolog, Ear Opacity/Pulse, two (2) Portapres Units and the Isolation Amplifiers PCB). Also a Military Input Attenuator Module provided ElectroMagnetic Interference (EMI) filtering and offered complete input transient, surge and spike protection. Reverse polarity protection and overvoltage lockout provided additional safeguards against potentially damaging line conductions. Finally one of the most important characteristics of these DC/DC converters, is that their input to output isolation characteristics meet CSA's safety standards: DC/DC Converters Isolation = input/output capacitance (C): typical = 50 pF or maximum = 75 pF. Using the voltage and frequency generated by the aircraft generators i.e. V =115 volts AC and f = 400 Hz then

$$I_{leakage} = V/Xc = V \times (2\pi fC) = (115\ V)\times(2\pi\ (400\ Hz)(75\times10^{-12}\ F))$$
$$= 21.7\ uA$$ which is less than 100 uA rms recommended by CSA 22-2 (ref [7]).

Also, it is to be noted that the biomedical equipment, supplied by DCIEM, already incorporated shock hazard protection. Figure 2 shows how the test subject was isolated from any direct/indirect source using the isolation amplifiers and DC/DC converters.

(2) **Egression and/or Ejection of the Test Subject:** All equipment located in the rear cockpit, including biomedical units, measurands attached to the test subject, mounts to support the camera and the visual cue system and the arm rest, was required not to obstruct the egression or ejection of the test subject in case of emergency. Therefore, since some of the biomedical measurands were directly attached to the test subject, unique ejection and egress procedures had to be developed by AETE, practiced (a minimum time-to-egress had to be met) and understood before the test subject could be cleared to fly; and

(3) **ElectroMagnetic Compatibility (EMC) Testing:** Due to the presence of new equipment in the aircraft a thorough EMC test had to be performed on the plane to ensure that a minimum of interference would be caused by its integration.

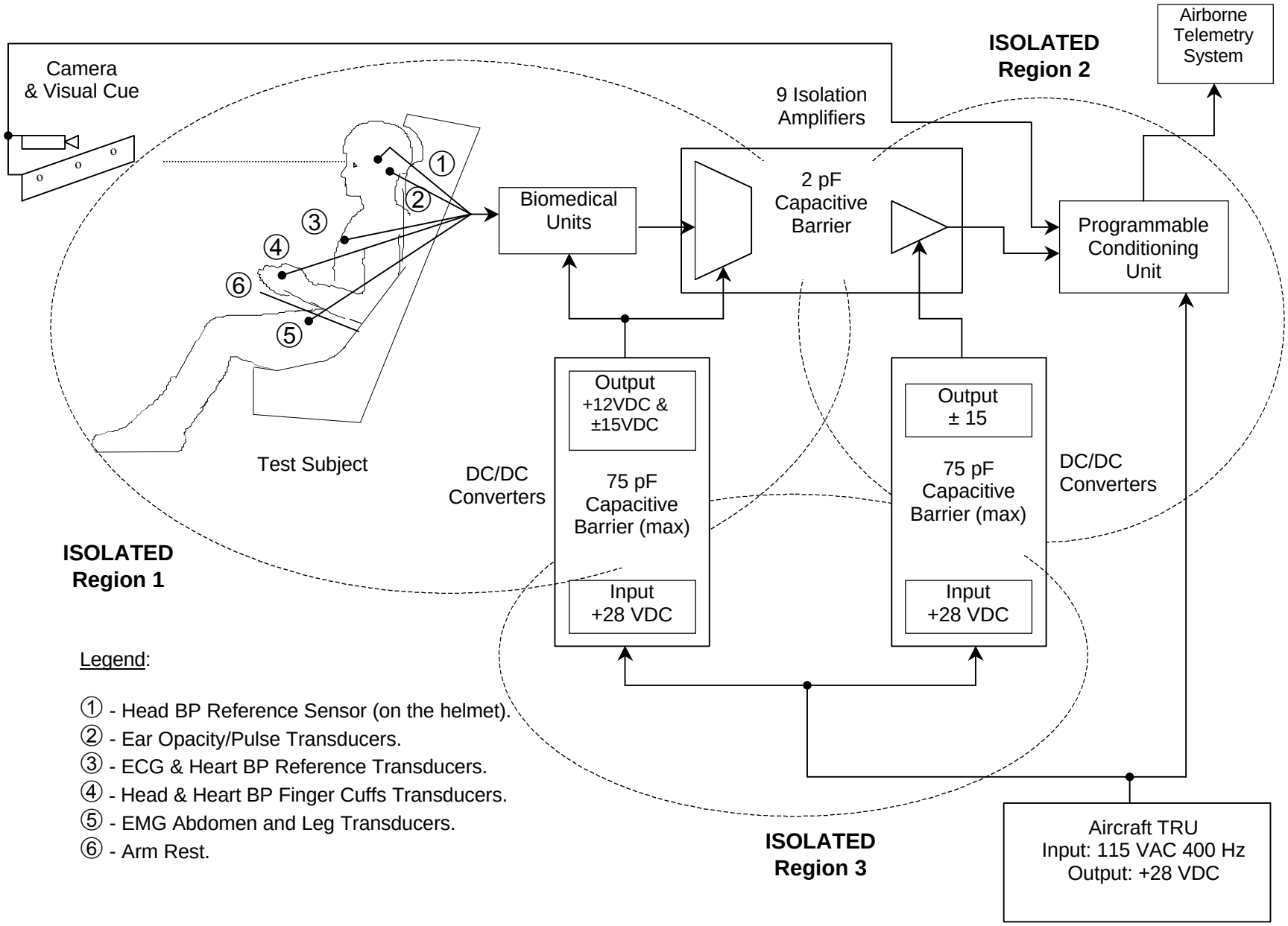

Figure 2 – Isolation of the Push-Pull Test Subject

PUSH-PULL FLIGHT TEST PROFILE & DATA ACQUISITION

Flight Test Profile: To conduct this IFR program, a total of 16 test subjects were used. The test subjects consisted of 5 volunteers from DCIEM (four (4) of which were non-aircrew personnel) and 11 jet aircrew military personnel from the Canadian Forces Base (CFB) Cold Lake. To prepare these test subjects for this IFR, each of them had extensive training on the experimental procedures in the DCIEM human centrifuge in Toronto, Canada. These procedures were based on well-established methods used in acceleration research (ref [10]) and were approved by the DCIEM's Human Ethics Committee (HEC) and AETE's Safety Review Board (SRB). After their training in the human centrifuge, the test subjects were ready to participate in the IFR program. Figure 3 graphically shows the sequence of 3 phases of Gz levels performed during the IFR. The same type of profiles were performed in the centrifuge with the exception of the negative Gz which

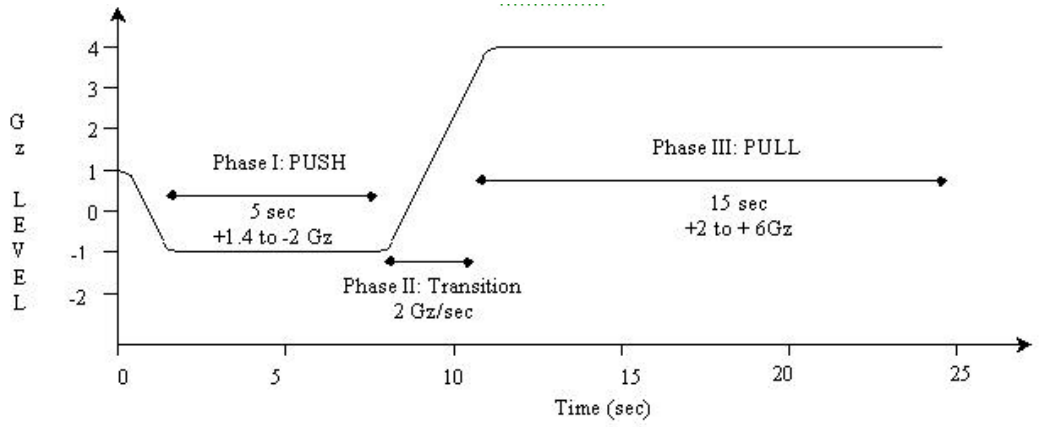

Figure 3 – Push-Pull Typical Test Profile

can not be reproduced in DCIEM's centrifuge. As shown in this figure, Phase I (Push) indicates the profile for the low Gz ranging from +1.4 to –2.0 Gz (in 0.5 Gz steps) after an onset rate of –2 Gz/sec and stabilizing the aircraft at the target Gz level for a maximum 5 sec duration. This maximum 5 sec duration flight is due to the fact that the CF188907 aircraft's negative-G baffles in the feed tanks provides limited fuel supply during -Gz or inverted flight. The second phase, Phase II (Transition), represents the Gz transition period and utilizes approximately a 2 Gz/sec onset rate. Finally, Phase III (Pull), ranged from +2.0 to +6.0 Gz in 0.5 Gz steps and duration lasted approximately 15 sec after stabilizing the aircraft at the target Gz level. During two successive profiles, 1.5 minutes were allowed for the test subject to restore baseline blood pressure status and re-calibrate the blood pressure unit as indicated earlier. Also, this elapse time allowed the pilot and the FTCR personnel to prepare for the next profile. Ref [11] provides more information on the exact aircraft manoeuvre and flight test techniques.

Data Acquisition and Real Time Analysis: The profile flight described above was performed at PLER. As mentioned earlier, all the data including digital video was telemetered real time to the PLER TM station and rebroadcasted real time to the FTCR for analysis. In the FTCR, an AETE Flight Test Engineer (FTE) acting as the mission controller and two (2) DCIEM biomedical research scientists could monitor, using strip-charts, video monitors and LORAL 500 computer displays, the data from the different biomedical measurands attached to the test subject and see the facial expression of the test subject as the Push-Pull manoeuvre was performed. Therefore the DCIEM scientists could abort a profile if they felt that the test subject was going to G-LOC. After each profile, the subjects assessed their most severe visual effects from Gz exposure using the 6 category rating: Clear, Slightly Dim, Dim, Slightly Grey, Grey or Very Grey (refer to [12]).

PUSH-PULL IFR's PRELIMINARY RESULTS

Each test subject performed different test flight profiles, varying the Gz levels during phases I and III (see figure 3). A history of each test subject was plotted with respect to their different profiles (ref [12]) in order to evaluate their Gz tolerance. As expected and as recorded in the human centrifuges (ref [6]), the greater the level of +Gz exposure in Phase III of the Push-Pull profile the more predominant were the visual symptoms effect on the test subject. Moreover, the +Gz tolerance of Phase III decreased as the Phase I Gz's was decreased (i.e. greater –Gz). However, this pattern was not as drastic for all the test subjects. For some test subjects, the Gz tolerance decreased by +2.0 Gz from one profile to another one. For other test subjects, the Gz tolerance only decreased by +1.0 Gz between profiles. On average, the decrease in Gz tolerance for the 16 test subject was approximately 1.3 Gz as reported in ref [12]. Also, as mentioned in ref [12], similar mean Gz tolerance reduction s (1.2 Gz) were measured in centrifuge testing which tends to confirm the validity of the centrifuge data. Note that the above preliminary results are based on the visual effects experienced by the subjects during flight. The biomedical scientists at DCIEM are performing all the data reduction of the non-invasive physiological measurements gathered by AETE and will report on the results in the near future.

CONCLUSIONS

The biomedical instrumentation of a CF-18 fighter aircraft was performed to accommodate flight test measurements of the Push-Pull Effect on the human body. The integration of all the biomedical transducers had to be performed in such a manner to minimize any impact on the safety of the test subject and the pilot which included the utilization of devices having isolation characteristics meeting set standards and other safety mechanisms such as quick disconnect connectors . Real time video telemetry was necessary for such a research project in order to monitor the test subjects facial

expression in advance of possible G-LOC during flight. The test subject's biomedical measurands also had to be monitored real time (telemetered) for safety purposes. The lack of space in the aircraft made the design of mounts and brackets to support the biomedical instrumentation a real challenge. Finally, meticulous design considerations were taken to minimize EMI and therefore provide valid data. With respect to this data, the preliminary results seem to be consistent with the human centrifuge's testing performed by DCIEM scientists (ref [12]). Thus, this IFR might confirm the validity of the centrifuge's data compared to the Push-Pull phenomenon in an aircraft and therefore would allow future work to be carried out in human centrifuges. In the future, it is believed that the pilots will be protected from the Push-Pull effect with new G-Suit pressure schedules. DCIEM proposed in ref [13] that a micro-processor controlling an anti-G valve could deliver the correct amount of pressure to the pilot's G-suit in response to continuously monitored +Gz levels, therefore protecting him/her from G-LOC and a potential crash.

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