

High G Centrifuge Training

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The modern, highly maneuverable fighter aircraft are capable of imposing excessive acceleration forces on the aircrew beyond their physiological tolerances. Aerial Combat Maneuvers (ACM), resulting in variable high G forces, can lead to symptoms ranging from grey out, black out, almost loss of consciousness (A-LOC) to the dreaded G induced loss of consciousness (G-LOC). This may result in performance decrement and loss of situational awareness, thus compromising flight safety and mission accomplishment.

Aircraft designers and aviation physiologists have been constantly striving to improve protective measures for the pilot to control the aircraft in the high sustained G environment. Various protective methods have been developed to enhance the G tolerance of fighter aircrew; of those Anti G Straining Maneuver (AGSM) has proven to be the most effective in providing maximum protection against high G forces of ACM. The protection provided by AGSM is as good as its practice and performance by the aircrew. This realization and increased incidences of in-flight G-LOC in the air superiority fighter (ASF) aircraft led to the introduction of centrifuge training. Human centrifuge simulates +Gz forces akin to those encountered in aircraft. This allows pilots to be trained in the correct procedure and practice of performing AGSM in safe and controlled environment.

Centrifuge Training – International Scenario

The United States Air Force (USAF) is the pioneer in centrifuge training for fighter pilots. Dr. Sidney D. Leverette Jr. of USAF School of Aerospace Medicine (USAFSAM) commenced high G training for the fighter pilots of USAF Tactical Air Command (TAC) in 1971 [1]. This training was stopped due to logistical problems faced by the TAC. However, an increase in the incidents of G-LOC in the F-16 fleet in the early 80's and G-LOC being attributed as a cause of some of the fatal accidents, the centrifuge training for the F-15 and F-16 pilots was reintroduced in 1983.

Besides the US, several other countries including Germany, China, Canada, Turkey, Japan and Sweden also conduct high G training for their combat pilots [2]. There are about 25 centrifuges across the world, predominantly in the NATO countries with USA accounting for about 20% of them. The centrifuges vary in their capabilities including the difference in profiles in terms of the onset and offset rates. Several of the centrifuges, especially those focusing on aircrew training, use close loop flight profile and target tracking to make centrifuge training more realistic and acceptable to the aircrew.

The training aim and objectives of centrifuge training across the world remain identical. These norms and standards for aircrew are based on NATO Standardisation Agreement (STANAG) 3827 AMD and Air Standardisation

Coordination Committee (ASCC) Advisory Publication (ADV PUB) 61/26A. Both the documents state that the qualifying G load for an aircrew during centrifuge training is to withstand +7 Gz 15 sec rapid onset run profile, while wearing an anti-G suit and performing straining manoeuvre (AGSM). The centrifuge training essentially has two components. This includes improving the aircrew's awareness about G forces and related human physiology through didactic lectures and centrifuge training (Table 1). The duration of training varies from one day to five days. Some of the Air Forces conduct refresher courses as well. Studies from most of these countries have established centrifuge training as a useful and safe method for increasing G tolerance of their combat aircrew.

High G training in the Indian Air Force (IAF)

IAF has a German manufactured Human Centrifuge at the Institute of Aerospace Medicine (IAM), Bangalore since 1966. Since its installation in 1996, it has been extensively used for research, evaluation and training purposes. Consequent to the evident advantages of the centrifuge training by USAF for its combat pilots, centrifuge training for the IAF fighter pilots was formalised and commenced in 1991. The course content was modeled on similar aims and objectives as stated in the NATO STANAG 3827 AMD and ADV PUB 61/26A. Necessary modifications to meet training requirements tailored for the IAF aircrew were also incorporated.

The training initially started as a 5 day high G training course. Subsequently the duration was increased to 2 weeks with the intention of imparting comprehensive aeromedical training rather than just high G training to fighter aircrew. This included didactic lectures on subjects of aeromedical interest and exposure to simulated

aviation stresses utilizing various aviation simulators, besides the centrifuge based high G training. This course was thereafter rechristened as Advanced Fighter Aeromedical Indoctrination Course (AFAIC).

Unlike the single day, five high G runs and an optional SACM run of the USAF, the high G training component of AFAIC at IAM lasts a week. Initially the aircrew attending AFAIC were subjected to approximately 12 rapid onset rate (ROR) profiles starting from 3 G and going up to 9 G. In addition 7 ROR simulated aerial combat manoeuvre (SACM) profiles of 4G-15 s, 8G-10s, 2 SACM profiles with pressure breathing under G (PBG), 2 gradual onset rate (GOR) SACM profiles, 1 GOR profile and 2 Spatial Disorientation (SD) runs were given. With the dawning of realization that the number of runs for the IAF aircrew were much higher than other Air Forces; and the scientific evidence that GOR runs are more stressful to the cardiovascular system without any operational significance, the GOR runs were removed from the course content. Subsequently the repetition of SACM profiles was also reduced. Main focus of the training at present is that the aircrew must learn the correct technique of AGSM and qualify the training goals of minimum +7 Gz 15 sec ROR. The remaining time is now gainfully utilized for imparting training on other aeromedical subjects and simulator experience. This includes SD training after the recent acquisition of the SD simulator at IAM. Encouraged by the success of the centrifuge training of operational fighter pilots of the IAF, a capsule course for ab-initio pilots of two days duration was also started at IAM in 1998 [3,4].

Aims and Objective of High G Training. The aircrew are imparted centrifuge training so as to enhance their G level and duration tolerance and

increase their awareness about the G environment. The primary aim of the high G training in the IAF is to improve the skill in proper performance of AGSM during exposure to high G stress so as to enhance the G tolerance of the trainee. The secondary aims are to impart an understanding of the physiological mechanisms of G-stress and G-tolerance; to inculcate a better appreciation and healthy respect amongst the aircrew for the hazards associated with the high G environment; and to build confidence in their ability to tolerate high G-stress.

High G training syllabus

As the high G training progressed over the last decade and a half, the course syllabus has undergone suitable modifications, without compromising the aim and objectives. The syllabus consists of didactic lectures on +Gz physiology, preventive and protective measures to combat high G with special emphasis on correct performance of AGSM. This is followed by centrifuge training. The centrifuge training uses various high G profiles and includes the following runs:-

(a) Relaxed ROR G tolerance. The aircrew are subjected to ROR runs at 1G/s to determine their relaxed G tolerance. The aircrew remain relaxed through out the run and are without an anti-G suit (AGS). The end point for the run is peripheral light lost (PLL) from 56° to 52° on the Graduated Dynamic End Point System (GRADEPS).

(b) ROR runs. Before subjecting them to ROR (1G/s) high G runs, the aircrew are demonstrated a few cycles of correctly executed AGSM at 1G. At IAM the L-1 respiratory maneuver is taught and practiced. Care is taken during these demonstrations to emphasize to the trainee, the fact that a properly executed AGSM can elevate

the blood pressure at the head level to about 200 mm of Hg, which is not desirable at 1G. Individual aircrew is then instructed to perform a minimal number of AGSM at 1G which is critically analyzed and corrections made. Video demonstrations of correct technique are used to reinforce the correct technique of AGSM. This is followed by ROR runs of 4G for 15 s, 5G for 30s, 6G for 30s, 7G for 15s, 8G for 10 s and 9G for 5s. During the 4, 5, and 6 G runs the aircrew gets an opportunity to practice and fine tune his AGSM correctly, while the instructor uses the opportunity to make suitable corrections if required. The aircrew is then subjected to 7G for 15 seconds which is the training goal. This requirement of sustaining 7G for 15s without PLL of 56° to 52° on the GRADEPS has been adopted from the NATO STANAG 3827 AMD, which states that aircrew who do not successfully complete a ROR 7G for 15s centrifuge profile with anti-G suit and straining maneuver, will be considered to have low G tolerance. Those who successfully complete the run are subjected to 8G -10s and 9G - 5s runs. In the event of failure to complete 7G for 15s or 8 and 9G for the stipulated period, due to PLL or inadvertent G-LOC these runs are repeated on subsequent days with adequate briefing and corrections in the technique. Repeated failure entails a detailed analysis and decision is arrived at labeling the individual as having failed to qualify and attain the training goal.

(c) Simulated Aerial Combat Maneuvers (SACM). In addition the aircrew is subjected to SACM profiles of alternating 4G - 15s, 8G - 10s with onset and offset rates of 1G/s. This gives the aircrew an opportunity to practice AGSM under somewhat more realistic conditions than encountered in ROR runs. SACM profiles subject the aircrew to variable G profiles which are repetitive, continuous and without predetermined

Table 1: Centrifuge Training Profiles in different Air Forces

Country	Duration (Day)	Standard Profiles	Centrifuge	Onset Rate	Offset Rate	Training goals	Refresher	Remarks
United States of America (USA) USAFSAM [7,8]	1	3 diff types of profiles for initial training; pilot instructor training; & Qualification profile each consisting of 5 profiles with rest period of 2 min between profiles	Max 30 Gz	6 G/s	2 G/s	7G 15s	3 years	SACM Optional; Check 6 essential
USA US TAC			Max 15 Gz	10G/s	2 G/s from 9 to 3 G and then 0.2 G/s till stop		3 years	
USA US Navy [9]		5 profiles - Resting Tolerance (RT); 1G>RT; 2G>RT; 7.5 G ACM, 7.5 G check six		6 G/s				
Canada [10,11]	1	3 profiles 1) GOR to +9G to check relaxed & straining tolerance 2) 3 ROR runs to 4-5G to practice AGSM 3) Final ROR depending on ac (a) without AGS: 6G-15s (b) with AGS: 7.5G-10s followed by 5G x 10-30s	Max 15 Gz	GOR 0.1 G/s ROR 4 G/s				As per STANAG 3200 & ASCC Advisory 61/51

Country	Duration (Day)	Standard Profiles	Centrifuge	Onset Rate	Offset Rate	Training goals	Refresher	Remarks
Russia	3	Sequential exposure	Max 30 Gz					
Germany [12]	2		Max 15 Gz	10 G/s				
Turkey		2 profiles	Max 15 Gz	GOR 0.1 G/s ROR 6 G/s		8G 15s	3 years	
Japan [13,14]	1 week	8 profiles: GOR & ROR Relaxed tolerance, Tracking performance; SACM		2 G/s	2 G/s			Closed loop training
Sweden [15,16]		+9G x 15s		14.5 G/s				Closed loop training
China	6	4 profiles		10-15 G/s				Qi-Gong Maneuver
Poland [17,18]		3 profiles 1) 4 runs separated by 2 min: (a) GOR @ 0.1G/s to check G tol (b) ROR @ 4G/s to +6G-30s (c) ROR to + 8G-15s (d) ROR to + 9G-15s 2) Push-pull profile @ 3 G/s: 1.5G-15s alternating with 4.5, 5.5, 6, 6.5, & 7G-5s 3) SACM : 4.5G-7G						

duration limit. The end point for SACM runs is fatigue or inadvertent G-LOC.

(d) Pressure Breathing for G (PBG). The course curriculum also provides the trainees an exposure to PBG as a means of protective measure for enhancing their endurance to SACM tolerance. A modified oxygen regulator is used to deliver oxygen to the mask at a pressure of 30 mm Hg throughout the respiratory cycle. This is done to make the trainee experience the ease and reduction in fatigue due to PBG while performing AGSM during SACM profiles.

(e) Physical conditioning program. The aircrew is introduced to the principles of physical conditioning program beneficial for the fighter aircrew, including performing AGSM during ACM. The importance of strength conditioning of muscles which are used in the performance of AGSM is emphasized. A multi-station gymnasium in the Department of Acceleration Physiology along with a trained physical instructor is available to conduct the training.

(f) Failure to qualify. The qualifying requirement for the aircrew undergoing the course is to complete 7G - 15s ROR run and two peaks of SACM. Those not qualifying are considered to have inadequate G level and duration tolerance for the air superiority fighter class of aircraft. However, after excluding causes known to produce low G tolerance, these pilots continue to be fit for fighter flying. They are further advised to improve their physical fitness and repeat the course at a later date.

(g) Safety. Safety standards being followed at the Institute are very high and no injuries have been reported since the installation of the Human Centrifuge in 1966. Medical supervision and

physiological monitoring have largely contributed to the safe record.

(h) Operational Benefits. A questionnaire study involving feedback from the pilots six months after the course revealed a significant decrease in the incidence of in-flight G-LOC. 47% of the respondents found the course very useful while another 51% found it to be useful. 70% pilots were doing AGSM routinely during combat sorties [5,6].

Future perspective

The IAF is in the process of commissioning a state of the art high performance human centrifuge (HPHC) from AMST Austria. The HPHC should be operational by mid 2008. The HPHC has capabilities similar to the best in the world. High onset and offset rates, motorized roll and pitch drives, close loop operations with target tracking tasks, capability to generate push-pull maneuver, state of the art physiological monitoring system and quick pilot evacuation system make the HPHC a very safe research and training tool.

The capabilities of the HPHC shall help train pilots in learning the correct skills of performing and practicing AGSM under more realistic high G environment and maintaining their situational awareness and performance levels. The vast experience of the faculty at IAM in centrifuge training will complement the advanced technology of HPHC in imparting meaningful and effective training to the fighter pilots of the IAF.

IAM will be able to offer dedicated short duration and refresher high G courses to its pilots. The course will offer a combination of didactic lectures and centrifuge training. Didactic lectures will be aimed at understanding the physiological changes due to +Gz stress and how they limit tolerance and affect performance. Awareness

amongst the aircrew regarding the physiological basis of various protective methods to enhance G tolerance specially the usefulness of AGSM will be generated through lectures, demonstrations and interactive sessions. With the HPHC providing a realistic environment through close loop operations with target tracking tasks; and SACM profiles simulating present day tactical air combat scenario, the course will enable the aircrew to learn the skills in performing AGSM under realistic task oriented conditions. Thus the HPHC based centrifuge training will expose the aircrew to high G profiles akin to those being encountered in high performance aircraft. Centrifuge training is in vogue for over three decades now and expertise in this area is enormous. Tactical air combat situations are fast changing. Acceleration physiologists need to keep pace with such changes. In this direction, sharing of experiences by different laboratories will be a major step that needs to be encouraged.

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