***BY ORDER OF THE SECRETARY OF THE AIR FORCE***

***AIR FORCE PAMPHLET 11-419***

***1 DECEMBER 1999***

***Flying Operations***

# ***G-AWARENESS FOR AIRCREW***

**NOTICE:** This publication is available digitally on the AFDPO WWW site at: http://afpubs.hq.af.mil.

OPR: AFMOA/SGOA (Col Albert A. Hartzell)

Certified by: AF/SG/SGM2 (Col Michael D. Parkinson)

Supersedes AFPAM 11-404, 19 August 1994

Pages: 15
Distribution: F

This pamphlet implements AFPD 11-4, *Aviation Service*, and AFI 11-403, *Aerospace Physiological Training Program.* It provides all high-G aircrew with a source of reference for information and techniques, and covers basic physiology of high-G flight. It explains how to prevent G-induced loss of consciousness (G-LOC) and includes the effects of G-forces on the body, the factors that increase and decrease G-tolerance, and countermeasures to avoid G-LOC. This pamphlet applies to all high-G aircrew and is authorized for issue to each aircrew member. As a minimum, each unit will ensure the local Publications Distribution Office orders enough copies to make the pamphlet readily available to each aircrew member.

Send comments and suggested improvements through the parent MAJCOM Aerospace Medical Office, to AFMOA/SGOA 110 Luke Avenue, Suite 405, Bolling AFB DC 20332-7050.

## ***SUMMARY OF REVISIONS***

This revision renumbers the AFPAM, updates information on Class A mishap rates (paragraph 1), adds information about high intensity circuit training (paragraph A2.3.6.), aerobic conditioning (paragraph A2.5.) and deletes illustrations (paragraph A2.6.) Changed or revised material is indicated by a bar (|).

## ***Section A—PHYSIOLOGY***

### **1. Importance of G-LOC Avoidance.**

1.1. G-LOC continues to be a very real threat in fighter aviation. Class A mishap information shows that 26 aircraft were lost to G-LOC between 1982 and 1998. Reported Class C mishap information shows 402 G-LOC between 1985 and 1998. Research in both physiology and hardware improvements continue to be pursued. Until our knowledge and technology provide the means to greatly reduce the impact and threat of high-G forces, survival is the responsibility of each aircrew, on each and every flight. An understanding of the basic physiology of G forces as they affect the heart, brain, and eyes is necessary to facilitate later discussions on factors that influence G tolerance.

## 2. Introduction to G-Forces.

2.1. An increase in gravitational (or ”G”) forces results in reduced blood pressure and blood flow to the brain and eyes. Without blood flow, these organs can only function for about 4 to 7 seconds on oxygen reserve (less if at greater than one G), after which the sequential effect is grayout, tunnel vision, blackout and loss of consciousness. With a rapid reduction in blood pressure (such as that seen with rapid G onset or with relaxation of straining at high G), these sequential effects may go unnoticed, and loss of consciousness can occur without visual warning.

2.2. With a fall in blood pressure, the cardiovascular system responds with a reflex increase in blood pressure and heart rate. The full reflex response takes 10 to 15 seconds to complete.

2.3. G stress greater than resting G tolerance (with or without the cardiovascular reflex response) requires an anti-g straining maneuver (AGSM) to maintain consciousness. Rapid G onset or relaxation of the straining maneuver at high G levels can lead to G-LOC without any visual symptoms or warning signs. After a G-LOC, the brain requires an average of 24 seconds (range 8 to 80 seconds) before awareness of the environment returns, and even greater time may be required before mental skills are back to normal.

## 3. Heart, Brain, and Eyes.

3.1. The heart is a pump, supplying oxygenated blood throughout the body. In a discussion of G stress and G tolerance, the brain and eyes are the most important organs to consider. Blood pressure, flow rate and vertical distance from the heart to the head all influence the heart’s ability to supply adequate blood flow to the brain during G stress. Consciousness depends on blood being available to the brain while vision depends on blood supply to the retina of the eye. The eye requires a slightly higher blood pressure since it has a static inflation pressure (intraocular tension) which must be overcome. Both the brain and the eye have a 5 to 7 second reserve of oxygen, which will maintain function following sudden loss of blood flow.

## 4. Effect of G-Stress.

4.1. The most significant effect of positive G-forces on the brain and the eyes is the reduction of blood pressure and blood flow. The eye reacts first to the reduced blood pressure. As G-forces increase and blood pressure drops, aircrew experience grayout (loss of color and clarity), tunneling of vision, and then visual blackout. Visual blackout can occur without loss of consciousness, and this differentiation should not be confused. These visual symptoms reverse immediately upon restoration of blood flow and oxygenation to the eye.

4.2. When the brain loses its blood supply and exceeds its oxygen reserve, it abruptly fails. Once it fails, it stays “turned off” for a variable length of time, even after blood flow is restored.

4.3. Consciousness can be maintained when the G-onset rate is slow enough that visual symptoms are recognized and the AGSM is intensified accordingly. When G-onset rates are high and the peak G level sustained is high, as is often the case in modern fighters, G-LOC can occur without any visual warning signs when the oxygen reserve is depleted. Aircrew exposed to lower onset rates and peak G levels can also G-LOC if they ignore the visual symptoms, but should never use visual symptoms to test current G-tolerance. Mishap statistics and surveys have shown that no aircrew is immune to G-LOC susceptibility; it can happen to anyone flying any aircraft at any time when under G stress.

**5. Post G-LOC.**

**5.1. Initial Recovery.** Once G-LOC has occurred, the brain enters a state called "absolute incapacitation" which lasts an average of 12 to 16 seconds (range 5 to 30 seconds). This will occur even if aircraft G has been unloaded. During this time, the individual is in a dream-like state, unaware of his or her environment and unable to respond to any outside stimuli. The brain's blood supply returns during this period, if G is reduced. After this absolute incapacitation period, the brain starts to "wake up" and enters a "relative incapacitation" period which lasts on average another 12 seconds (range 3 to 50 seconds). The combined absolute and relative incapacitation times are referred to as the total incapacitation time; this total period averages about 24 seconds (range 8 to 80 seconds). At the end of this total incapacitation period, the individual is able to recognize where he or she is and respond to the environment. Aircraft recovery may be possible in the "relative incapacitation" period, as the aircrew member may respond to directive calls such as "pull-up, pull-up".

**5.2. Full Recovery.** There is a third phase to recovery from G-LOC: the return of cognitive processing skills. This may require several minutes before a full return to function. During this time, BFM skills and situational awareness may be severely impaired. In addition, a sudden high-G attempt at aircraft recovery soon after a G-LOC may induce a subsequent G-LOC episode. The implications of G-LOC and its potential immediate after-effects in a combat scenario are obvious. You may be conscious after a G-LOC, but you won't be a full-up combat aircrew member.

**5.3. G-LOC Recognition.** G-LOC may go unnoticed due to a partial amnesia that can occur as a result of impaired oxygen flow to the brain. You should suspect that G-LOC may have occurred if you cannot explain a sudden loss of altitude or have difficulty recognizing your aircraft attitude. Tingling around the mouth or in the extremities or a sense of dreaming are just two of the various sensations you may experience upon recovery from G-LOC. It is possible that review of your head-up display (HUD) film during debriefing may be your first clue that you experienced an inflight episode of G-LOC. NEVER USE VISUAL SYMPTOMS TO TEST YOUR CURRENT G TOLERANCE. If you experience grayout under G, you have only a 10 percent oxygen reserve remaining and are dangerously close to going to sleep. Visual symptoms should be considered a last resort warning that your are near G-LOC.

***Section B—G-TOLERANCE***

**6. G-Tolerance Factors.**

6.1. G-tolerance is the ability or capacity to maintain vision, consciousness, and effective performance when under G-stress. To do this, blood pressure and flow must be maintained to the brain and eyes. Factors which affect an aircrew's G tolerance include: 1) the effectiveness of the anti-G straining maneuver; 2) anticipation of the G-onset, 3) aircrew physical, physiological and psychological characteristics; 4) G-protection equipment and 5) G-discipline and awareness. The straining maneuver is the critical component of high G-tolerance, but G-awareness and "G-discipline" for high onset rates and sustained G are the critical elements of G-LOC avoidance. For quick reference, these factors and their corresponding explanatory paragraphs are listed below.

**7. Anti-G Straining Maneuver.** The AGSM is the best G-defense measure available to aircrew members. Equipment measures (anti-G suit, COMBAT EDGE, reclined seat, etc.) were never meant to replace the AGSM, only aid it. Aircrews must properly perform a timely AGSM in order to gain maximum benefit. It is very important that you perform the same, correct AGSM each time you anticipate and or apply G, regardless of the amount of G. This will ensure positive feedback, and will imprint the proper AGSM to make it an automatic response.

**7.1. Tolerance.** Average aircrew relaxed G tolerance in the F-16 seat is about 5.2 G (about .5 to .75G less in aircraft without a reclined seat); the G suit can add another 1G, and a good AGSM can add another 3.5G or more of tolerance. When these are totaled, one can see that 9G is a big challenge for most aircrew; there is little or no safety margin.

**7.2. Preparation.** The straining maneuver should precede rapid G onset. It is extremely difficult to "catch up" to a G load if you get behind from the start. In addition, proficiency in performing the maneuver may decrease (decondition) when you have not flown recently. Physical conditioning, fitness, and mental preparedness, proficiency and currency are all keys to an effective AGSM.

**7.3. Components.** The AGSM consists of two components: maximal contraction of lower body muscles and forced exhalation against a closed glottis. Performing one without the other may significantly reduce the effectiveness of the strain.

**7.4. Checklist.**

7.4.1. Anticipate the G.

7.4.2. Simultaneously tense all lower body muscle groups legs, butt and abdominal muscles (maintain this strain)

7.4.3. Deep breath, with forced exhalation against closed airway.

7.4.4. Quick breath every 3.0 seconds, once at peak G.

7.4.5. Minimize communications.

7.4.6. Don't relax until G is unloaded.

**7.5. Details.**

**7.5.1. Muscle Tensing.** Muscle tensing increases usable blood volume and return of blood to the heart.

7.5.1.1. Begin with lower body muscle groups, legs, butt and abdominals; this reduces the space in which the blood may pool.

7.5.1.2. The tighter (more tense) the muscles the greater the reduction in the tendency for blood to pool.

7.5.1.3. The legs are most important.

7.5.1.4. Tensing of all skeletal muscles, especially abdominals, helps to raise blood pressure and "push" blood back to the heart.

**7.5.2. Upper Body Muscular Strain.**

7.5.2.1. The upper body muscle strain may be varied depending on the G-load, but the tenseness must continue until unloaded.

7.5.2.2. The muscle strain must be maintained continuously, even when breathing.

7.5.2.3. If the muscles are relaxed while still under G, the blood will immediately rush into the extremities (opened spaces). This makes it almost impossible to catch up if at moderate G (4 to 5) or higher and may even result in almost instantaneous G-LOC.

**7.5.3. Increased Chest Pressure.** Increased chest pressure increases heart output pressure. Works as a "boost pump" for the heart. The greater the pressure generated in the chest, the more the heart and blood vessels leading from it are squeezed, and the greater the resultant blood pressure. This keeps brain blood pressure in the functioning range.

**7.5.4. Breathing Cycle.**

7.5.4.1. Take a deep breath prior to the onset of G, close the glottis (throat), and bear down with the chest muscles as in trying to exhale, but keep the throat closed. This process will generate the pressure.

7.5.4.2. Every 2.5 to 3.0 seconds, take a breath. Exhale a small amount of the air. Immediately pull the air back in and regenerate the chest pressure. The exhalation and inhalation process should ideally take about 0.5 seconds.

7.5.4.3. Minimize communications during G.

**7.5.5. Common Errors.**

7.5.5.1. Having proper knowledge of the technique, *but* failing to turn that knowledge into a skill, which is integrated with other flying skills.

7.5.5.2. Developing good chest pressure, but failing to tense the lower body musculature. This causes the blood to pool in the extremities and the overpressure in the chest impedes the return of blood to the chest. The result of this counterproductive strain can be G-LOC or severe visual loss regardless of the G load.

7.5.5.3. Failing to anticipate the G. Performance of the AGSM should begin before G is loaded on the aircraft. Failure to do so will result in the aircrew member either trying to catch up on the AGSM (a very dangerous practice) or having to unload in order to buy time to catch up.

7.5.5.4. Failing to maintain chest pressure (loss of air). Occurs while talking or whenever the strain is audible. As air is lost from the chest the amount of pressure generated falls. This directly reduces blood pressure to the brain. If air loss is heavy, as might occur with speech, the subsequent loss of blood pressure in the brain may result in G-LOC without visual loss. Other causes of air loss are "groaning" (letting the air escape slowly) and trying to hold the chest pressure by sealing the lips rather than with the throat.

7.5.5.5. Holding the breath less than the required 2.5 to 3.0 seconds. Results in lower average blood pressure in the brain, and fatigue is accelerated.

7.5.5.6. Holding the breath longer than 3.0 seconds. The increased chest pressure impedes return of blood to the chest where it is available to the heart. If blood return to the chest is blocked for 4 to 5 seconds the heart may run out of blood to pump. This can be very dangerous when wearing COMBAT EDGE.

7.5.5.7. Taking too long to complete the exhalation and inhalation cycle. Total time for this cycle should be 0.5 seconds.

7.5.5.8. Performing a strain with the intensity necessary to stay awake at 9G when the G-load is only 5G, will result in early fatigue and increase potential for G-LOC in subsequent engagements. The intensity of the AGSM should be graded in relation to the level of G. It is always safe to overestimate the intensity of the strain, and always unsafe to underestimate the intensity required.

**7.5.6. Training and Proficiency.** While the aircraft and personal G-protection equipment are passive, the AGSM is active. It requires anticipation of the maneuver and is a practiced skill which must be integrated with numerous other cockpit tasks. The efficiency and intensity of the AGSM depends on multiple factors, including strength, endurance, training, motivation, and proficiency. The AGSM is like other athletic skills in that it is susceptible to deconditioning. Scientific studies indicate there is some decrease in the endurance of the AGSM when the aircrew member is not current and proficient. Tolerance to peak G for short intervals may not be affected, *but* ENDURANCE TO MULTIPLE OR SUSTAINED HIGH G ENGAGEMENT MAY BE DEGRADED AFTER A LAYOFF FROM HIGH G FLYING; ESPECIALLY IF ILLNESS WAS THE CAUSE!

7.5.6.1. The best time to practice the correct AGSM is during the G-awareness maneuver. This is a part of the sortie during which you can devote almost all of your conscious attention to G and to your AGSM technique. Once the engagements start, your attention will be directed toward the mission and practice of the AGSM will probably be a distraction. You should use hot mike during the G-awareness turn, so you can review your AGSM during the debrief. *Do not waste this opportunity!*

7.5.6.2. Centrifuge training has proven to be an invaluable tool in teaching aircrew a proper AGSM without worry about the consequences of a G-LOC in flight. The Combat Air Forces (CAF) require that all high-performance aircraft aircrew members go through centrifuge training. Training requirements and policy are described in AFI 11-404, *Centrifuge Training for High-G Aircrew*.

**7.5.7. VTR Review.**

7.5.7.1. There are several requirements that should be met in order to provide the best appraisal of an individual's AGSM through VTR review. The Flight Supervision, flight surgeon, or aerospace physiologist should perform the following during the VTR review:

7.5.7.2. The aircrew should be on "hot mike", and the HUD should be easily read.

7.5.7.3. The aircrew should be performing other tasks while under G. Ideal situations: BFM, ACT, etc.. Several engagements on a single sortie should be appraised.

7.5.7.4. The adequacy and correctness of tensing the extremities and other musculature cannot be judged. The automaticity of the strain cannot be adequately judged during "canned" maneuvers such as G-Awareness turns.

7.5.7.5. Listen for a preparatory inhalation just before the G is loaded. If it is not there, the aircrew may already be behind the G.

7.5.7.6. Listen for exhalation sounds or talking during the G-onset. This signifies loss of air from the chest and reduced efficiency of the strain and G-tolerance. Additionally, the aircrew is likely to be behind the G and will have trouble catching up. This may cause the aircrew to either unload some of the G or sharply increase the intensity of the strain (usually audible). The latter may be a result of recognition of vision loss. Ideally, the first breath should be held until the desired G-level is reached or 3.0 seconds, whichever occurs first.

7.5.7.7. Listen for the first exhalation. It should be short and immediately followed by a quick inhalation. The end of the inhalation may be noted by a sudden grunt sound or a sudden absence of breathing sounds. Total time for the breath ideally should be 0.5 second, but in no case should be longer than one second.

7.5.7.8. Breath sounds should not be heard for 2.5 to 3.0 seconds. If breath sounds are more rapid, average chest pressure is lower and G-tolerance is negatively affected. As G-tolerance is negatively affected, the aircrew will have to work harder at any given G-load. Fatigue during the engagement or especially in subsequent engagements will most likely become apparent. This may be evidenced by even more rapid breathing or breathless, gasping sounds. Observation of the G-load at these times may provide evidence that the individual is apparently working too hard for the G or is unable to maintain the G necessary for the tactical situation.

7.5.7.9. If breath intervals are 4.0 seconds or longer, there is high risk of G-LOC. This is critical when using COMBAT EDGE because it decreases blood flow back to the heart.

**7.6. The Aircrew.** Survival in the high-G environment can be improved by optimizing our daily habits and activities.

**7.6.1. Physical Characteristics.** There is no one body type that is immune to G-LOC. Some aircrew are "G naturals", some are not; but ALL of them can significantly increase their G-tolerance. High levels of anaerobic fitness in combination with moderate aerobic capacity are important for all high-G aircrew.

**7.6.2. Why Physical Traits Do Not Necessarily Predict G-Tolerance.** Evidence suggests that tall individuals are more likely to have a lower resting tolerance but may be able to compensate with an effective anti-G straining maneuver.

**7.6.3. How Physical Conditioning Plays an Important Role in G-Tolerance.** Anaerobic training has been shown to improve G tolerance in both Air Force and Navy studies. Muscular strength and endurance training has been shown to increase strength, endurance and cockpit mobility during flight in the high-G environment. Moderate amounts of aerobic activity have not demonstrated any degradation in G-tolerance. The cardiovascular fitness improvements from aerobic exercise (aerobic capacity) may enhance the ability to recover from straining maneuvers and shorten the recovery time between engagements and sorties. Attachment 2 to this pamphlet presents a comprehensive program of strength training and aerobic training designed to increase your G-tolerance.

**7.6.4. G-Awareness.** Application of a timely AGSM is the critical component of high G-tolerance, but G-awareness and "G-discipline" (for high onset rates and sustained G) are the critical components of G-LOC avoidance. G-discipline controls the rate of onset and the level of sustained G; these should be adjusted for multiple human factor variables. Anyone can G-LOC if good G-awareness and discipline are not employed. Pilots who have been "humbled" in an earlier sortie or engagement could have their fangs out further than they realize. They may then apply G-onset rates or sustained G that exceed their capability that day. Ego control and an objective assessment of one's mindset can be a critical factor in the avoidance of a G-LOC. Enhanced situational awareness includes more than just tactical and spatial awareness; it also includes assessing one's own physiological and psychological state throughout the flight. You must develop a subconscious anticipation of impending G-exposure. There is no time to "think about it" with high-G onsets. Using predictive and anticipatory skills will result in proper "G-discipline" in the cockpit. Proper G-discipline, if employed, would have prevented nearly all of our G-LOC fatalities in the CAF. ***POINT:*** ASSESS BOTH PHYSIOLOGICAL AND PSYCHOLOGICAL STATES DURING HIGH G SORTIES; TO KNOW YOUR LIMITS AND USE GOOD "G-SA".

**7.6.5. Technique.** Flying technique relates to the previous paragraph as well as to the aircrew's learned air-to-air combat methods. The proper application of G-onset rates and of sustained G is something learned through training and experience. Resist becoming complacent with an aggressive style that disregards these factors. Assess your own technique objectively, and apply the G for the situation. Manhandling the jet is not consistent with optimal "G-SA" and is rarely tactically required if SA is high.

**7.6.6. Other Human Factors Affecting Our Ability to Tolerate G-Stress.**

7.6.6.1. Fatigue. The ability to perform a maximal AGSM directly correlates to strength and endurance, and these characteristics are related to rest and fatigue. Fatigue from inadequate sleep is different than muscle fatigue. Muscle fatigue severely degrades the AGSM, whereas inadequate sleep degrades alertness and G-awareness. Either way, your G-tolerance is compromised.

7.6.6.2. Heat stress degrades the body's ability to do work and reduces G-tolerance. The combination of dehydration and blood moving to the skin for cooling significantly reduces G-tolerance and work capacity. Studies have shown that with only 3 percent dehydration, G-tolerance time may be reduced up to 50 percent. Always stay well hydrated, especially in hot conditions; increase fluid intake before and during the mission. WHEN HEAT STRESS IS PRESENT, REALIZE YOUR G-TOLERANCE MAY BE REDUCED AND ADJUST YOUR G ONSET RATES AND G-LEVELS ACCORDINGLY!

7.6.6.3. Poor nutrition can affect your performance in the cockpit. It is important to eat regularly two or three times a day. A "proper" diet should emphasize complex carbohydrates (rice, breads, pasta, potatoes, etc.) and less fat and protein than most American diets now contain. Avoid high sugar "coke and candy bar" snacks when you are unable to eat regularly. G-tolerance is reduced if your blood sugar drops below normal ranges. To minimize this potential problem, avoid "substitute" snacks high in sugar content.

7.6.6.4. It has been well documented that alcohol and its hangover effect have a significant negative impact on G-tolerance. Alcohol degrades sleep quality, causes dehydration and salt loss, and depletes body sugar stores. It also tends to dilate blood vessels. All of these factors have a negative effect on your body's ability to tolerate G-stress.

7.6.6.5. Illness or infection also degrades G-tolerance. Although the amount of degradation is unknown, some G-LOC mishaps have occurred just after pilots have returned to flying after being ill. Performance may be reduced after a recent illness, and your body is probably not ready to support the intense effort for an aggressive BFM or ACM sortie. When coming back on status, your body's energy level and muscular strength may be lower and the cardiovascular system may be "detuned" and detrained (slower and less intense response). The use of medication can potentially further degrade your G-tolerance and performance. Together, these effects can reduce your body's ability to tolerate G-stress.

**8. G-Protection Equipment.**

**8.1. Anti-G Garments.** The current standard anti-G suit, CSU 13B/P, provides about one G of protection over the relaxed G-tolerance. Its primary purpose is to provide mechanical resistance against which the leg and abdominal muscles can "push", and to reduce the available space for blood to pool, helping to increase blood pressure.

**8.2. Life Support Regulations.** These regulations require periodic refitting of the anti-G suit and describe the proper fit.

**8.3. Future Developments.** New G-suit concepts are undergoing development and may be able to afford greater G-protection. Hopefully, they will be incorporated into an integrated life support ensemble in the next generation combat aircraft.

**8.4. Pressure Breathing For G (PBG).** Pressure breathing for G-protection, COMBAT EDGE, is currently in F-16/15 operational, training, and flight test units. COMBAT EDGE helps increase G-endurance but it does not protect against rapid G-onset. The AGSM is performed the same as if you were flying without COMBAT EDGE. Because of the pressure scheduling and brief delay in onset, COMBAT EDGE DOES NOT PROTECT AGAINST RAPID G ONSET RATES. An anticipatory anti-G straining maneuver is still required prior to the onset of high G to protect against G-LOC with this system. The pressure delivered to the chest cavity provides the equivalent of nearly 3G of protection with aircraft at 9G. The result, sustained G can be tolerated with less fatigue and for greater periods of time. Studies have demonstrated approximately a doubling of G-time tolerance on the centrifuge with assisted positive pressure breathing.

***Section C—APPLICATIONS***

**9. Maximizing G-Tolerance and Preventing G-LOC.** Many variables come into play in maximizing G-tolerance and in preventing G-LOC. You, alone, are ultimately responsible for your mental and physical condition and preparedness. How do you stack up? A quick review of the following items before each flight may help you assess your personal capability to fly each time you step to the jet.

**9.1. Lifestyle.** Regular exercise, good nutrition, and regular sleep allow you to fly at peak condition (peak G capacity).

9.1.1. Participate in a regular exercise program, using both anaerobic (strength) conditioning with moderate aerobic training. The use of strength training with a large anaerobic component (e.g., leg, butt, and abdominal muscles) appears to be the most effective form of muscular training and consequent G tolerance for pilots who fly high-performance aircraft. The use of moderate aerobic training is also recommended since it does not reduce G tolerance and its combination with weight training supplements the endurance criteria required for sustained, prolonged anti-G straining maneuvers.

9.1.2. Practice good nutrition and good sleep discipline. Fly nourished and rested to the maximum extent possible.

9.1.3. Limit the use of alcohol.

9.1.4. Don't fly when ill, fatigued, dehydrated, or while on medications!

**9.2. Mission Assessment and Planning.** How G proficient are you? Are you rested and fit? Are you well hydrated? Plan your G-employment (onset rates, peak G, sustained G level). Set limits on your G plan of attack.

9.2.1. Consider how long it has been since you were exposed to a high G sortie. If you are coming off a break from high-G missions, plan your G-maneuvering on the assumption that your G-proficiency and G-tolerance will be low. Review the mission, and formulate your own plan for employing high-G maneuvering. Decide what onset rates you will accept, and what G levels you intend to use. Realize you may have to alter your plan inflight if your G-tolerance is not as effective as you had predicted, or if you become fatigued.

9.2.2. Get a good night's rest and a nutritious prebrief meal. Assess your personal fatigue level and adjust your G-plan of attack accordingly.

9.2.3. Drink plenty of water to maintain hydration; don't wait until you feel thirsty.

9.2.4. Although exercise is important, avoid strenuous activity 3 to 4 hours prior to flight due to the temporary reduction of energy stores in the muscles.

**9.3. Preflight.**

9.3.1. Make sure COMBAT EDGE and the G-suit fits properly and snugly, and that comfort zippers are zipped.

9.3.2. Warm up your muscles in life support, during the walk-around, and in the seat. This should include stretching of the trunk and neck, including rotational movements.

9.3.3. In the cockpit, check G-suit connection and perform ops test.

9.3.4. Review once again the plan: how do you anticipate high-G maneuvering will be employed in this mission, and how do you intend to monitor your G performance? What high-G maneuvers will you NOT accept?

**9.4. Inflight.**

**9.4.1. Performing a G-Awareness Maneuver.** This is important in:

9.4.2. Assessing your G-proficiency, and getting back your timing and execution of the anti-G straining maneuver.

9.4.3. Checking G-suit and COMBAT EDGE connections and operation.

9.4.4. Recalibrating how you apply (onset) and control (peak level) aircraft G.

9.4.5. Providing an exposure to the cardiovascular system to activate its reflex response to a drop in blood pressure. A maneuver of 3 to 5G for about 10 seconds is required to fully develop this reflex response.

***NOTE:*** The maneuver is not performed in order to test how many G you can pull that day. Don't G-LOC on the G-awareness turn!

**9.4.6. Rehearsing the Anticipation of G-Load.** Predict when and how much G will be needed, anticipate the maneuvers, and employ your plan to employ a timely AGSM for G-LOC avoidance.

**9.4.7. Performing a Good AGSM Ahead of the G-Onset.** Don't wait for the G suit to inflate or for visual symptoms to cue your strain.

**9.4.8. Keeping Your "G SA" High.** Be aware of how fast and how many G you are commanding. Snatching high G when unprepared may be fatal.

**9.4.9. Becoming Fatigued.** Remember, as the mission proceeds, you may become fatigued, and your G tolerance may be reduced as your ability to perform an effective straining maneuver is compromised.

**9.5. Post Flight.** Assess your G-performance. Did you predict your G-tolerance correctly? Did you make appropriate inflight adjustments if needed? From video tape review, did you apply G as expected? Review your AGSM.

9.5.1. Report any physiological problems to your Commander or Supervisor and life support officer. Report any equipment problems to maintenance and life support personnel.

9.5.2. Review the mission on your HUD film; analyze your G-discipline and the effectiveness of your straining maneuver. Did you use more G than you intended? Does your straining maneuver seem to have appropriate pacing? Did you take a quick breath approximately every 3 seconds? Did you blow off too much air? Did you get on top of the G? Did you talk during high-G exposure? Was your G-tolerance lower than expected?

PAUL K. CARLTON, JR., Lt General, USAF, MC
Surgeon General

## Attachment 1

## GLOSSARY OF REFERENCES AND SUPPORTING INFORMATION

### *References*

AFPD 11-4, *Aviation Service*

AFI 11-403, *Aerospace Physiological Training Program*

AFI 11-404, *Centrifuge Training for High-G Aircrew*

### *Abbreviations*

**ACM—**Air Combat Maneuvers

**ACT—**Air Combat Training

**AGSM—**Anti-G Straining Maneuver

**BFM—**Basic Fighter Maneuvers

**CAF—**Combat Air Forces

**G-LOC—**G-Induced Loss of Consciousness

**G-SA—**Situational Awareness of G

**HUD—**Head-Up Display

**MAJCOM—**Major Command

**PBG—**Pressure Breathing for G

**RM—**Repetition Maximum

**VTR—**Video Tape Recorder

### *Terms*

**G—**Any force that produces an acceleration of 32.2 $FPS^2$ (FPS = Feet Per Second), which is equivalent to the acceleration produced by earth's gravity.

## Attachment 2

## PHYSICAL FITNESS PROGRAM TO ENHANCE AIRCREW G-TOLERANCE

**A2.1. Purpose of the Physical Fitness Program.** Flying combat aircraft is a challenging and rewarding career. It takes tremendous desire, knowledge, and skill to be a successful combat aircrew. But winning and losing also depends on your ability to overcome the high G-forces generated by today's modern fighters. This attachment contains specific recommendations for establishment of a personal physical conditioning program to enhance your G-tolerance. Various strength training programs will be described. An outline for a moderate aerobic conditioning program is also provided. This total personal physical conditioning program is designed to increase your strength, endurance and cockpit mobility; in short, to give you the edge in combat.

**A2.2. Physical Conditioning To Improve G-Tolerance.** Being in good physical condition holds definite advantages for your performance in the cockpit, especially your G-tolerance. Increased muscular strength and endurance allow you to efficiently perform the AGSM with less relative muscular effort, therefore less "mental" effort is required. The AGSM must become an automatic muscle activity, concentrating solely on performance of the AGSM will erode your attention to such tasks as good BFM. During fighter maneuvers, high G-forces may be sustained for a short duration requiring performance of the AGSM. This maneuver expends energy at a rate similar to sprinting or weight lifting. Researchers have shown that high intensity strength training increases your ability to withstand high G-forces for a longer duration with less fatigue. Additionally, moderate aerobic training has been shown to decrease the recovery time needed between centrifuge training runs. Therefore, a combination of both training programs is recommended for maximum G-tolerance and performance.

**A2.3. High Intensity Muscular Training.**

**A2.3.1. Program Requirements.** A well balanced muscular conditioning program must consist of two parts: strength AND muscular endurance. It requires a good deal of strength to restrict blood flow to the skeletal muscles. It is also important to maintain the muscular contraction for the period of time spent under the G-load, as well as repeating the contraction time and time again with equal effectiveness. This aspect of the strain requires muscular endurance. Since it is critical to have both strength and muscular endurance, a well balanced program will incorporate both.

**A2.3.2. Strength and Power Workout.** As with any type of training, strength training workouts should begin with a brief 5 to 10 minute warm-up period. This warm-up should include stretching and slow jogging in place or brisk walking. Rest periods of 1.5 to 2 minutes should occur between sets and between exercises. The weight that is to be used should be calculated from a "one repetition maximum (RM)" lift. One RM is the most weight that can be lifted once in a slow and controlled fashion for a given exercise. This amount should be established for each exercise that will be done during the workout. Once this amount is measured, multiply it by 0.8 to find 80 percent of the 1 RM. This weight is the training weight for any given strength exercise. Each set should consist of six repetitions. One repetition is when the weight has been lifted then returned to the starting position. For example, in a bench press, one repetition would be lifting the weight until the elbows are straight (but not locked), and lowering it back to the chest. After six repetitions are completed, the rest period begins. Three sets of the same exercise should be accomplished during each workout. All three sets should be completed before another exercise is begun. Weights should always be lifted slowly and deliberately, being lowered slower than they were lifted. Some find it helpful to lift to the count of 2 and lower to the count of 4.

**A2.3.3. Endurance Resistance Workout.** A 5 to 10 minute warm-up similar to that described for the strength workout should precede the endurance workout as well. The rest periods for endurance workouts should be 1 to 1.5 minutes. Once again, the 1 RM for each exercise must be determined. The 1 RM is multiplied by 0.6 to find the weight to be used for training. Three sets of each exercise are to be completed with each set containing twelve to fifteen repetitions. If desired, endurance workouts may combine two separate exercises that are training the same muscle group. In this case, the individual would complete a set of exercise A, rest 1 to 2 minutes, then complete a set of exercise B, rest, return to exercise A, and so on until three sets of both A and B are completed.

**A2.3.4. Combination Program.** To simply combine both programs for muscular strength and endurance training, use the 1 RM times 0.7 (70 percent). This method will give both strength and endurance gains without neglecting either. The rest period for this workout program should be 1.5 to 2 minutes. There should be three sets of eight repetitions.

**A2.3.5. Reevaluating 1 RM.** 1 RM should be rechecked after four weeks of training in order to increase the weight being lifted as strength increases. Another way to increase weight is to add 5 to 10 percent more weight once a person is able to complete an additional two repetitions at the current weight for the strength program or an additional four repetitions for the endurance program after completing the last set.

**A2.3.6. High Intensity Circuit Training.** This strength and endurance training program is a high intensity activity. Exercise sets are performed one muscle group after another. 60% of 1 RM is used, exercises are performed at 12 - 15 repetitions for each exercise. A sample exercise rotation would be as follows: 12 repetitions of quadriceps, hamstring, calf, butt then abdominal group. A two minute rest period then begin again. Three times through this circuit constitutes one exercise session. Once you can complete the exercise session with 12 repetitions each exercise work to reduce the rest period to 30 seconds. Cardiovascular training must be accomplished along with this workout.

**A2.4. Specific Exercises.** Regardless of the type of program (strength, endurance or combination) being followed, it should include at least two exercises for each of the muscle groups listed below. For specific exercises you should consult the local Aerospace Physiologist, human performance team member, Exercise Physiologist, or fitness center instructor.

A2.4.1. Legs: leg extensions, leg curls, quarter or half squats, lunges, and toe raises.

A2.4.2. Chest: wide and narrow grip bench press, incline bench press, fly's, and pullovers.

A2.4.3. Arms: biceps curls, triceps extensions, and dips.

A2.4.4. Abdominals: stomach crunches, cross crunches, leg drops, reverse stomach crunches, and flutter kicks

A2.4.5. Neck and shoulder: shrugs and upright rows.

A2.4.6. Butt: flutter kicks and, quarter squats.

**A2.5. Aerobic Conditioning.** In addition to weight training, it is important to participate in some type of moderate aerobic training. Aerobic conditioning develops a stronger, more efficient heart and increases the blood supply to the working muscles which will significantly reduce recovery time between engagements and sorties. In a combat situation, more aerobically fit individuals will better tolerate the multiple sorties per day schedule. The recommended program consists of 20 to 60 minutes of activity, three times per week, at an intensity that elicits a heart rate in the target zone for that individual. [Target heart rate zone = (220-age) x 0.6-0.9] Another way to measure intensity is a talk test: while performing any aerobic activity the participant should be able to converse with relative ease and breathing should not be labored. The type of activities which lend themselves to aerobic conditioning include: running, jogging, swimming, cycling, rowing, stair climbers and aerobic dance. Activities not included are: racquetball, basketball, golf and tennis [these are good fitness activities but they do not rely exclusively on the aerobic system for the energy required].