

## Air to air refueling : A comprehensive aeromedical overview

Gp Capt VN Jha\*, Air Cmde UB Mathur VSM (Retd)#

### ABSTRACT

Air to air refueling (AAR) has become a reality in the IAF. The usual fighter operations of 45-60 min could now become a 5-6 hours sortie. The refueler is also capable of flying for more than 12 hours at a time. For these long duration sorties, strengthening of the weakest link i.e. the man, in the man-machine-mission concept, has become essential. The pilots require in-flight food, water and urination. Oxygen management becomes critical both in terms of prolonged in-mask safety pressure and the on-going practice of using 100% oxygen during night flying. Lowering of the oxygen mask for in-flight feeding during operational flying poses a different problem. Other aeromedical factors including permissible length of continuous vigilance task, aspects of monotony, biorhythm, cumulative aviation stresses, fast changing ground perspectives, strapped confinement to the ejection seat and requirement of stringent physical fitness need equal consideration. Problems related to flight refueler are different from fighter operations owing to its multi-crew, multi-provisioned, high pressure cabin. Isolation of the air refueler director (ARD) in the aft cabin has also been discussed.

IJASM 2005 ; 49(2) : 41-47

**Keywords :** Long duration flying, in-flight feeding, aeromedical issues

With the introduction of Air to Air Refueling (AAR) in the IAF, there will be a sea change in operational planning. AAR permits continuous fighter flying for 5-6 hours, unlike the usual sortie of 45-60 min. Flight Refueler Aircraft (FRA) on the other hand can operate for 6-12 hours. Thus, with the requirement of an optimal physical and physiological performance for such a long duration operation, man becomes a weak link.

During operational sorties, the performance level of the aircrew is required to be kept at an optimum. Deterioration even though insignificant, may not be acceptable due to flight safety concerns.

The following limitations need

consideration:-

**(a) Food.** Pre-flight meals are usually adequate to provide energy for 6 hours. However, high energy demand of some of the aviation stresses may deplete the body glucose / glycogen reserve early. Further, the possibility of reactive hypoglycemia at 2½ hours post meals especially following high carbohydrate diet, needs consideration [1]. In any case, operations of 4-6 hours will impose an additional requirement of nutrients for providing sustained calories to the body. This calls for in-flight feeding at suitable times.

---

\* Chief Research Officer and Head  
Dept of Acceleration and Vestibular Physiology  
Institute of Aerospace Medicine, IAF, Bangalore-560017

# Ex- PMO HQ, CAC, IAF

**(b) Water.** There is a persistent water loss from the body in the form of insensible and urinary losses amounting to approx. 40 ml and 60 ml per hour respectively [2]. The former is directly proportional to the environmental temperature and the latter primarily to the water and salt load. Water loss up to 450 ml (i.e. < 1% total body fluid) elicits no symptom. Losses between 450-675 ml (<1.5% of the total body fluid) causes mild dryness of mouth and thirst, though not jeopardising the performance. This discomfort even though mild, is unacceptable during operational flying.

**(c) Micturition.** Formation of urine in a normal hydrated person is @ 60 ml / hr. Urinary bladder volume in an adult is 500 ml. Micturition reflex starts when urine in bladder exceeds 300 ml, however, that could be controlled voluntarily. Beyond 400 ml, the intra-vesicular (bladder) pressure increases rapidly and causes discomfort [2]. Inflation of anti-G suit may cause significant discomfort with even 300 ml urine in the bladder. Inflation of the anti-G suit can also squeeze and partly restore the sequestered body fluid in the dependent parts of lower limb, thus increasing the circulating blood volume and urinary formation secondary to increase in Glomerular filtration rate (GFR).

The paper is an attempt at formulating a comprehensive Standard Operating Procedure (SOP) for long duration AAR assisted operations, both in fighters and FRA.

### **Material and Methods**

In the absence of existing literature, conceptual draft guidelines incorporating all possible factors and variables relevant to aeromedical concerns of AAR operations, were forwarded to the users for their feedback on its perceived / actual existence in the Indian context. The users constituted the Squadron Commanders,

Chief Operation Officers and specialists in Aerospace Medicine of AAR aircraft squadrons. In addition, users' experience of trials on in-flight meals and in-flight urination, both on ground and in-flight, conducted as separate studies during familiarisation AAR missions was also incorporated in the feedback. All such feedback from different squadrons/bases was obtained for incorporation in the draft paper so as to form a comprehensive aeromedical guideline for AAR operations.

### **Results and Discussion**

The feedback received from the users at different bases were incorporated into the draft guidelines. These are discussed under the following headings:-

- (a) Aeromedical factors
- (b) Operational and other considerations affecting aeromedical factors.

#### **Aeromedical Factors (Fighter Operations)**

**(a) In-flight food.** In-flight feeding must be considered for all single crew operations of >2 hours. It should preferably be a pre-packed, low salt, moderate carbohydrate 300-400 calorie food, to be consumed every 2 hours after the pre-flight meal. Since the oxygen mask has to be lowered while partaking the in-flight meals, the cockpit altitude ought to be reduced at <10,000 ft. The food items could be carried 'in person' or be placed in the aircraft.

**(b) In-flight water.** Requirement of water will be felt after approx. 4 hours of the pre-flight meals, after which mild dryness of mouth or thirst may be felt. Fresh potable water (100 ml) could be had at this stage and every hour thereafter, only to quench the thirst and not to over hydrate oneself. There could be a variation in the requirement of

fluid at different environmental temperatures. It could be fresh filtered / mineral water, in a squeezable polypack or a clear plastic bottle with or without a straw. It should be of a dimension that fits into the pockets of the anti-G suit, carried in person or a place designated for it in the cockpit.

**(c) In-flight micturition.** If the precautions against over hydration are taken, the need for in-flight urination would be felt at take-off plus 5 hours. This fact is supported by the operational trial carried out so far [3]. In case a 5 hour plus sortie is envisaged, it would be advisable to ease the bladder after 3-4 hours rather than waiting for 5 hours by which time, discomfort may set in. There could also be situations when need for in-flight urination is felt earlier due to an over hydration. Provision for in-flight urination is a must.

An important consideration for the micturition will be to put the aircraft on a wings-level controlled flight at least for 5-6 min when the hands will be off controls. Whereas such acts are feasible in aircraft having autopilots [4,5], it is extremely difficult in aircraft without an autopilot [6,7]. For an exigency of uncontrolled urge or extravasation due to anti-G suit inflation in the latter, the crew opted for diapers.

**(d) Vigilance tasks.** The average human capacity for optimum performance on continuous vigilance task is approx. 1 hour, beyond which it starts declining [8]. There however, is a large individual variation besides variables like task complexity, risk margin etc., that make significant difference [9]. Intermittent vigilance task with 20-30 min of break every 2 hours (for in-flight feeding) may be acceptable up to 6 hours. This aspect needs to be studied further with an aim to enhance the vigilance capability of the aircrew.

**(e) Safety pressure in oxygen mask.** Oxygen regulators of fighter aircraft in general provide a

safety pressure of 2-3 mm Hg to the oxygen mask at cockpit altitudes >4 km. The safety pressure is capable of reversing the passivity of the expiration and if exerted over long duration, may cause irritation in throat and also induce an early respiratory fatigue.

**(f) Aircrew equipment.** The flying helmet, oxygen mask and anti-G suit etc. have to be of proper size and fitting. Any tight spot could become a source of considerable discomfort and pain in a long duration flight. On the other hand, any minor malfunction may aggravate during prolonged flight and jeopardise mission completion. Daily pre-flight operational checks by the crew and a monthly check of such equipment by aviation medicine specialist should be ensured. It will be preferable to have an air conditioned flying clothing room to prevent premature aging of the rubber components of aircrew equipment. Feedbacks also have been received from the users for some modifications such as a side opening / sideways running lower part of the zip in the existing flying overall and also availability of a similar type of undergarment that could ease the act of in-flight micturition [4].

**(g) Monotony.** In some of the operations where the cockpit workload is likely to be minimal or R/T silence is warranted, monotony may set in that needs to be broken. Depending upon the operational situation, this could be prevented by introduction of some periodic mandatory checks / procedures, provisioning of a chat frequency with ground / FRA or tuning in the ADF to a pre-designated frequency. Some fighter aircraft have an additional UHF R/T on which a regular communication with FRA / ground could be made.

**(h) Biorhythm.** The duration of the night sorties may superimpose upon the nadirs of the circadian rhythm (mostly between 2300 to 0400 h) when

the performance level of the crew could be low [10, 11]. Preventable measures need to be adopted in the form of pre-flight nap, periodic in-flight check procedures etc. necessitating communication with other aircraft/ ground control. This will ensure that an occasional aircrew does not fall off to in-flight sleep. Some of the countries use alertness enhancing drugs in consultation with the flight surgeon, if the sorties exceed 6 hours [12]. On the other hand, a short acting sleep inducing drug could be prescribed under supervision of aerospace medicine specialist, to an aircrew having cumulative loss of sleep two days prior to the sortie.

**(j) Cumulative aviation stresses.** Prolonged exposure to physical aviation stresses such as heat, vibration, noise etc. are likely to induce cumulative fatigue. The duration of flying involving repeated high +Gz forces and spatial disorientation predisposing conditions (i.e. poor visibility, cloud flying) would need reconsideration.

**(k) Fatigue.** A prolonged vigilance task of solo single aircraft operations, long duty hours including pre and post flight tasks, continuous safety pressure in the oxygen mask, monotony of radio silence and boredom, a deranged biorhythm and excessive aviation stresses could all lead to aircrew fatigue. It has been observed as a common occurrence that the maneuvering for 2<sup>nd</sup> and 3<sup>rd</sup> refuelings becomes increasingly difficult for the crew. A study on this issue is desirable so as to assess its quantum and effect.

**(l) Changing ground/air perspective.** In AAR assisted long duration sorties, both aerial and ground perspective could keep changing due to different weather and geographical features (i.e. plains, jungle, mountains, desert or sea) at different

places in the long stretch of flying. One only needs to be aware of this phenomenon otherwise it may predispose to spatial/geographical disorientation.

**(m) Physical fitness.** Long duration fighter operations is likely to impose an increased physical and mental workload. Aircrew ought to have a greater level of fitness. A pilot with borderline or doubtful fitness must be kept away from such operations. Even minor ailments such as dyspepsia may become incapacitating.

**(n) Motivation and morale.** Long haul flying of 6 hours will virtually consume the entire working day of the crew. If such sorties were to be flown by the crew on successive days, some of his semi-official and personal / family errands may be affected. This needs to be taken care of.

#### **Operational and other considerations affecting aeromedical factors**

Certain operational considerations will directly affect the aeromedical factors of long duration sorties :-

**(a) Autopilot.** Provision of automated flight controls in some form or the other, is a necessity in aircraft having AAR capability. It is the only solution for the crew to take his hands off the controls for in-flight meals and micturition.

**(b) Pressurisation schedule.** Possibility of aircraft pressurisation schedule permitting cockpit altitude <10,000 ft at usual cruise altitude need to be looked into. It will enable the oxygen mask to be taken off during the in-flight feeding. This will also alleviate the problem of the in-mask safety pressure as discussed earlier. Lowering the oxygen mask off the face above 10,000 ft cockpit altitude in fighter aircraft is not recommended.

**(c) SOP on operations.** Review of the SOPs of various operations may be considered which though, allow a permissible cockpit workload for a routine '1 hour plus' sortie, could become excessive for a long haul operation especially in the presence of undue aviation stress. Such stresses are high +Gz environment, cloud flying, heat stress, continuous vigilance etc.

**(d) 100% Oxygen in night flying.** SOP on night flying requirement of 100% oxygen from ground level may also need review. 100% dry oxygen breathing for 5-6 hours of the entire stretch of the sortie may neither be required nor be advisable as it may cause problems like dryness and irritation in throat. It may be advisable to start on 100% oxygen at the ground level and switch over to normal air mix at altitude where oxygen enriched air cuts in through the regulator. This will economise the use of oxygen as well as take care of the safety aspect of the adaptation for night vision (rod function) till oxygen enriched air is available.

**(e) Availability of adequate on board oxygen.** During night flying with 100% O<sub>2</sub> (as per the current practice) it has to be ensured that adequate reserves are available for G-suit inflation wastage, emergency oxygen requirement etc. Otherwise, it will become a limiting factor for the duration of sortie. Selection of anti-G valve to 'OFF' as recommended by some users [7], is not recommended in-flight.

**(f) Lower torso stiffness.** By virtue of being strapped in the ejection seat, the lower torso and limbs become prone to stiffness and aches especially if the duration of the sortie is prolonged. It is advisable to move these body parts periodically to avoid stiffness. Periodic transfer of weight on either sides of buttock will help blood flow to the other side and thus prevent tingling, numbness and

'sleep' of that side of the limb. Similarly, periodic movements of the lower trunk, hip, knee and ankle joints will prevent stiffness. Lower backache is possible due to increased disk pressure following pelvic shift and rotation. This could be prevented by maintaining an erect sitting posture that retains the normal lumbar lordosis of the spine.

**(g) Sanitary care.** A routine sanitary cleaning of the cushion and ejection handle along with the floor of the aircraft cockpit for an inadvertent spill / contact with urine or falling off of the food stuff should be incorporated in the checklists of the post-flight services.

### **Aeromedical Factors (Refueller Aircraft Operations)**

**(a) In-flight food and water.** In-flight feeding must be considered for all operations of >2 hours. It could be in the form of fresh / warm snacks, water and beverages like tea / coffee / soup / non-aerated non-alcoholic drinks etc. The aim of in-flight feeding will be to prevent hypoglycemia (due to depletion of the glycogen reserve), meet the fluid requirement and also provide stimulant / beverages to keep fresh / alert. The snacks could be had every 2 hours in situ, harnessed in to the seat or alternately one after another by the crew if so desired. If the sortie is likely to continue beyond 6-8 hours, a full meal may be had in-flight alternately by the crew 'not on guard'. With the availability of on-board oven in the refueller aircraft, having warm food will not be a problem. For the Air Refueller Director (ARD) seated in the aft cabin, the snacks and tea/coffee could be carried separately in a small hot case and flask. For sorties extending beyond 6 hours, it is advisable to carry an additional ARD crew and change over every 4 hours by descending below 12,000 ft for a short time, de-pressurising the cabin to facilitate the change over.

**(b) In-flight micturition.** An on-board toilet with flushing facility with requisite ground support of 'Toilet Cleaning Trolley' must be made mandatory. With this, the crew will have no problem of periodic easing out [13]. For the ARD, the urine receptacle may suffice. However, if they are to have a change over at 4 hours, they may well use the main cabin toilet. The modification sought in the receptacle of the aft cabin for an in-flight drain out to atmosphere, will have to take into account any possible material failure at those high differential pressures that may cause rapid / explosive decompression.

**(c) Monotony.** In a refueller multi-crew aircraft where inter-crew communication is a rule, monotony may not be a problem. Further, regular in-flight feeding with a hot cup of tea / coffee / soup could keep the crew fresh and alert. The isolation of the ARD in the aft cabin could be of concern in a long duration sortie.

**(d) Fitness and drugs.** Long duration flying demands a greater level of fitness. Those on drugs that require supplementation in-flight, will have to carry in person and take it at the prescribed time.

**(e) In-flight rest and sleep.** For sorties exceeding 6-8 hours, an additional set of crew (i.e. 1 pilot, 1 navigator, 1 refueller director) need to be carried on-board. Provision of as many comfortable beds for rest / sleep for the crew 'not on guard' will be helpful. Organisational needs for authorisation of these additional crew may be catered to.

**(f) Search and rescue.** During long haul flying, local flying zones are no longer relevant. An aircrew taking off from a base in central India may have to be rescued at Andaman Sea or in the

isolated jungles of the North-East. Hence, he needs to be equipped with a standard survival kit. The SAR help will also have to be coordinated accordingly extending to larger areas covering multiple AF Commands and maritime zones.

## References

1. Guyton & Hall. Text book of medical physiology. 10<sup>th</sup> ed. Bangalore, Prism books 2001; 264-265.
2. Turner AN, Savill J, Stewart LH, Cumming A. Renal diseases. In: Davidsons' Principles and Practice of Medicine. 19<sup>th</sup> ed. London: Churchill Livingstone, 2002: 581.
3. Chakraborty D. In Flight Ration : Jaguar aircraft. A report by AF Stn Gorakhpur, vide 17W/1918/1/Med dated 02 Dec 03.
4. Jha SK. Report on in-flight urination in Mirage-2000 vide Report No.40W/1130/1/Med dated 17 Mar 2004.
5. Feedback from users on aeromedical aspects of AAR in SU aircraft vide report no. 15W/631/1/Med dated 09 Jul 04.
6. Chakraborty D. In-flight urine disposal – use of diapers. A trial conducted at 17 Wing vide 17 W / 1918 / 1 / Med dated 09 Mar 2004.
7. Feedback on Aeromedical aspects of AAR, observations and comments by users (Jaguar) vide 17W/S 20/1/9/Air dated 08 Jan 04.
8. Nicholson AN. Aircrew and their sleep. In: Ernsting J, King P eds. Aviation Medicine. 2<sup>nd</sup> ed. London: Butterworths.1998:580-584.
9. Rosekind MR., Gander PH, Gregory KB, Smith RM, Miller DL, Oyung RL et al. Managing Fatigue in Operational Settings. Physiological Considerations and Countermeasures. Behavioral Medicine. 1996; 157-65.

10. Hawkins FH. Human Factors in flight. 1<sup>st</sup> ed. New Delhi : Himalayan Books. 1989: 41.
11. Jha VN. Aircrew rest schedule in Ops. Flight Safety Vol LIX, Oct 1999.8-12.
12. Naval Strike and Air Warfare Centre USA. Performance maintenance during continuous flight

operations. NAVMED P-6410). 01 Jan 00. A report circulated by IAF vide Air HQ / 26521/1/29/Med-8 dated 05 Mar 03.

13. Feedback from the users FRA, vide 78S/S 7007/1/ Air dated 09 Jan 04.