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DEFENCE

Tanks for 2000 and beyond

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Air Defence Choices

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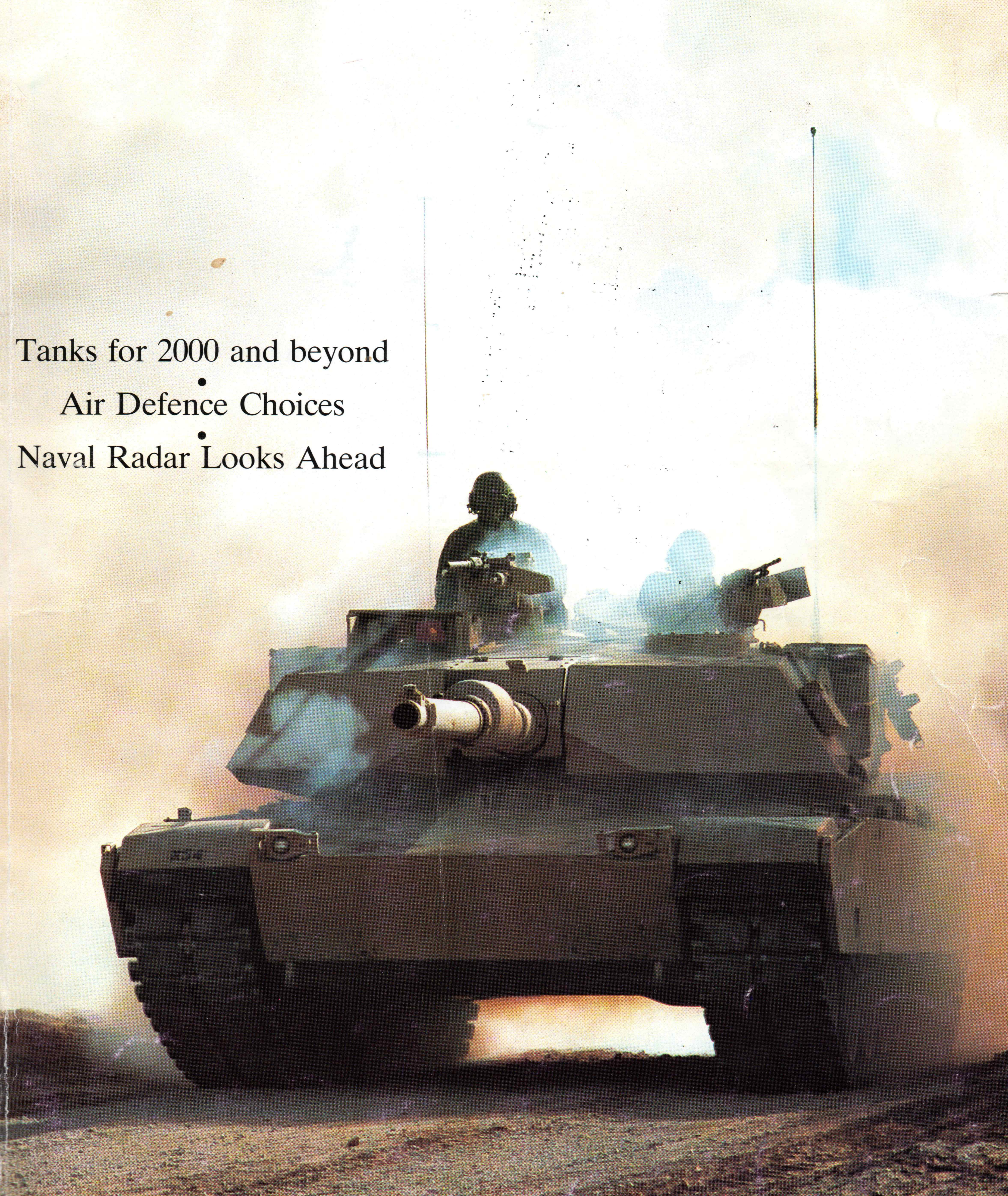
Naval Radar Looks Ahead



Technology

CF-188 Hornets of Canada's 409 Sqn, based in Germany: Some of the paraphernalia of flight safety equipment (helmet, oxygen mask and seat restraints) can be seen. Is the pilot suitably equipped to survive the physical forces imposed on him by his high-tech mount? (Photo: Canadian Armed Forces)

The fighter pilot's real enemy

As fighter speeds increase and agility assumes a pressing urgency in the fighter design requirements, severe physical strains and stresses are imposed on the pilots of such aircraft. The need for life support systems to cope with this severe environment appear to have been secondary in the development of fighter technology. *Defence* looks at the major problem for pilots of today's high-performance combat aircraft – G-induced Loss of Consciousness (G-LOC).

by Vince Santoro

"Over the azure skies of the Persian Gulf, an Iraqi Mirage F1 prepares for a 'dog-fight' as it manoeuvres behind a US Navy F/A-18 Hornet. The Hornet has flown into enemy territory from the flat, treeless landscape over Iraqi-controlled ports. The dust-coloured sky makes it difficult for the pilot to discern the horizon. The 22 year-old pilot in the F-18 cockpit quickly veers away but the Mirage matches him, move-for-move. The Hornet pilot disregards the myriad of information displayed in his HUD and instrument panel, pushes the throttle to increase speed and tries to outmanoeuvre his enemy.

"As the 'Top Gun' graduate pulls his turns in repeated accelerations, he begins to feel the effects of the G forces – his oxygen mask presses against his face; his skin feels like it's coming down his face and his breathing becomes heavier. He begins to see dots, his vision turns grey and then black. He ignores all these warning signs and then loses total consciousness. His fighter spins out of control. He becomes victim to his enemy."

Had the above scenario actually happened, the pilot would not have been killed by the Mirage, but his own inability to take advantage of the capabilities of one of the most sophisticated flying machines ever devised. Those inabilities are brought about because a pilot cannot overcome the psychological and physical demands placed upon him and because the aircraft is poorly equipped with a life support system to prevent the most dreaded scenario, G-induced Loss Of Consciousness – G-LOC.

His fighter is so technologically advanced that it pushes him beyond his human physiological limits. Yet there are many scientists today who believe that more technological improvements will give a pilot what he needs to win a 'dog-fight'. What they have not realised is that more technology is the pilot's real enemy.

The technology that exists today, in an F-18 for example, is enough to question a pilot's physical and psychological ability to handle the fighter. The F-18 is equipped with just about everything a pilot could dream about from imaging infrared Maverick missiles to an XN-6 mission computer with high processing speed that interfaces with control systems to help the pilot achieve his mission goal.

Yet is this built-in technology more than a pilot should be asked to handle? What seems to be needed is not a human pilot but, rather, a mechanical one to compliment the flying machine and not break down when both pilot and fighter are needed the most. But still engineers, technicians and scientists insist that more technology will minimise a pilot's problems.

More technology does not, necessarily, mean building a more sophisticated fighter but making changes to a pilot's life support system to enable him to overcome physical demands. Part of that system is the traditional G suit – an inflatable garment that squeezes the abdomen and legs to prevent blood from 'pooling'. This allows better circulation of blood while making high-speed turns.

Dr Manny Radomski, chief of the Defence and Civil Institute of Environmental Medecine (DCIEM) in Toronto, says, "A pilot with a traditional [G] suit and less G tolerance doesn't want to pull too many Gs". According to Dr Radomski, "A big problem is preventing blood from pooling," and even though the traditional G suit – a configuration that is over 40 years old – helps prevent blood from pooling, "a fully integrated G protection system will significantly increase G tolerance. What's been happening is that with this integrated system a pilot can concentrate on his work load or target acquisition."

Problems of Integration

Integration involves adding other devices to further help prevent the blood from pooling and to help the pilot breathe easier. These additional measures, such as pressure vest and an improved mask-and-helmet, are designed to diminish the effects of G forces – effects that can seriously impair a pilot and his ability to fly, specifically G-LOC. G-LOC is defined as "a state of altered perception wherein [one's] awareness of reality is absent as a result of sudden, critical reduction of cerebral blood circulation caused by increased G force". Studies have shown that an average of 15 seconds is lost before a pilot regains consciousness from G-LOC. A fighter travelling at 500mph could lose 10,000ft (3,048m) in a dive during those 15 seconds. In the last five years, more than 20 US pilots have died in aircraft accidents, possibly as a result of G-LOC. Also, according to a 1985 survey of 1,900 US pilots, it was revealed that the second most common cause of G-LOC-related accidents was the inability of the G-suit to provide sufficient protection.

DCIEM's aerospace physiologist, Dr Fred Buick, describes what happens as a pilot reaches G-LOC. "Just as your body becomes heavier at nine Gs, so does the blood in your cardio-vascular system. The blood in the system that is also exposed to the G-forces tends to want to pool. The problem is that while the blood stays at the lower extremities, it doesn't get back to the heart and if it doesn't do that then it can't get to the head. If you have no blood in the head, you also have no oxygen and, therefore, can lose vision and consciousness."

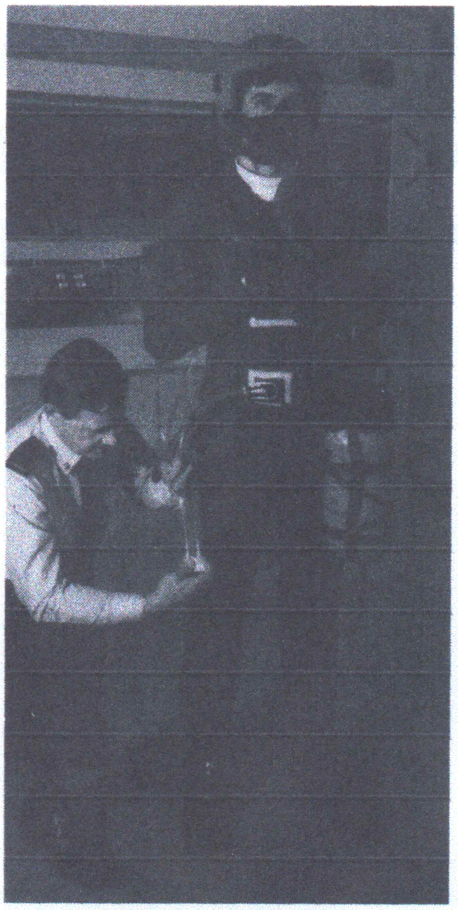
G-LOC is not a new phenomenon. It was first identified in Great Britain during the First World War and was described as "fainting in the air". It took scientists almost half a century before they made any serious attempt to give pilots more protection from the hazards affecting their performance. The introduction, in the mid-1940s, of the first G suit (pioneered by Dr W. R. Franks of the RCAF) seemed to provide the answer to "fainting in the air". Other equipment, such as the pressure vest or jerkin, was also being developed during this time, by another Canadian, H. C. Bazett. Yet advancement of the concepts behind these garments moved relatively slowly compared with the rate of technological advance in aircraft, such as the F-16 and F-18. Scientists neglected basic human limitations and concentrated on making sophisticated fighters. Now the focus has shifted and the goal is to find ways to increase G tolerances.

According to Dr Radomski, a fully-integrated tactical life support system (TLSS) should significantly increase G tolerance. The TLSS programme began in the early-1980s, prompted by the USAF's growing concern with G-LOC. The Statement of Requirement in 1982, issued by the USAF, detailed provisional requirements for a 'get-me-down' protection system from 60,000ft, improved sustained G-protection for up to 9G and thermal conditioning for pilots at cockpit temperatures up to 50°C.

The integration system includes the suit, pressure vest, an improved helmet and the technique of 'pressure breathing', which is caused by the breathing regulator pressurising the air in the lungs. "This type of ensemble is now being flown in a typical 'Top Gun' scenario by the US Air Force," says Dr Radomski. However, its effectiveness is questionable because it has not been totally tested.

Sharp Turns

So, now we have a pilot at 24,000ft making sharp turns to get away from the enemy. The G forces trigger the G-valve to begin pumping air pressure to the G suit, causing it to inflate, creating pressure against the abdomen and legs, which reduces pooling. The bladder behind the improved helmet inflates automatically and pulls the mask tightly against the face. The pilot then feels the effects of pressure breathing, which is similar to trying to inflate a balloon. This means that the greatest effort is in exhaling and, if the pilot is not careful, this could result in some serious damage to his lungs. As the air in his lungs is pressurised, the pressure vest kicks-in. As he pulls the high Gs, the vest also starts to inflate, thus creating pressure and counter-pressure against the chest, helping the pilot to breathe easier. All of this for an extra 2G tolerance above what the G suit would normally offer.



Bob Michas, life support engineer, DCIEM, suits up with help from technician Jean Steffler to demonstrate the tactical life support system made up of the standard anti-G suit, pressure vest, and improved helmet. (Photo: via author)

Eliminating G forces all together is impossible. Physiologist Dr Buick admits that, "The G forces will always be there. You can't take them away. All we're trying to do is improve the life support system and reduce some of the physiological effects of G forces."

In addition to the physical aids to combat G – G suit, pressure vest and improved helmet – a pilot has to perform anti-G 'straining' manoeuvres (AGSM) in order to prevent G-LOC. These AGSMs consist of vigorously tensing arm and leg muscles to minimise pooling of the blood in the extremities. There is a lot of physical work involved while pulling Gs and it is obvious that pilots have to have excellent strength and endurance.

Pilots are taught the straining manoeuvres and how to improve their endurance in the centrifuge. The difference is that, in the centrifuge, the biggest obstacles to overcome are the G forces. In the air, a pilot has to fight the enemy, the G forces and his aircraft. It is difficult to operate the systems and fight the enemy at the same time. There is no time. Time is everything. And time is gained only through speed. To a fighter pilot, "speed is life".

Speed is Life

This notion of "speed is life" goes as far back as early air combat. The basics of 'dog-fighting' have not changed. It is the ability to manoeuvre from in front of the enemy to behind the enemy. After the pilot manoeuvres his fighter into this position, he shoots and hopes to hit either the enemy plane or enemy pilot. The main difference, however, is that in 1917 a typical visual siting distance of 20 miles between enemy fighters would give each pilot enough time to plan their strategy. Today, two fighters 20 miles away from each other flying at more than 500mph each is about 60 seconds away. Hardly enough time to plan an attack.

Somewhere in the evolutionary process, it was determined that speed was more important than agility. Therefore, if you could spot the enemy and be able to get to him within seconds, you had a better chance of success. This belief in speed over agility was so strong that the F-4 Phantom, introduced in 1956, was designed without a gun. With such fast-moving fighters, a pilot could never get close enough to use a gun. As air-to-air missiles replaced the gun, technology introduced another problem.

These missiles not only travel at supersonic speeds but can follow a fighter as if it knew its every move. And missiles are not only launched while in the air but also from the ground. Surface-to-air missiles (SAMs) travel at the speed of sound and explode a few feet from a fighter. The pilot needed more help and so technology introduced a computer that 'talks', known as a voice-warning system.

Unlike an F-18, the F-16 has a computerised voice-warning system. If the computer determines that the pilot is diving too quickly, it will tell him so. If the pilot does not respond, either because he did not hear it or he has passed out because of G-LOC, the computer will take over and fly the fighter to safety. But pilots are 'artists' and want to be in control of their fighters at all times. Studies of brain waves indicate that the right side of the brain governs our artistic talents while the left side is the decision-maker. If we apply this to pilots, it can be related to their natural desire to be in 'artistic control' of their fighter.

Meanwhile, the left side of the brain checks the data and makes the decisions. Periodically, the two sides check with each other to make sure everything is all right. But when a pilot flies at 600mph; pulling nine Gs to avoid being shot at by the enemy; dodges SAMs; performs anti-G straining manoeuvre breathing techniques; listens to a computer telling him what to do: and tries to read the instruments in the cockpit – the left side of the brain has to work harder. Soon the brain does not know who is in control. There are too many things happening, too many things to do at the same time. There is no balance and the brain can no longer handle the situation. The result is 'information overload' and when you add G forces, you get a serious problem called the 'biology barrier'. This barrier is unique as it is created for the pilot by the adverse effects of G forces and the overload of information to the brain. The mind and the body are no longer in balance.

To overcome this barrier, technologists are developing another type of helmet: one which gathers information and projects the results in 3-D. All the pilot has to do is respond by voice command and the fighter does the rest. The only problem is that, at present, the helmet is too bulky and cannot fit in a cockpit, nor can the pilot move his head with relative ease. This is, perhaps, another step closer to replacing the human pilot with a mechanical one.

It is obvious that when engineers were designing fighters, they did not bear the pilot in mind. Engineers were interested in solving engineering problems, not human ones. Bob Michas, life support engineer at DCIEM, agrees. "Traditionally, pilots were low in priority when designing an airplane. Engineers want certain functions that they want the plane to perform. Then later they add the life support system. But the human body has critical limitations." Today, that approach is changing and pilots are considered more and consulted in the initial stages of development. Their input, as part of the engineering team, helps design a fighter that takes into account human limitations and makes it necessary to strongly consider the right type of life support system for the new generation fighter. But these new approaches have come too late for the thousands of pilots who have to try and handle the sophisticated fighters in service today. It is a problem shared by all countries that have high performance fighters.

Michas believes that, "all the [air] forces in the world are experiencing the same kinds of problems and looking into the same kinds of solutions." He points out that the biggest problem is integrating all the various components that make up the life support system. It is not an easy task, especially when considering protection against G forces, but one that has been long overdue.

Combat Experience

The Vietnam war saw too many US pilots die, given the level of the enemy's fighter technology and pilot expertise. The Alt Report identified the deficiencies that caused two and a half enemy pilots killed for every one US pilot = a significant drop from the Korean war of 13 to one. Pilots lacked skills in identifying threatening situations and how to manoeuvre from in front of the enemy to behind the enemy fighter. Something had to be done. It was not the enemy that caused the deaths, it was the pilot's inability to 'fight' his aircraft.

As a result, the US Navy initiated 'Top Gun' in 1971, closely followed by the USAF's 'Aggressors', to train pilots to be well versed in 'dog-fighting' tactics. When the graduates returned to Vietnam one year later, the kill ratio changed. For every one US pilot killed in combat, 13 enemy pilots were killed. 'Top Gun's' motto served them well – "Fight like you train and train like you fight." The motto was as good as the Red Baron's, in the First World War, "It's not the crate but the man sitting in it that counts." However, for engineers it seemed that the 'crate' mattered more than the man. So just when you think you have solved one problem, another surfaces.

Chemical warfare is the latest challenge for technology. Dr Radomski explains that challenge. "If a pilot battles in a chemical warfare environment, there are other problems and challenges. The life support system needs to be supplemented. For example, a chemical suit consisting of the G pants, with bladder, must be completely sealed to prevent seepage of chemicals. The pilot must wear rubber gloves and charcoal impregnated underwear that act like a filter." However, this solution causes another problem.

Since the body generates considerable heat, the chemical suit will add to heat stress. In order to keep the pilot cool, a water-cooled vest is being developed. But this will require a refrigeration system and it has to be fitted into the cockpit. Cockpits are small and everything already is tightly packed. Engineers not only have to miniaturise the refrigeration system but also find a place for it in the cockpit. The heat that is generated from all of this presents yet another problem.

"Blood vessels open up and increase the chances for the blood to pool," says Dr Radomski. "Also, if the pilot is on a long flight or in a chemical environment for more than a day or even a couple of hours, he has to replenish the water. The trick now is how to get water in him and keep it chemical-free. It is a huge problem and expensive too."

Today, scientific and philosophical debate over what constitutes chemical warfare does not help the fighter in the Gulf. Canada's 409 Squadron's aircrews and groundcrews have trained to dress in cumbersome protective suits. Even if the suits are designed to protect someone from lethal gases, there is still the desert heat to contend with.

Today simulator test grounds and training missions are the closest thing to war. But as realistic as the scenarios may be, they are not 'the real thing'. In a simulator, a pilot always comes out alive, not necessarily so in a war. Only the pressures of flying have been simulated, not the total environment. If a pilot has a difficult time taking advantage of his fighter because of the human limitations, then he certainly can do no better in a real 'dog-fight' situation.

There is no doubt that a fighter pilot's job is one of the most demanding in the world and, as demands increase, so do the problems. The circle is vicious. As he pulls 12Gs, there is also the never-ending escalation of problem-solution-problem-solution- etc., which places the pilot in greater jeopardy.

Someone once said that "the chief cause of problems are solutions". In this case, the chief cause of technical problems are technical solutions. More technology for the pilot is not the answer although it may be for the aircraft. The creation of a robot pilot, able to respond to any situation as efficiently as the fighter itself, may be the way of the future. It will not only solve problems with how to deal with human limitations, but more importantly, it will save lives – pilots' lives. ■

A pair of Saudi Tornado IDS strike aircraft fly low over the Arabian peninsula. Low flying is standard operating procedure for many strike profiles and imposes particularly physical problems for aircrew.