by Carlo Kopp

MAN PORTABLE MISSILES VS AIRLINERS

The recent media debate over the threat of terrorists using MAN Portable Air Defence Systems (MANPADS) or shoulder launched surface-to-air missiles against airliners understates in many respects the complexities of the issue involved.

With hundreds of thousands of rounds manufactured worldwide since the 1960s, MANPADS are among the most common guided weapons in service, and a technology which is almost impossible to prevent from proliferating. Expectations that border controls and interdiction will successfully prevent such weapons from falling into the hands of terrorists are quite unrealistic, at best such measures can only slow down the problem.

Like narcotics, MANPADS are a compact high value commodity which are easily concealed and easily smuggled. In the hands of a competent operator who knows how to exploit the strengths of these weapons, they can often be highly effective against a wide range of aircraft. But overstating the effectiveness of these weapons can be as dangerous as understating their capabilities.

In the airpower debate MANPADS have not been a major issue – classed as 'trash fire' and regarded to be relatively ineffective, not unlike barrage small arms and artillery fire, MANPADS are seen as a risk primarily to low flying 'slow movers'. Helicopters, tactical transports, observation aircraft and low flying close air support platforms are most at risk. For a high flying or fast moving tactical jet at the edge of the MANPADS kinematic envelope, these weapons are deemed more of a nuisance than a real threat. While MANPADS were by far the most successful SAMs employed during the 1991 Gulf War conflict, this success was dubious in terms of the number of missiles fired and the number of aircraft which recovered safely after taking hits.

The game changes very much if the target is not a military aircraft hardened to sustain and survive enemy fire, and flown tactically to make life very difficult for the MANPADS shooter. An airliner on takeoff is close to an ideal target for a MANPADS – low, slow, heavily laden with kerosene, unmanoeuvrable, emitting a vast infrared signature and presenting a large area to hit even by a missile which has relatively inaccurate homing guidance.

There are no simple panacea solutions to the MANPADS threat, as will become obvious with a closer exploration.

A MENAGERIE OF MISSILES

The first MANPADS to enter operational service was the US Army's FIM-43A Redeye, introduced during the early 1960s and produced until 1970. The weapon established the now dominant model for such weapons – an infrared guided rolling airframe missile with some variation on the pursuit or proportional navigation schemes, ejected from a bazooka-like shoulder launch tube. While European manufacturers largely sought a different path with command-to-line of sight and beam riding missiles like the Blowpipe, Javelin and RBS-70 series, the US and SovBloc put their investment exclusively into heatseeking missiles.

Numerically by far the most important MANPADS today is the SA-7 Grail family, which has both evolved, been licence built and also cloned by a number of nations. Widely available in the arsenals of developing nations, SA-7 Grail variants are the most likely weapon to be used by a terrorist targeting a passenger aircraft.

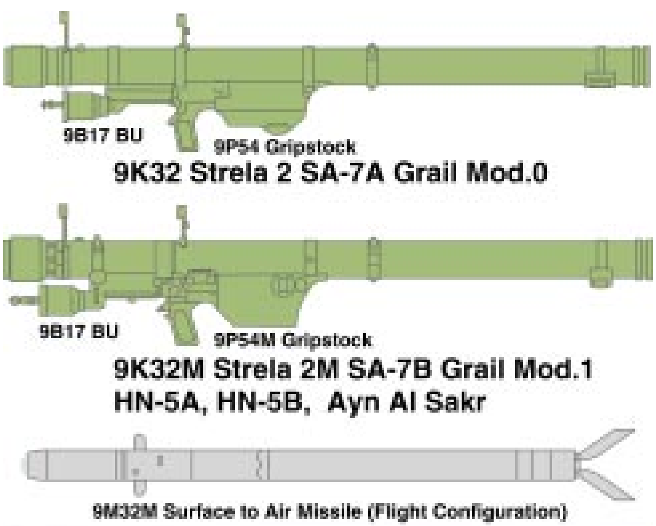
Flares remain widely used as countermeasures against heatseeking missiles. Dispensed while the missile approaches the target aircraft, the flares are intended to seduce the missile away. While highly effective against first generation weapons like the SA-7B which use primitive guidance and simple IR filters, they can often be quite ineffective against newer missiles with two colour seekers and advanced signal processing in the guidance package. In Australia flares would present a genuine bushfire hazard if dispensed by RPT aircraft.Depicted is a maximum effect flare release (wisely over water!) by an RAAF C-130H. (Defence PR)

The original 9M32 Strela 2 'Perenosniy Zenitniy Raketniy Kompleks' (PZRK or Portable Air Defence Missile System) had a convoluted development history. During the late 1950s the FIM-43A impressed the Soviet General Staff and the Tushino based Toporov OKB, who previously reverse engineered the AIM-9B, were nominated to develop the weapon. The resulting weapon, which entered service in 1966, was in many respects a clone of the FIM-43 series and analysts often speculate that technical intelligence played a large part in its design. Regardless of this, the rolling airframe heatseeking design concept adopted inevitably leads to similar end products. The basic weapon package comprises the 9M32 missile in a 9P54 fibreglass launch tube, the reusable 9P53 gripstock connecting to the missile via a 24 pin harness. A set of four removable thermal batteries is provided with each 9M32 system.

The baseline 9M32 uses an uncooled lead sulphide detector (PbS) sensitive in the 2 micron 'shortwave' infrared band, and capable of tracking only an exposed tailpipe. Cited acquisition ranges for this seeker vary between 600 and 2100m but the relatively primitive reticle seeker was susceptible to seduction by sunlight reflected off clouds and bright terrain features. Propellant performance is often regarded to be mediocre and the missile is usually credited with a top speed of 385 metres/sec (mildly supersonic) and an effective range inside 3.7 kilometres (2nm). The baseline warhead is a 1.8kg blast/fragmentation device with 0.4kg of RDX/Aluminium explosive.

In operation the shooter will engage the thermal battery when the target is sighted, the battery nominally operates for 60 seconds but is reported to often exhaust itself earlier.

The mostly widely deployed MANPADS is the ubiquitous SA-7B Grail, available in Soviet, Chinese HN-5 series and Egyptian Ayn Al Sakr variants, and indigenously upgraded variants operated by other former Soviet clients. The SA-7 series typically use uncooled lead sulphide seekers, but late models are credited with a limited all aspect capability. Given the vast numbers of these missiles exported to developing nations over a three decade period, the most likely weapon to be used by terrorists is an SA-7B variant (Author, PLA).



The shooter will then attempt to acquire the target. The gripstock produces a tone and a green light in the sight comes on once the seeker has detected the target's signature. The trigger is then depressed halfway to uncage the seeker, and the reticle gyro is spun up in 4 to 6 seconds. The aiming sight has markers to aid the shooter in estimating the lead angle for the shot. Full trigger depression results in a launch – the ejector charge expels the 9M32 round from the tube at 28 metres/sec, while imparting initial axial spin, upon which the boost/sustain motor ignites and accelerates the weapon to full speed inside two seconds. The contact fuse is armed 45 metres into the flight. Missile control is effected by a pair of canard surfaces, using a rolling airframe control law.

The 9M32 was first fired in anger in 1971 over the Suez Canal, when one embedded itself in the tail of an Israeli jet and failed to explode. By mid 1972 the SA-7 was being fired in South Vietnam in large numbers accounting for 45 aircraft in 500 launches by the time of the US withdrawal. The initial kill rate of 33% soon dropped to several percent with evasive manoeuvring and the use of flares. Most kills were against helicopters and slow moving prop transports and fire support gunships.

The 9M32 performed poorly in the 1973 Yom Kippur war as most of its targets were fast and agile tactical jets with pilots expecting the threat.

The conflict where the 9M32 was seen to perform best was the final phase of the SE Asian conflict in 1975 where the 9M32 took a devastating toll on the South Vietnamese AC-47 and AC-119 gunships and A-37 strike aircraft. The 9M32 attracted little further attention until the escalation of the Rhodesian civil war where missiles fired by black nationalists downed two Vickers Viscount turboprop passenger aircraft (registrations VP-WAS, YND).

The Afghan conflict saw the 9M32 in use again when CIA and Arab nation supplied missiles used by Mujahedeen successfully destroyed several helicopters and transports. The Russians responded by dropping flares and fitting IR suppressors to helo exhausts, countering the 9M32's simple seeker. The Afghans were subsequently supplied with Stingers and Blowpipes, the former achieving a good kill rate throughout the conflict.

The baseline 9M32 SA-7A was supplanted by the improved 9M92M Strela 2M or SA-7B in 1972. The 9M32M saw numerous improvements. The 9P58 gripstock interfaced to the improved missile via a 28-pin umbilical. The missile seeker was equipped with an infrared bandpass filter to reduce susceptibility to unwanted infrared sources, and a much improved propellant increased speed to 580 metres/sec and range to 5500 metres.

The 9M32 and especially 9M32M were exported by the Soviets to almost every client state in the SovBloc, be they Warpac members, allies in the developing world, or even 'revolutionary' movements feeding from the Soviet aid trough. China cloned the 9M32M as the 'Hong Nu 5' or HN-5. The HN-5 was replaced in production by the improved HN-5A which has a cooled infrared seeker to improve detection range, and later the HN-5B. The Egyptians also cloned the Strela 2M as the Ayn Al Sakr and likely exported it to other Arab nations. Pakistan also manufactured an SA-7B clone, the ANZA MK-1, which is reported to be based on the Chinese HN-5B series clone.

The vast number of original and cloned SA-7 variants exported in the developing world make this the most likely MANPADS to be used by terrorists, but not the only possibility.

The Soviet successor to the 9M32 series was the 9K34 Strela 3 or SA-14 Gremlin. In appearance very similar to the 9M32M, the Strela 3 has notable improvements. The 9M36-1 missile has nearly double the warhead mass, an improved rocket motor, improved guidance electronics, and most importantly a nitrogen gas cooled lead sulphide detector. The 9P59 gripstock mounts the distinctive spherical 9P51 battery/coolant module containing a thermal battery and gas bottle. The missile is credited with a range of 600 to 6000m, and altitude of 50 to 6000m.

The Soviets sought further improvements in the Strela series and deployed the 9K38 Igla or SA-18 Grouse in 1983. It used a substantially better 9M39 missile design, with a distinctive tail design. Most sources indicate the main improvements were in the seeker, which used a proper proportional navigation guidance algorithm and had further improvements to defeat countermeasures. The 9K38 was followed in production by the 9K310 Igla or SA-16 Gimlet. It is credited with a two colour seeker, making it an equivalent to later models of the US FIM-92 Stinger, and capable of all-aspect engagements. Poland introduced an Igla derivative called the Grom. The Igla series was the subject of the successful FBI sting against arms dealer Hemant Lakhani in August this year.

China further developed its HN-5 series, producing the Qian Wei 1 (QW-1) missile during the 1990s. This missile has a distinctive vertically mounted cylindrical battery/coolant module, and uses an all aspect gas cooled Indium Antimonide (InSb) 'midwave' 4 micron band detector, capable of all aspect engagements. The missile is credited with a 16G manoeuvre capability, and a 5000m range. Pakistan began licence production of this missile in 1994, and called it the Anza MK-II. China also improved the QW-1 and is now marketing the QW-2 derivative.

Other than Soviet and cloned Soviet MANPADS, the possibility of western built weapons being used cannot be discounted. The most likely candidates would be early variants of the FIM-92 Stinger (originally named Redeye II), specifically examples of FIM-92A and B models provided during the Afghan campaign against the Soviets and never accounted for. Unlike Soviet and cloned missiles for which spare batteries can be easily sourced, replacing time expired Stinger Battery/Coolant Unit (BCU) modules could present a challenge. The French Mistral, equivalent to late model Stingers, has been exported to a number of Middle Eastern and Asia Pacific nations.

As even a superficial survey illustrates amply, there is enormous diversity in the number of missile types which could be used by terrorists. While the most likely candidate missiles are older types, the wide availability of newer weapons means that they cannot be ignored. This in turn means that defensive measures must account for a wide range of missile technologies.

China has become a major player in the MANPADS export market. The HN-5B MANPADS was supplanted in production by the QW-1 with a cooled Indium Antimonide all aspect midwave infrared seeker. The more recent QW-2 incorporates incremental improvements and is being marketed as an equivalent to the Igla, FIM-92B Stinger and Mistral series. The QW-1 series are easily recognised by the cylindrical BU/BCU module mounted at a right angle to the missile tube. Pakistan is a major export client for the PRC and has licence built the HN-5B as the ANZA MK-I and the QW-1 as the ANZA MK-II.

LETHALITY AGAINST PASSENGER AIRCRAFT

There is no simple answer to the lethality question, given the diversity in missiles, target aircraft, and strong dependencies on engagement geometry and operator skill levels.

In best case scenarios the operator may fire the missile at the limits of viable geometry and it will fall out of the sky before it hits. If it hits with low kinetic energy it may not do much damage. If the missile is time expired the warhead may lose effectiveness or the fuse may fail. However, reliance on such factors is policy by guesswork and not a sensible idea.

If the missile used is an older design, with a cooled or uncooled seeker, and properly operated, the shooter will opt for an aft hemisphere shot against a climbing target. The missile will track the exhaust plumes and as it nears the target, select the brightest infrared source, either the nearest engine or the engine at the highest throttle setting. Depending on missile type and engagement geometry, the weapon may fly up an engine tailpipe, impact an engine nacelle, cowling or pylon, or even the aircraft's wing. A newer missile with a two colour seeker fired in the forward hemisphere may track the aircraft's centroid rather than engines, and impact the fuselage or centresection.

How much damage is done by a missile impact will vary significantly with target aircraft type, engagement geometry and missile type. In principle the missile will inflict damage through the kinetic energy of a metal tube impacting with a relative velocity of hundreds of metres per second, if the warhead works as intended this damage will be enhanced by the blast effect of the 0.3 to 0.5kg of high explosive, and the puncturing and shredding effect of the kilogram or more of warhead casing.

A missile entering an engine tailpipe will destroy the engine hot end, and often sever fuel lines causing an engine fire which may or may not respond to onboard fire extinguisher discharge. Hot turbine blades are likely to further enhance the damage effect, especially if the warhead can cause the turbine shroud to break up. As a result the wing or fuselage around the engine may be punctured by high velocity and hot engine parts, aside from warhead spall and fragments.

An impact on an engine could inflict enough damage to produce an uncontrollable engine fire, with the possibility of a fuel fire occurring outside the engine and beyond the effect of the extinguisher systems.

If the missile impacts the nacelle from the side rather than entering the tailpipe, the damage effects could be less severe as the engine casing and nacelle cowls must be punctured before the rotating parts can be destroyed.

Another possibility is the missile impacting an engine pylon or wing near the engine, not impossible given the primitive guidance control laws and low G capability especially of older MANPADS designs. A pylon impact could produce enough structural damage for the engine to separate as the pylon is under load mechanically, or it could cause a fuel fire.

A wing impact could cause two principal damage effects. The first is where the missile body impacts a spar – depending on the load bearing member design of the wing this could cause a catastrophic wing failure. The other damage effect is fuel tank puncture and fuel ignition, not unlike the Concorde tragedy.

To say that every SAM hitting an airliner is a guaranteed kill is to misunderstand the complexity of the problem. In a worst case scenario the aircraft could be lost

Russia remains a significant manufacturer of MANPADS. The 9M32 series was supplanted by the improved 9M34 Strela 3 or SA-14 Gremlin, in turn replaced by the largely redesigned 9K38 Igla or SA-18 Grouse and 9K310 Igla 1 or SA-16 Gimlet. The Igla series of missiles is credited with a cooled two colour seeker making it a technological equivalent to the FIM-92B/C series and highly resistant to flares. The distinctively shaped BCU makes these weapons easy to identify. (Author/Rosoboronexport).

not unlike the Concorde crash, or other situations where catastrophic fires or structural damage occurred. However, other combinations of circumstances could see the aircraft damaged but capable of limping on and making an emergency landing.

In principle the bigger the aircraft and the more engines it has, the better its odds of survival, especially against older missile designs. Most vulnerable will be twin engine aircraft with lower thrust/weight ratios, higher fuel fractions, and lowest structural redundancy.

DEFEATING TERRORIST SAMS

Much public debate has been seen around the issue of how to deal with a situation where terrorists acquire MANPADS and have opportunities to use them against RPT aircraft. To be honest much of what has been said publicly qualifies as bunk.

The idea that terrorists can be prevented from acquiring MANPADS is a little like the idea that drug runners can be denied access to drugs. While western nations with good border controls and Customs will do vastly better than developing nations, certainty is never achievable.

The proximity of major airports to urban areas makes denial of launch sites extremely difficult. While it might be feasible to 'sanitise' the best sites within a couple of kilometres of major runway thresholds, the problem of patrolling larger footprints is simply too hard. An urban slum in a developing nation is an unbeatable hiding place for a two man MANPADS shooter team. Geometry permitting they might even be able to shoot from a backyard – if rooftops are unusable.

In practical terms this leaves two possible approaches. The first is to actively defeat the missile's guidance so it cannot hit the target aircraft. The second is to introduce passive measures to reduce the damage effects of a missile hit, and procedures to deal with a missile hit.

Defeating the guidance system has been the subject of much effort since the 1960s. Flares have proven quite effective against early generation missiles, but the introduction of infrared filters, kinematic filtering in the guidance and two colour seekers in later missiles renders flares nonviable against newer weapons. In Australia flares present another problem – they are a genuine bushfire hazard if dispensed at low level.

The other alternative is the jamming of the seeker with a modulated infrared light source. This technique can be highly effective but usually requires specific knowledge of the reticle modulations used within particular missile seekers. Older generation IR jammers would flash at one or more modulation frequencies intended to seduce the reticle seeker with a false angle signal sending the missile off course. Early generation jammers would flood a relatively wide angle, and thus required a high infrared power output to be effective. Infrared lamps were often used.

A more recent and effective approach is the strategy of directed infrared jamming, where a Missile Approach Warning System (MAWS) or tracking sensor is used to measure the angle to the incoming SAM. A turret with a modulated infrared lamp or laser is then directed at the missile to point a narrow pencil beam of infrared jamming energy. This approach permits much more jamming power to be delivered using a smaller jammer, and a laser system has the potential to saturate the SAM's infrared detector regardless of modulation, defeating it by blinding rather than angle deception.

Whether an aircraft is to drop flares or use a jammer, knowledge of an attack in progress is vital. Missile Approach Warning Systems remain an area of controversy. Three technologies are used – active Doppler radar, passive infrared and passive ultraviolet. For military applications the Doppler radar approach is often rejected as it is

This BAe 125 corporate jet lost its starboard engine to an SA-7 whilst over Southern Africa. Incidentally, the crew thought the engine had simply failed and flamed out as their engine instruments went dead. It wasn't until they landed that they realised what had happened. The object of the attack was to destroy the aircraft and its African Head of State passenger. Note the extensive pattern of missile and engine fragment damage on the fuselage and flaps. Primary and secondary damage effects to structure, fuel, flight control and hydraulic systems can be more lethal than the loss of an engine as evidenced by numerous catastrophic engine loss case studies.

a beacon advertising the presence of the aircraft, leaving the passive techniques which often suffer high false alarm rates. The false alarm rate problem is difficult, as increasing detection range forces higher sensitivity and inevitably higher false alarm rates. A good case can be made that active Doppler radar systems would be best suited for airliner protection as terrorists are not in the habit of deploying multimillion dollar precision ESM receivers.

Active systems for missile defeat present a genuine cost issue for the airline industry if they are mandated, even if this is limited only to aircraft flown into airports known to be at high risk, such as those in developing nations. The cost of fleetwide retrofits of transport aircraft with infrared jammers has discouraged military operators, and at costs of the order of a million dollars per aircraft this would be a killer for any major airline. Two or more jammer turrets would typically be required to effect proper coverage.

Passive measures such as aircraft hardening are much cheaper, but also less effective. Fitting engine nacelle cowlings and pylons with Kevlar or other layered armour could do much to reduce or contain damage effects of an impacting missile. Similarly Kevlar or other laminated panels fitted inside wet wings (as per the Concorde fixes) could much reduce the vulnerability of wing tanks to direct impact damage and especially shrapnel and spalling damage. The cost of such measures would depend on the aircraft and how comprehensive the hardening was.

Given the extensive experience of military operators, there are no issues in introducing such measures other than cost, increased aircraft empty weight and aircraft downtime for retrofits. Nitrogen fuel tank inerting systems, used on a number of military aircraft, could also prove useful, again at a cost. Fuel additives to reduce the potential for fuel fires remain an unsolved problem.

A key issue which has not received any media airplay in this debate is that of cockpit procedures for dealing with a MANPADS attack. Unlike emergencies arising from engine or other technical failures in aircraft, a MANPADS hit is likely to produce wider damage. Standard cockpit procedures may not be adequate most of the time – an engine failure checklist must be supplemented by fire procedures and an effort to assess wider damage to the aircraft. Fixed closed circuit TV cameras covering the lower wings and engines could be vital to saving an aircraft.

Another issue which has not been discussed is that of reducing MANPADS firing opportunities by changing the climb flightpath. A technique reported to have been used successfully in Rhodesia was to fly a 'corkscrew' climb above the airport rather than climb out on the intended heading. This forces MANPADS shooters to get much closer to the runway, making it easier for security forces to interdict them. The cost is increased fuel burn as the aircraft needs to reach 10,000 to 15,000ft AGL before it can safely depart on its desired track.

It is clear that the problem of terrorists using MANPADS against airliners is not one which is easily solved, nor is it one which will be easily understood by lay observers. The problem is technically complex and difficult, and will ultimately require a lot of intellectual effort to solve. Multiple measures will almost certainly be required, both technical and procedural. This discussion has focussed on the technical issues – there remain to be resolved issues of legal liability, insurance coverage and funding.

From a strategic perspective, MANPADS will become an increasingly attractive commodity for terrorists as they permit standoff attacks and rapid escape for the shooters. Not unlike landmines, MANPADS are a relatively cheap and common weapon manufactured widely and extremely difficult to control in a globalised arms market. As western military and security forces continue to inflict attrition on terrorist movements, terrorists will be under pressure to shift tactics increasingly to standoff attacks permitting the survival of the terrorists.

Australia should not choose to ignore this problem as the costs to human life and the economy could far outweigh short term budgetary savings.

The state of the art in infrared countermeasures are directed infrared jammers. These use gimballed infrared trackers and either a modulated laser or flashlamp to jam the MANPADS reticle seeker. Depicted is the Northrop-Grumman/Marconi DIRCM turret. A typical installation would use a Doppler radar, infrared or ultraviolet Missile Approach Warning System to cue the turret which uses its integral tracker to point the modulated light source at the incoming missile (Northrop Grumman).