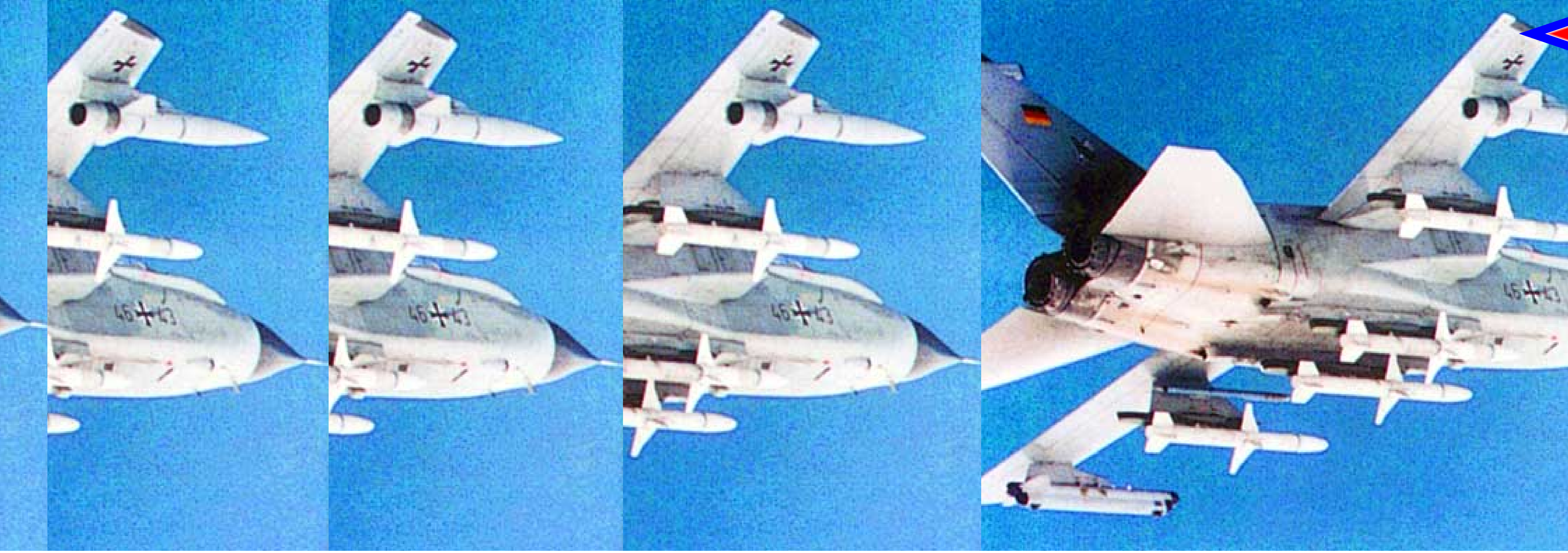


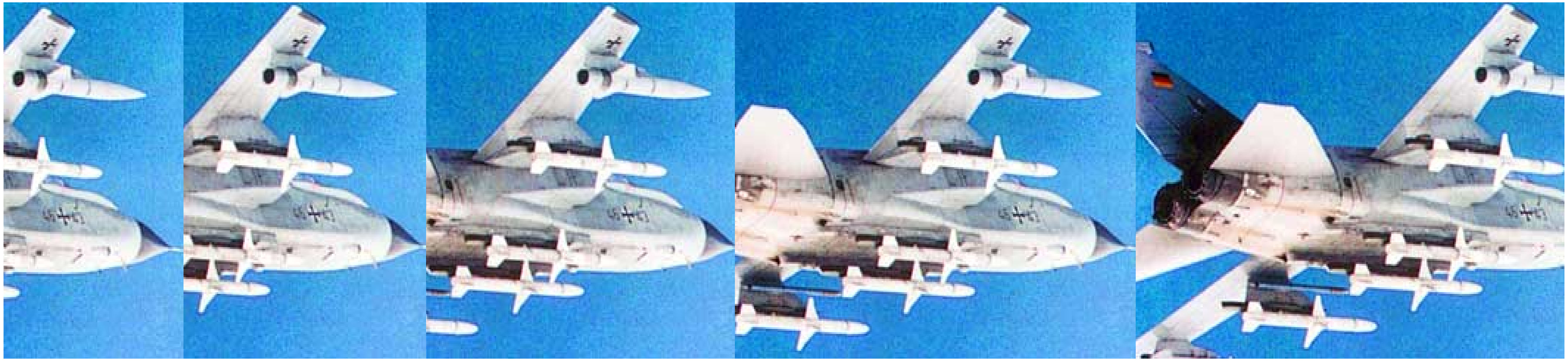
SUPPRESSION of ENEMY AIR DEFENCES

SEAD

By Squadron Leader D R Andrew RAF, No 31 Squadron RAF Bruggen

VORSPRUNG DURCH TECHNIK

There is long-running debate on Europe's need to play a more active role in its collective defence and in policing the trouble spots that fall within the EU's sphere of influence and responsibility. Despite a good deal of rhetoric from senior military and political figures about the development of a European armed force, perhaps based on WEU[1] guidelines, it seems implausible to many that such a force could operate without American support. In the near term it is highly unlikely that European governments will be able to increase their defence spending significantly to cover any shortfalls. Defence spending in Germany, for example, has reduced to 1.5% GDP (from 3% in 1990)[2] and is likely to reduce further. There are many capability areas that would have to be improved before a solely European Air Force (EAF) could contemplate prosecuting a campaign such as that against Serbia in 1999. Without current levels of US involvement such a force would lack many capabilities, not least an ability to suppress an enemy's air defences. Undoubtedly such a European force would be short of tactical jammers, such as the EA 6B. However, there is a common misconception that without a fleet of F16 C/J aircraft armed with the latest block of AGM 88 High-Speed Anti Radiation Missile (HARM) and equipped with the HARM Targeting System (HTS), any such EAF would have no real SEAD capability at all (or would it?). This paper assumes that European governments will not provide additional funding to rectify any perceived capability gaps and will argue that today's European air forces possess sufficient lethal SEAD capability for future operations, but only if steps are taken to improve co-operation between member forces.



THE ECR / ETS TORNADO

Although a number of European countries have the ability to carry Anti Radiation Missiles (ARMs) only the German and Italian air forces have a tactical location system with which to cue the missiles onto their targets. The Electronic Combat Reconnaissance (ECR) Tornado has been in service with the Luftwaffe since 1992. It was designed to be a reactive SEAD platform able to detect hostile radar emissions and engage the associated system using its American built HARM. At the heart of the ECR Tornado is the Emitter Location System (ELS). Built by Texas Instruments (now Raytheon), the ELS is made up of a series of line replaceable units which are distributed throughout the airframe. The receivers, located in the wing roots, operate generally in the search and acquisition part of the radar spectrum and are not open to scan the whole spectrum all of the time. They selectively search different parts of the radar spectrum under the control of the aircraft Weapons Systems Officer (WSO).

The Luftwaffe has 35 ECR Tornados in service based at Lechfeld in Bavaria and flown by 2 squadrons comprising the 32nd Fighter Bomber Wing. The pre-flight messages for the ELS, containing the parameters of systems in a particular area of interest, are written in Trier by the Luftwaffe equivalent of the Defence EW Centre. In 1998 the Italian Air Force took delivery of the first of its specialist SEAD Tornados. Based on the ECR Tornado, the Electronic Warfare Tactical Suppression (ETS) is also equipped with the HARM. The IAF has procured 12 ETS Tornados, which are flown by 155 Sqn based at Piacenza, and currently use software support from the Luftwaffe.

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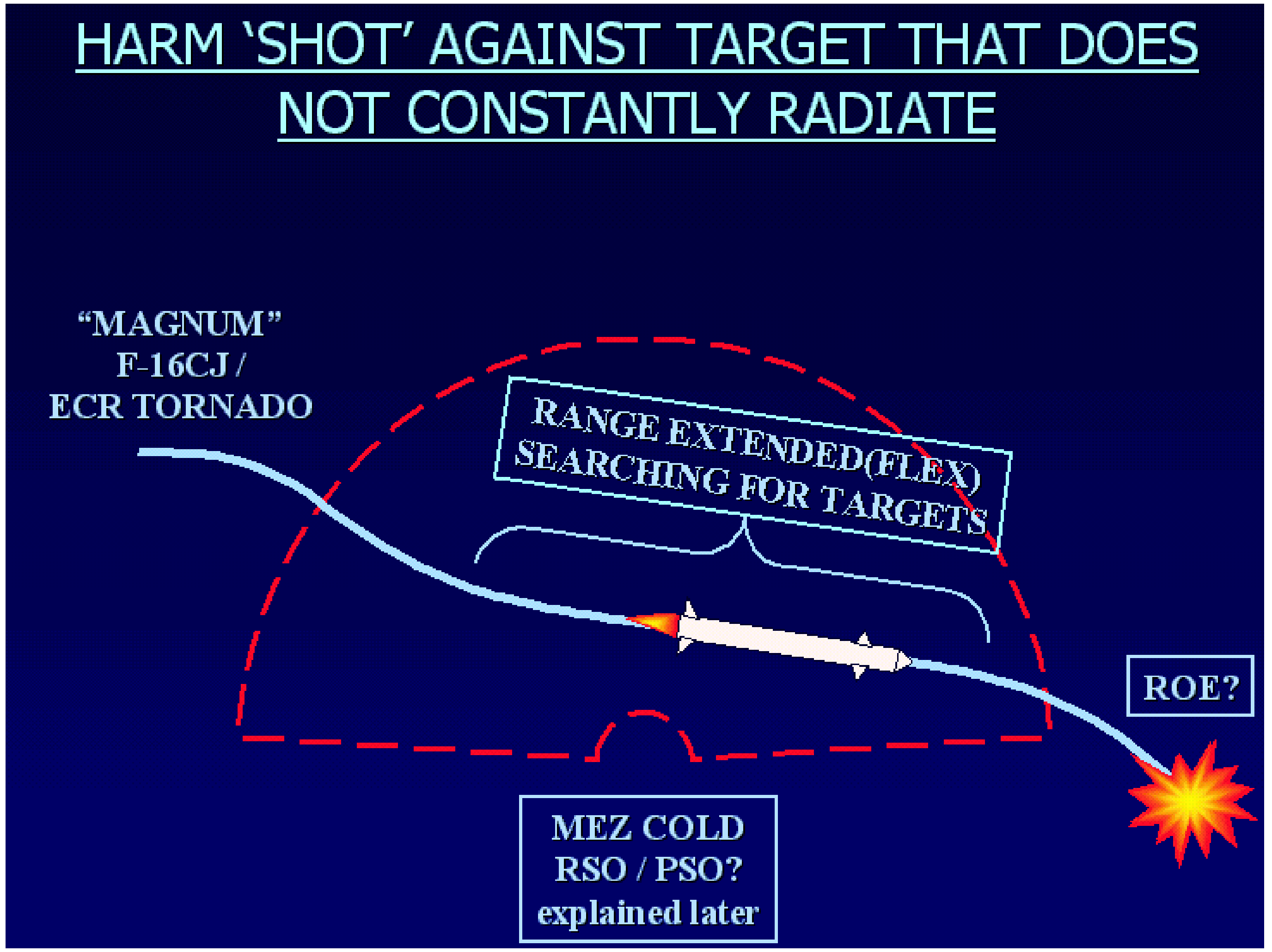
AGM 88 HARM

Both the GAF and the IAF are equipped with the AGM 88B HARM. Primarily designed by Texas Instruments, the missile entered service in 1980 and was first used in the 1986 ELDORADO CANYON attacks on Libya. The HARM was the technological follow-on to the AGM 65 'SHRIKE' missile of the Vietnam era, made famous by the F100 and later the F 4G using it in the 'Wild Weasel' SAM hunting role.

Although details of some HARM variants remain classified, the missile contains a nose mounted seeker, made up of a series of broadband receivers, a comparatively large warhead, a guidance and navigation system and a rocket motor.

The HARM seeker searches for radar energy whilst the missile is still on the aircraft. However, as the seeker has a limited field of view, unless the missile is pointing in the rough direction of the emitter the seeker will not see the energy. This makes the job of targeting unknown, mobile SAMs very difficult unless some other method can be used to cue the missile onto the target. Emitter location systems employed by the Germans and Italians in their Tornados and the USAF in their F 16 CJ HTS pods have a much greater field of view than the HARM and can detect systems even when the aircraft is not pointing directly at the target. By transferring the estimated origin of the radar energy from the ELS to the HARM (generally in range and bearing) and by pointing the missile in the correct direction, the missile will leave the rail and fly a profile that will allow it home down the targeted system's main beam (or close to it). This means that the missile seeker does not have to have acquired the target energy before launch, but a more precise profile will be flown if it has. It is possible to down-load the location of a suspected (intelligence determined) system to the HARM without any form of ELS cueing or acquisition by the HARM seeker. The missile will subsequently fly a profile that would allow it to home onto the system should it become active during the missile's time of flight. This is obviously the least preferable mode of HARM operation because of the lack of pre-launch confirmation of a radar's existence, however this option has been extensively employed against suspected but non-radiating targets.

A major disadvantage of HARM occurs during the homing phase of its flight profile. The missile will have positioned itself to home down the main beam of the targeted system (the HARM is unlikely to receive sufficient energy on which to home unless it is in, or close to, the main beam). If, however, the missile was fired towards an incorrect position (through, for example, out of date intelligence), or if a system detected by either missile seeker or ELS before launch shuts down for fear of attack, then the missile will 'flex' into a shallower flight path in the search for other suitable emissions on which to home. Eventually if it is unable to home onto anything the missile will glide into the ground. Although later HARM models could incorporate some form of flight limiting system, the point of impact could be some considerable distance away from its intended target and cause collateral damage. Nevertheless in a hostile and active SAM environment correctly cued HARMs have proved very capable against continually radiating targets.



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RAF SEAD – THE ALARM

The RAF adopted a markedly different approach to SEAD from that of its Tornado-flying NATO colleagues. Despite previous interest in the SHRIKE, the RAF decided against the procurement of specialist SEAD aircraft and opted instead to invest in an intelligent missile – the Air Launched Anti-Radiation Missile (ALARM). In 1977 the RAF issued AST 1228 for a defence suppression weapon. The 2 main contenders were the HARM (still on the drawing board, but based on proven SHRIKE technology) and the British Aerospace / Marconi ALARM. At the time of the procurement, during the Cold War, the perceived main role for RAF SEAD assets was to clear a gap through the robust SAM belt along the Inner German Border to allow the then new Tornado GR 1 bombers passage to their Offensive Counter Air targets. The procurement also presented the need to engage single systems deployed as point defence. The underlying difficulty for the companies competing for the contract was the requirement for the missile to do this from any launch platform and without the aid of an emitter location system to cue the missile onto the target. Despite competition from the proven technology of US ARMs and the success of US SEAD, particularly the 'Wild-Weasel' concept introduced during the Vietnam war, the contact was awarded in 1979 to the BAe / Marconi bid. To achieve its design specification the ALARM incorporates some very ingenious features.

Unlike the HARM which requires energy on which to home, preferably before launch, the ALARM uses its own navigation system to route to a position over a suspected threat radar before opening its sensors and looking for associated radiation

Unlike the HARM which requires energy on which to home, preferably before launch, the ALARM uses its own navigation system to route to a position over a suspected threat radar before opening its sensors and looking for associated radiation. Details of the system to be targeted, such as location and expected emission parameters, are loaded into the missile on the ground. It is possible to fire the ALARM from almost any platform if it is launched from a pre-planned position, however this is not the preferred method of employment. The primary launch platform for the missile is now the Tornado GR 4, with IX (B) and 31 Sqns specialising in the SEAD role. Through the displays in the rear cockpit the navigator can change any of the target parameters, and the launch position, aircraft heading, attitude and speed are down-loaded from the launch aircraft to the missile at trigger press.

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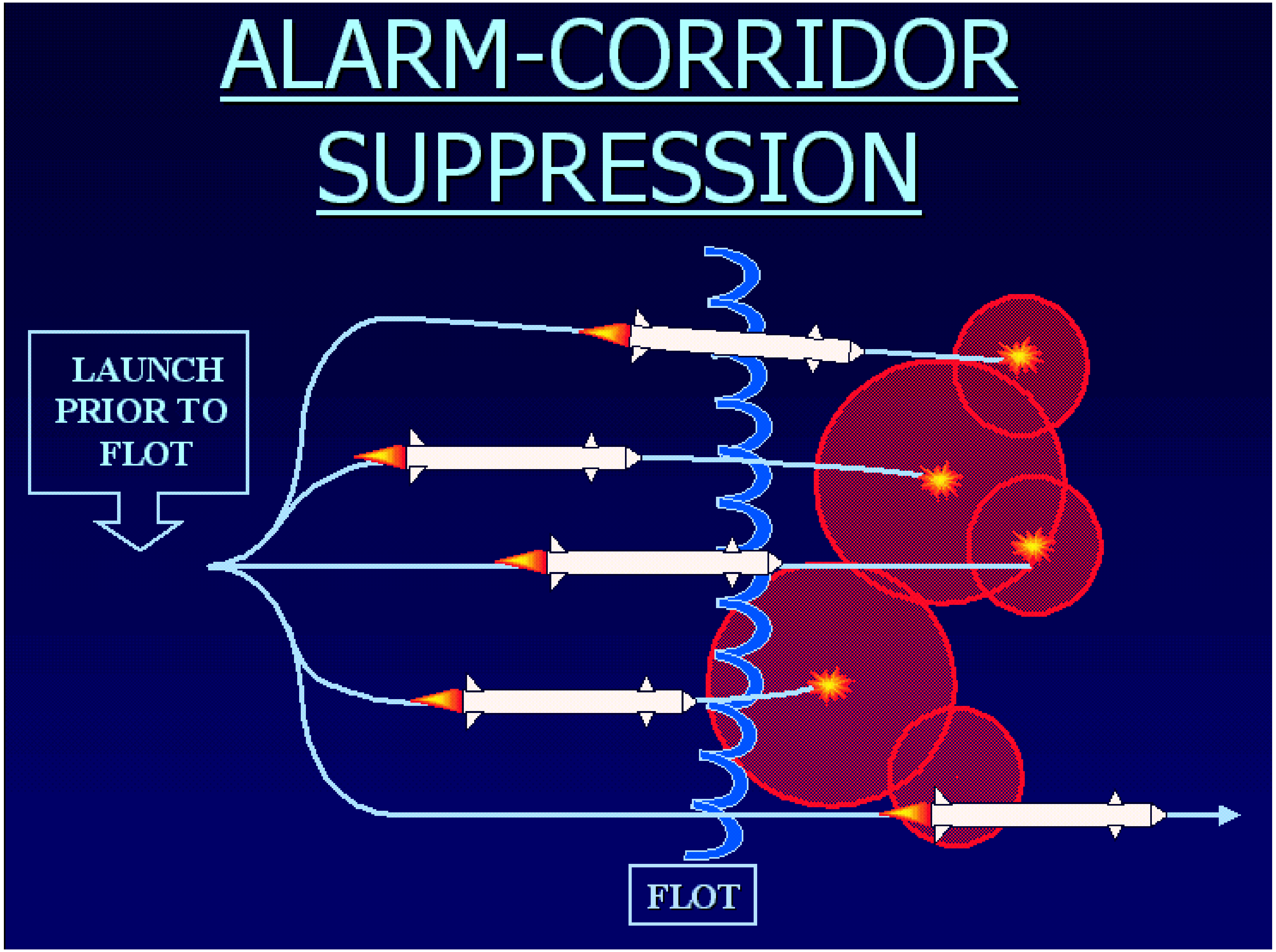
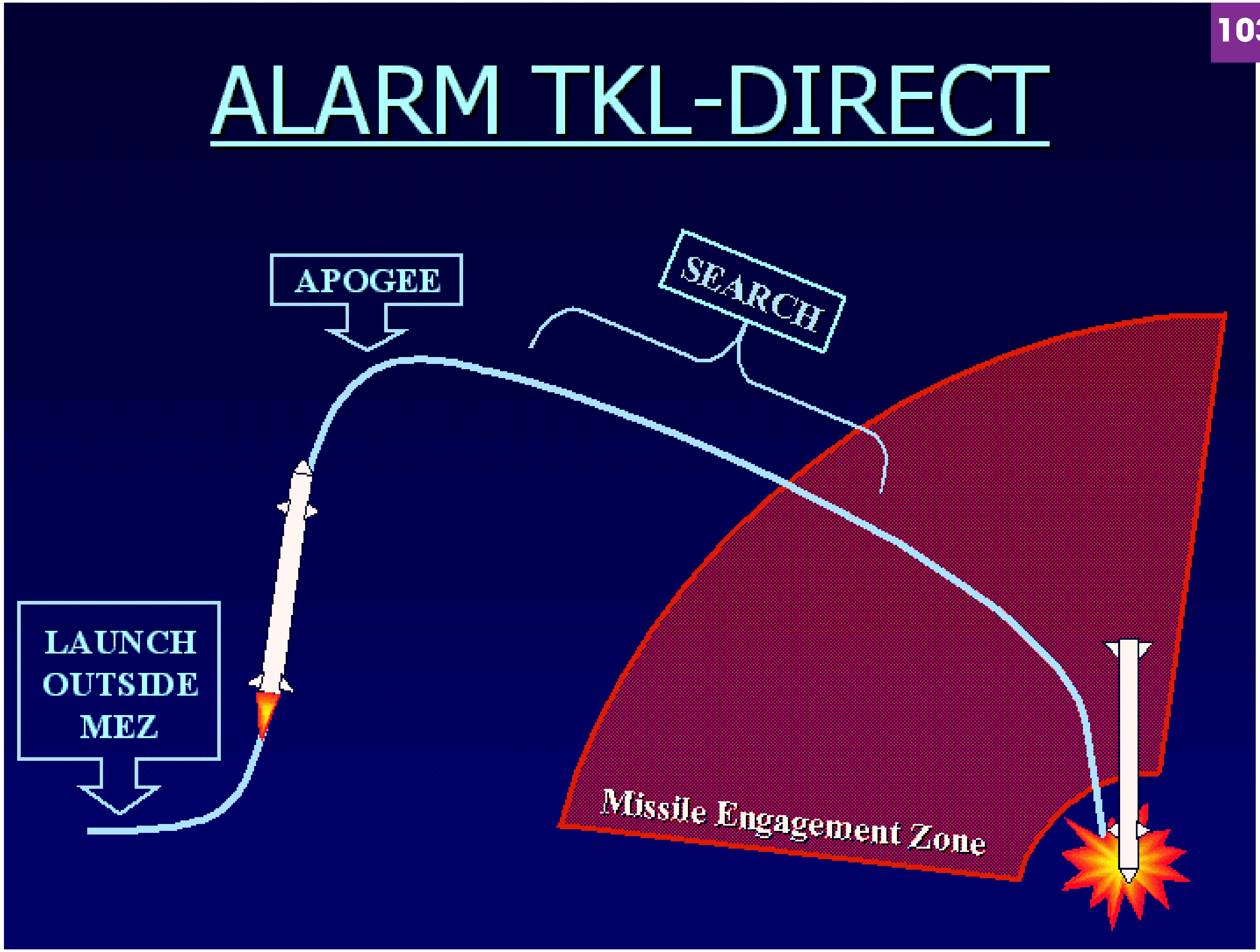
The ALARM has 2 distinct modes of operation: Corridor Suppression and Target of Known Location (TKL).



Corridor Suppression In Corridor Suppression mode ALARMs would be used to create a corridor in SAM defences to allow attackers to cross a FLOT. Although the specific location of these SAMs is unknown, the missiles are pre-programmed with co-ordinates to define the centre of the corridor. The centre missile would sweep along this axis searching for threat radars, using its on board IN to navigate. Other missiles fired in the package would then ‘fan out’ either side of this missile to target systems located outside the search footprint of the centre missile but which still pose a threat; thereby creating a hole in the defences for the bomber package to fly through.

Target of Known Location The second of ALARM's modes of operation utilises the missile against targets of known location. The co-ordinates of emitters to be targeted are loaded into the missile before launch. Once launched the missile then navigates to this pre-programmed position. TKL mode can be further sub-divided to fly one of 3 pre-determined profiles. In DIRECT mode the missile climbs after launch and upon reaching its apogee opens its sensors, searching for the emission characteristics of the targeted system. If, during its descent, emissions from the target are detected, the ALARM homes onto them. The missile's control unit will also renew the location of the target based on the received energy. This provides the ALARM with a 'blind homing' capability should the targeted system switch off. If the ALARM receives no energy at all during its descent, the missile will drop onto its pre-programmed position.



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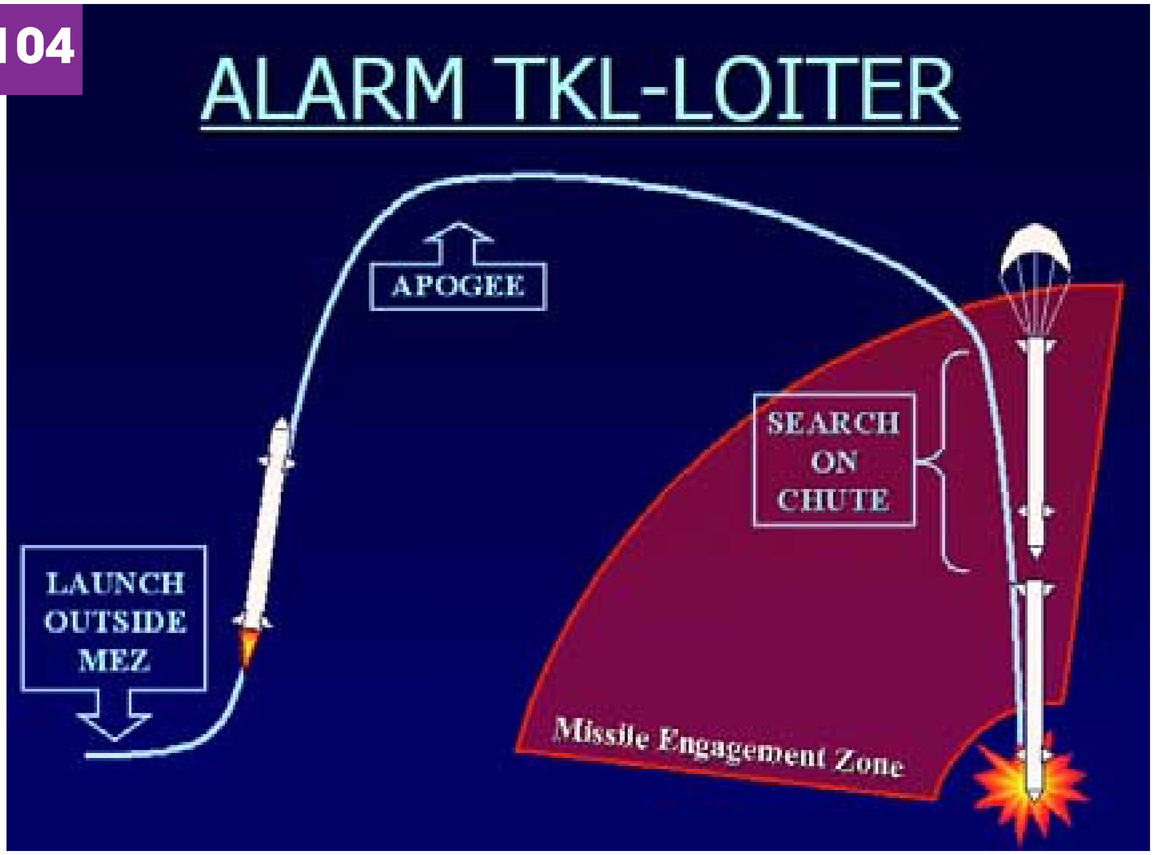

In LOITER mode the missile will navigate to overhead the target and deploy a parachute. The missile then descends under gravity towards its pre-programmed co-ordinates, its sensors searching for target emission characteristics

In LOITER mode the missile will navigate to overhead the target and deploy a parachute. The missile then descends under gravity towards its pre-programmed co-ordinates, its sensors searching for target emission characteristics. If sufficient signal is received the missile will update its target location position, cut the parachute and home onto the system. DUAL mode is a combination of both. If at apogee target radiation is detected the ALARM will continue to home in DIRECT. If nothing is received the missile will deploy a parachute and LOITER.

Just before ALARM's planned in-service date its intended main role, against the East German SAM belt, was made redundant by the fall of the Berlin Wall and of communism as a whole. Nevertheless, the missile entered service in January 1991 during the Gulf war. During the conflict some 120 missiles were fired. Despite the majority being targeted against specific SAM sites, most were launched in the corridor suppression mode because of the lack of timely intelligence of SAM location available to the crews. Post-war analysis of all ARM shots against Iraqi IADS proved particularly difficult. The lack of tangible evidence, coupled with integration problems experienced on

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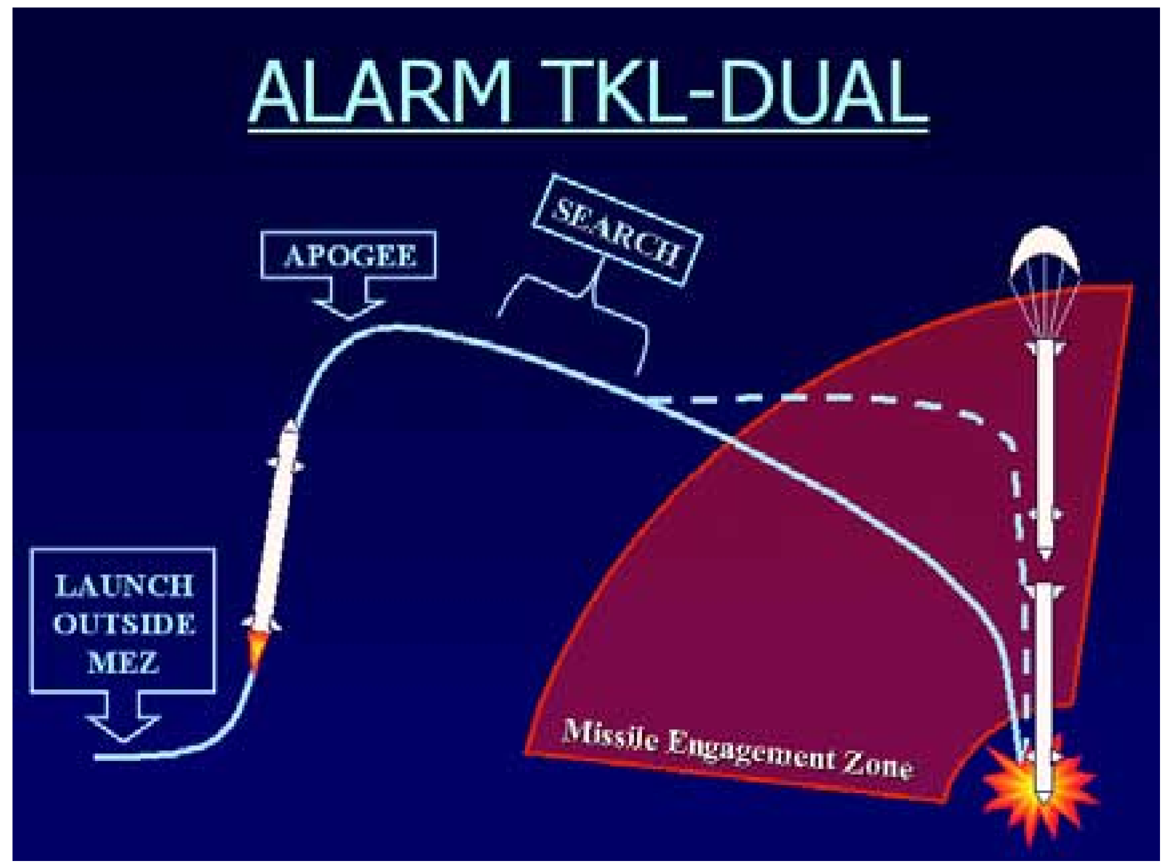

early sorties and the knowledge that the missiles were perhaps not fired in their optimum modes, has possibly generated a view that ALARM did not perform as it should have. If these reservations are compared with the upbeat American assessment of HARM performance from similar results, it can perhaps be understood why there has been reluctance in the RAF throughout the last decade to champion ALARM as a credible alternative (complementary?) system.

ANTI ARM TACTICS

Since its first use against Libyan air defence systems in 1983 some 3,000 HARMs have been fired in combat from US, German, Italian, Spanish and Turkish platforms. About 2,000 were fired during the Gulf War alone and over 800 in the recent conflict with Serbia. As described earlier, the targeted system has to emit so that the HARM can home onto it. If the system stops emitting during the time of flight of the missile the chances of a hit are greatly reduced. During the Gulf War US forces intended its HARMs to kill SAM systems and remove them permanently from Iraq's inventory. To ensure Iraqi systems were emitting during HARM attacks coalition planners used drones that mimicked the radar signature of incoming strike aircraft. In reaction to these drones the Iraqis switched on their radars to defend against the perceived attack and were then targeted by HARM carrying F/A 18s and F4 Gs.[3] During one wave on the first night of Desert Storm over 200 HARMs were fired against Baghdad air defence systems. This was a deliberate attempt to "Hard" kill these systems so that they would no longer be a factor in the conflict. But experience gained from combat is not solely the domain of the attacker and, by the end of the conflict those Iraqi air defence units still functioning had learned to shut down to save their systems whenever attack by HARM was suspected.

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Defensive measures taken by defenders against ARM attack are now considered by SEAD specialists to be either pre-emptive or reactive shut-off (PSO or RSO). Defenders will employ PSO tactics to prevent their being targeted by SEAD aircraft. However, if the threat of attack forces a defender to employ PSO to save its systems for another day, then it can be said (and often is by supporters) that the suppression aspect of SEAD, or “Soft Kill” has been achieved by default. Typical use of RSO tactics would see a radar system radiate long enough to entice SEAD assets into an engagement and, after ARM launch was detected, the defender would shut-off to deny homing to the missile. RSO and PSO tactics have been used by Iraq and Serbia during the recent conflicts.

HARM & ALARM – AN IDEAL MIX

Air warfare planners now regard SEAD assets as a critical part of any package operating over enemy territory. Unfortunately these assets are at a premium. Although HARM is in service with many air forces around the world, only the USAF with its HTS equipped F16 CJs and the German and Italian ELS equipped Tornados provide a genuine reactive SEAD capability. With SEAD assets so thinly spread it is difficult to support large packages of aircraft tasked with attacking geographically diverse targets, such as those tasked to support packages during the recent Serbian campaign. The strikers naturally expect to have SEAD protection for the duration of their time over enemy territory, but unfortunately there are simply not enough assets to cover the whole package all of the time. The SEAD package commander must balance the requests from the strikers with the intelligence picture and use his own expertise to devise a plan that satisfies all players. Once the main threats have been identified an optimum route and SEAD CAP will be devised that gives the most coverage to most strikers for the most time. As a compromise to those strikers who must fly through known SAM threats to execute their missions the SEAD

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commander may be forced into firing a missile towards a SAM pre-emptively (PET shot) in the hope that the system may switch on during time of flight of the missile. This is not how the HARM is designed to be employed and more often than not the missile would receive no energy from the intended target and would extend its flight path in the search for suitable emissions, eventually impacting long of targeted system with the associated collateral problems. This technique has had only limited success and has greater utility in providing the bomber crews with a *warm and fuzzy* feeling as they transit through missile engagement zones en-route to their targets than suppressing SAM systems. If RAF SEAD assets had been included in SEAD packages during the Kosovo conflict, ALARM could have been fired pre-emptively against locations of suspected SAMs and would have brought the following advantages to the package:

In any realistic combat fit both F16 and Tornado ECR would fly with 2 HARMs. RAF Tornados could sensibly carry 5 ALARMs; therefore could target more systems whilst allowing reactive SEAD assets to save their HARMs to target pop-up SAMs reactively using their ELS.

In its parachute modes ALARM gives far greater time coverage per missile than HARM. This not only provides a longer window of protection for the attackers but also gives a better chance of kill should the system switch-on whilst the missile is in the ‘chute’.

Although ALARM will constantly search for suitable emissions on which to home, unlike the HARM it will not modify its flight path to do so. If no signal is received from the targeted system the missile will drop vertically, within the accuracy of its navigation pack, onto its pre-programmed target position. This obviates the collateral damage aspects of a HARM PET shot.

SEAD experts involved in the campaign (HARM operators included) have agreed that ALARM should have been the PET shot weapon of choice against systems whose location was known or suspected. Unfortunately, a lack of understanding of ALARM and perhaps SEAD in general as well as an understandably over-cautious approach to the collateral damage issues (HARM warhead is considerably larger than that of ALARM) amongst national decision makers limited the number of ALARM missiles fired in the conflict.

‘ROCKET’ – THE EUROPEAN SEAD FORMATION

Let us build an imaginary, but not unlikely, scenario that illustrates how a mix of HARM and ALARM could be used in the future.

Rocket Formation of 2 ECR plus 2 ALARM carrying Tornados is tasked as the SEAD support element of package B, the second package of the day to cross into enemy airspace. Since the outbreak of the conflict German, Italian and Royal Air Force Tornados have been co-located and have not only built up a solid working relationship, but have also been able to reduce their logistical burden by sharing support facets of the deployment. The lead crew *Rocket 1* liases with the strike package commander and decide that the standard load of 2 HARMs for each ECR Tornado and 5 ALARMs for the RAF Tornados should provide sufficient missiles for the package.

The majority of the strike package are tasked with targets just to the south of the heavily defended capital city, whilst one strike element callsign *Nova* is tasked against a motorway bridge some 100 miles further south. The Strike plan involves *Nova* crossing the border with the main package before splitting off to the southerly target. Unfortunately Nova has to fly through a strategic SAM engagement zone in order to carry out its attack. Although this SAM has been active recently it is known to move periodically between 3 pre-prepared sites and has not been targeted conventionally. Fortunately for *Nova* all the known mobile SAMs are believed to be protecting the capital or have been placed along the border to attack ingressing targets.

As well as the mobile SAMs the capital is defended by a ring of medium-range strategic systems. The main strike package will have to fly through 2 of these in order to execute its mission.

After an uneventful take-off *Rocket* refuels from an RAF VC 10 before joining the strike package in the hold some 70 miles away from the border. AWACS passes information to package B that the strategic SAM close to the motorway bridge had been reported active by aircraft of package A and confirmed by a Nimrod R, although the SAM had not radiated long enough for its position to be determined accurately enough for conventional targeting purposes. During the third holding pattern *Rocket 3*, an ECR, receives indications that a search radar, associated with mobile SAMs, is active close to the border.

The package leaves the hold with *Rocket* and the fighter sweep at the front. As it does so, *Rocket 4*, an ALARM carrier, receives indications on his radar warning receiver of a mobile SAM tracking radar on the nose. Immediately afterwards this is confirmed by one of the ECRs who fixes the position using its ELS and passes the co-ordinates in code to *Rocket 4*. As search radars in enemy territory detect the package leaving the hold all SAMs on the border are ordered to shut down by sector HQ to deny homing to any ARM attack (PSO). Nevertheless, as the package comes within range of the system 2 ALARMs are fired against it in a parachute mode. Although the mobile SAM radar remains off for the time of flight of the ALARMs, the missiles have been programmed with the system's latest co-ordinates just before launch and although no energy was received by either missile during flight the ALARMs impact close enough to the SAM to inflict damage that requires repair.

At the split point *Nova and Rocket 3 + 4* turn towards the motorway bridge. *Rocket 3* can give no update of target position and therefore *Rocket 4* fires 2 more ALARMs which position themselves overhead a point equi-distant from the 3 known prepared sites, deploy their parachutes and loiter. The ALARM launch was detected by a separate radar unit and all SAM systems in the sector were ordered to shut down (RSO) by the sector HQ. HQ staff believed that it had witnessed a HARM attack and, using time of flight graphs based on Iraqi observations of HARM shots, it ordered the strategic SAM to engage the rapidly approaching *Nova* formation once the perceived HARM threat had passed. Unfortunately for them, as the acquisition radar switches on it is seen by the loitering ALARMs above. The parachutes are cut and the SAM is destroyed. *Rocket 3 and 4* are already on their way to rejoining the rest of the package.

As the main package approaches the target area there is no indication of SAM activity. *Rocket 2* fires 5 ALARMs pre-emptively against the suspected positions of the 2 strategic sites. However, the ALARM kill of the SAM at the motorway bridge has been relayed to the other sector HQs and all the stategic SAM radars are ordered to remain silent. A 'Soft' kill has been achieved.

The mobile SAMs are a different matter. As the main package approaches the target *Rocket 1 and 3* each locate 2 mobile SAM threat radars on their ELS. Employing their pre-arranged target sort plan, 2 HARMs are fired from each ECR against each SAM. Unaware that they have been targeted the mobile radars remain tracking the main package. The HARMs home successfully and the SAMs are 'Hard' killed. The package rejoins post target and egress is made with *Rocket* at the front providing threat updates to the following package. The SEAD mission was a complete success and *Rocket* still has one ALARM remaining for use on the way out.

THE WAY AHEAD FOR EUROPEAN SEAD

Although this paper has concentrated on the possible closer integration of German, Italian and Royal Air Force SEAD assets, mainly because of the author's familiarity with those systems, the same principles of co-operation could (and should) be expanded to encompass all of ARM equipped aircraft. For instance, in the above scenario there is no reason why the ECR Tornado could not have been an F 16 equipped with a HTS pod to provide positional information to the ALARM carriers. Or why ECR Tornados could not give updated positional information to give HARMs carried by Turkish or Spanish aircraft a better chance of acquiring a target. There are many force permutations.

Even though the aim of this paper has been to identify what is available to any EAF now, it is appropriate, from a RAF point of view, to highlight the

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requirement for a tactical ELS and a data-link between RAF SEAD aircraft. National exercises have shown that although a limited location capability exists utilising the ESM equipment onboard AWACS and Nimrod R, for the RAF to maintain a national SEAD capability a tactical ELS should be procured to allow reactive targeting of SAMs. Ideally each SEAD platform would be equipped with an ELS and could operate autonomously. However, in reality because of the narrow beam of tracking and missile guidance signals, aircraft are unlikely to receive the same ELS picture even if they are flying close to one another. A requirement exists therefore for each aircraft to be data-linked so that each ALARM carrier, whether ELS equipped or not receives timely targeting data. This data-link must be compatible with those of our allies to allow combined *Rocket* formations of the future maximum flexibility. Further discussion is outside the scope of this paper.

There is a long way to go but general awareness of SEAD is improving. It needs to. A lot of work still has to be done before the fictitious *Rocket* can get airborne in anger. First, a realisation by national commanders that what currently constitutes limited national SEAD potential could contribute to an enhanced NATO capability or a credible SEAD force in a future EAF. Once this has happened then an exchange of ideas and information between SEAD units should be encouraged. Traditionally the security classification associated with SEAD, and EW technology in general, has precluded such a flow. But these problems are not insurmountable. A successful aircrew exchange programme already exists between the GAF SEAD units and the IAF, SpAF, USAF and RAF, and an Italian exchange officer flies on an ALARM equipped RAF sqn. Tactical Leadership Programme at Florennes, recognising the importance of SEAD, hold regular SEAD conferences and the GAF hold an annual SEAD integration exercise in southern Germany. The 3rd edition of AP 3000, RAF Air Power Doctrine[4] affords almost twice the space to SEAD as the 2nd edition, even though there has been little, if any, change in RAF capability between their publications. The SEAD campaign in the recent conflict with Serbia was a success – but it could have been better. Closer integration between SEAD assets could have enhanced missile utility. RAF Tornados armed with ALARM, LGBs and a designation pod could have employed Destruction of Enemy Air Defence (DEAD) tactics………but that's the subject of another paper altogether. The message in this story is: if you want to get to the SAMs before the Germans, buy yourself an ECR Tornado (or at least get co-operating with them). Vorsprung durch Technik – as they say in Lechfeld, Piacenza, Bruggen, Merzifon, Spangdahlem, Torrejon...

NOTES

1 The Economist – In defence of Europe February 26 2000

2 Edward Foster – Eagle with Talons of Clay RUSI International Security Review 2000

3 Richard P Hallion – Storm over Iraq Chapter 6 page 173

4 RAF Air Power Doctrine 3rd edition – page 2.5.6

Royal Air Force C-130
Hercules transport