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Innovation in the Air II

Developing a Remedy

Following the 1973 debacle, Ezer Weizman famously said, “The missile has bent the aircraft’s wing.”[[1]](#endnote-1) The trauma of the 1973 war had challenged the very ethos of the victorious air force of 1948, 1956 and 1967. “We felt humiliated” said fighter ace Aviem Sella, who played a key role in leading reforms after 1973, adding that “we were determined to find a way to restore our professional honor… the Yom Kippur exposed a number of gaps that the air force had to fill if it wanted a better outcome in the next round.”[[2]](#endnote-2)

Some officers believed that the air force had been outclassed technologically by Soviet anti-aircraft missiles. Others did not agree that technology was the core issue. Moshe Dayan notably insisted that the solutions to the problem would not be technological (“electronics will not win the war”) but tactical and operational: it was a question of fighting in a clever and daring way, relying on the intelligence of the warriors themselves.[[3]](#endnote-3)

But it was undeniable that the Soviet-supplied missile umbrellas had very severely restricted air operations throughout the war and also that the available electronic countermeasures and standoff weapons such as *Shrike* and the gliding-bombs could not neutralize them, thereby compelling the IAF to send its aircraft deep into the maw of the enemy air defenses, losing a quarter of them to SAMs and anti-aircraft guns.

After the war, the air force conducted a comprehensive investigation, identifying a long list of major deficiencies—and possible solutions for the future. In retrospect it was the planning that had been off course: *Dugman* and *Tagar*were both rigid and fragile plans because they were entirely dependent on exact knowledge of the locations of each missile launcher. When their mobility made that impossible given the slowness of the intelligence process at the time, the planning process left no room for any alternative tactics.

In response to these findings, the air force concluded it was essential to shorten the interval between the detection of SAM batteries, their identification as real operating batteries rather than simulations, and their effective attack, before they moved again.[[4]](#endnote-4) Also, it was necessary to find ways of reducing the risk to aircraft conducting the strike whether from the SAMs themselves or from their protective array of anti-aircraft guns. To achieve dramatic improvement on both fronts required a variety of innovations in technology, work processes, and tactics. The central goal of the IAF’s post-1973 development program was to achieve both goals.

IAF commander Benny Peled considered the key challenge the acceleration of the location-strike cycle, which could not be achieved without entirely new intelligence methods that would bring the process toward the ideal of “real-time” intelligence. That would enhance IAF capabilities for all missions, not just the counter-SAM mission. A study of the efficacy of the costly IAF effort to assist the IDF ground forces in the 1973 war also concluded that insufficiently up-to-date target intelligence had been the number-one problem.[[5]](#endnote-5) Soon enough it was determined that the key technological solution was to use RPVs (now “drones”) small enough to avoid being hit, with a flight endurance long enough to maintain an almost constant presence over the battlefield, and with a video-camera and datalink to enable real-time transmission of data to operational planners, who would no longer have to wait for aircraft to land to analyze photographs. It helped that Israel was a world leader in manufacturing increasingly capable RPVs.

The “Drone” Revolution

It was in *Artzav 19* that drones first played a central role in combat operations, and they greatly exceeded expectations, marking the beginning of a new military era. Yet the air forces of the world did not exactly rush to acquire drones, let alone integrate them into their operations. Nine years later, in the US buildup for the 1991 Gulf War, the only observation drones in hand were imports from Israel procured by the Navy and Marine Corps. No other service had shown any interest in unmanned aircraft, and the US Army had canceled its own promising *Aquila* program in 1985 for dubious reasons, while the Air Force did not even start one.[[6]](#endnote-6) That collective inaction was all the more remarkable because the Advanced Research Project Agency of the US Defense Department had successfully demonstrated a drone in 1972, just when the first Israeli drones were being tried. So the IDF was the first military force anywhere in the world to have the great advantage of operating routinely with near real-time intelligence, a lead that proved surprisingly persistent.

Responding to the ever-growing threat of abundant and effective Soviet-made surface-to-air missiles during the War of Attrition, the Israeli air force began using Teledyne-Ryan 124/BQM-34 *Firebee* target drones as SAM decoys, under the designation Mabat, the Hebrew acronym for “pilotless airplane.”[[7]](#endnote-7) Attempts were made also to attach cameras and send them to photograph areas deemed too dangerous for manned aircraft. In 1971, the air force acquired US-made Northrop *BQM-74* *Chukars,* designated *Telem* by the IAF, as noted with reference to their futile use on the Golan in 1973. The *Telems* were modified to follow a preprogrammed flight plan and enhanced electronically to simulate the radar cross-section of a (much larger) manned jet fighter, so as to awaken SAM batteries and radar controlled anti-aircraft guns into action, thereby revealing their positions to attacking aircraft.[[8]](#endnote-8) But using these drones for photographic reconnaissance proved less effective.

Shortly after the October 1973 war, after disappointing results with the converted US-made target drones, IDF Military Intelligence had begun using the Israeli-made RPV sold internationally as *Mastiff,* designated *Sorek* in the IDF. But it could not provide real-time coverage—it could only take still photographs the Intelligence Branch could use instead of requesting photographic missions by manned reconnaissance aircraft. Needing the real-time relay of the photographs, the air force attempted to retrofit a stabilized video camera with a datalink on a *Chukar/Telem*. It then turned to Israel Aircraft Industries, which responded quickly with the *Scout* (IDF name *Zahavan*), which could monitor large areas for many hours and relay photographs in real time to the analysts' video screens, to enable strike aircraft to take full advantage of the short exposure windows during which mobile SAM batteries were most vulnerable to attack. Other intelligence tools were also developed or procured, including airborne command and control systems, but the innovative use of drones was very much an Israeli advance.

*Mastiff* and *Scout* exemplified Israel’s small, modestly funded defense industry at its best.[[9]](#endnote-9) Their design was highly responsive to IDF needs because of the continuous intercommunication between the active-duty officers who wanted them and the engineers who were developing them, who were mostly IDF reserve officers. These RPVs were as simple as possible, mechanically robust, and designed for rough handling in field conditions. Because their design incorporated as many off-the-shelf components as possible, they were also cheap. The first models had television cameras and relayed imagery to the operators. Later, laser range finders were added to allow the use of the same drones by artillery spotters and to lase targets for manned aircraft.

At the start of what became the *Scout* project, Israel Aerospace Industries assigned a team of engineers to the task, including Yair Dobster.[[10]](#endnote-10) He described the project as “basically a Start-Up. [Youngsters] with an adventurous spirit were recruited and an experienced team leader was appointed to guide us to tame the youngsters’ tendency to wander too far as young, openminded, and fearless young people sometimes do.” The firm treated *Scout* as if it were an ordinary manned aircraft; “it was made of the same type of aluminum with the same rivets, just like airliners are made to this day,” according to Dobster. To save time and money, and to skip “trial and fix” iterations based on wind-tunnel experimentation, the proven double-boom design of the *Arava* light transport aircraft was simply downsized and paired with a single rear-facing engine. This design also made it easier to balance the weight distribution when operating with different payloads and/or extra fuel.

Designing the aircraft—the platform—was only the start. To operate the *Scout*, a ground control station was needed with displays, joystick activators, and telecommunications. The optical payload also had to be developed from scratch to suit the *Scout,* and a mode of operation also had to be anticipated, there being no established operating doctrine.[[11]](#endnote-11) One technical choice did not favor simplicity: in the US the first experimental drone (which never reached serial production) had a fixed camera built in, with a floating mirror apparatus to stabilize the image. That produced a reversed mirror image for the operator, adding a complication that would be undesirable if the system were ever used in real combat conditions. For Israelis that scenario was a given, and the IAI decided to solve the problem by developing a gyro-stabilized gimbal for the camera.

Much later, two members of the first crew of IDF operators described the initial growing pains, including part shortages that forced the cannibalization of some *Scouts* to keep others flying. Frequent, if small, engineering changes that had to be made on the go, with no pause for “verification” by outside test and evaluation inspectors or for the attribution of blame for errors, as redesign decisions were made on the spot. It was a process that had no end date, with continual tinkering that did not end even when the *Scouts* were first delivered. All the while, the *Scout*’s operating crews remained in close, informal contact with the developers, as is Israeli practice, to give them the feedback they needed. Initially there was much skepticism in the air force, which was apt to forget that drones existed at all. After sending in a debriefing report following a sortie that nearly ended in a crash, the drone squadron received phone calls from air force headquarters asking if the pilot was alive and well. Following that incident, every safety report from the drone boys sardonically included the reassurance that “the pilot is alive and well.”

In 1980, the first drone squadron participated in a divisional maneuver in the Sinai Peninsula. At the outset, the divisional commander, then BG Ehud Barak (later chief of staff, defense minister, and prime minister), told the air force drone unit commander that his unit was far down the priority list for the upcoming maneuver. But early in the morning, the squadron launched its drones with short-takeoff rocket boosters, only to discover that the pontoon bridge meant to simulate the crossing of the Suez Canal was being secretly moved to a new location by maneuver referees, in order to confuse Barak’s division. When Barak noticed what was happening on his monitor, he insisted that the drone squadron fly nonstop until told otherwise; he had discovered the value of extended, real-time intelligence.[[12]](#endnote-12)

The *Scout* squadron (the first of its kind anywhere) became fully operational in 1981, just when Syrian SAM batteries were deployed to the Beqaa valley in Lebanon, thus extending their SAM coverage and threatening IAF operations in the northern front. There was also another wholly unexpected episode on May 14, 1981: one of the squadron’s *Mabat* drones achieved a confirmed kill when a Syrian *MiG-21* flew into the terrain while trying to shoot it down.[[13]](#endnote-13)

But it was their use by the IDF in the 1982 Lebanon war that really validated drones, starting a global race to develop them. Certainly, it was a real trial by fire as *Scouts* successfully hunted down highly mobile SAM batteries, including the then formidable *SA-8*s.[[14]](#endnote-14) The first drone to succeed the *Scout* was its direct offspring, the IAI *Searcher 2* drone, which entered service with the IAF in 1992 as the *Khogla* (Alectoris). By then the IDF was using drones to lase targets for precision-guided munitions.

The Palestinian offensive of 2000-2006 highlighted the need for more capable drones, with more endurance, which was amply provided by the large IAI *Heron* 1 (*Shoval* in the IDF). A new drone squadron was duly added to monitor the dense urban environment. Drone footage that revealed the true course of reported events also proved invaluable in the diplomatic and media arenas to support Israel’s efforts to expose deceptive propaganda.[[15]](#endnote-15)

What began as a search for a survivable reconnaissance aircraft evolved after time to the design of a new type of strike aircraft. The air force entered the era of armed drones with the *Hermes* 450 (the IDF *Zik*), which served as an attack drone with guided missiles to provide divisional headquarters with a dedicated platform for real-time intelligence, but it can also be used to launch attacks on land or at sea.[[16]](#endnote-16)

By 2006 the IAF was operating a much bigger drone—the *Heron* TP (IAF *Eitan*) a much-enlarged derivative of the *Heron* that can attack ground targets at ranges in excess of 1,500 n.m (its one-way range is 4,000 nmi) with an endurance in excess of 50 hours. Hence it can advantageously replace manned aircraft for surveillance, reconnaissance, and also long-range attack. (Reportedly it has been used to interdict arms deliveries to Hezbollah deep into Sudan).[[17]](#endnote-17) Certainly, its operational range suffices for air attacks with significant payloads anywhere in Iran.[[18]](#endnote-18) A later addition to Israel’s drone arsenal, the *Hermes* 900 (IAF *Kochav*), which became operational in 2015, can reportedly operate continuously for over 24 hours without refueling and carry up to four AGM-114 *Hellfire* missiles.[[19]](#endnote-19)

A different type of Israeli-made strike drone was prominent in the 2020 Nagorno-Karabakh fighting. While other drones, specifically the Turkish *Bayraktar*, received more publicity, the IAI *Harop*, successor of the IAI *Harpy* attack drone or “loitering munition,” seems to have had the greatest impact on the battlefield. Originally designed as an anti-radar loitering munition, the canister-launched *Harop* has a mission endurance of up to nine hours and can serve for reconnaissance and area patrol but also has a 16Kg warhead to dive on high-value targets. The Azeris used the *Harop* and two other Israeli models of loitering-munitions, the *Orbiter* and the *Skystriker,* against all types of targets – SAM launchers, radars, tanks, APCs, artillery, infantry positions, and even trucks and buses used for troop transports, dissuading their use and thereby attacking both the morale and the mobility of their adversary.

Increasing Survivability

Avoiding the ground-launched missiles and gun danger zones required a no less precise knowledge of their location than was needed when striking them. However, if the targets were in the danger zones, evading missiles by flying low, as was attempted in the War of Attrition and the 1973 October War, brought the aircraft into the range of anti-aircraft guns, whereas evading the guns by flying above their effective ceiling, as was also done during those wars, exposed the aircraft to missiles. Furthermore, new missile types, such as the man-portable *SAM-7* (first employed en masse during the 1973 war), *SAM-9* (a vehicle-mounted version of the *SAM-7*), and *SAM-8* (both of which arrived during the 1970s), could hit aircraft at very low altitudes. During both wars the IAF finally chose to usually attack above the gun ceiling and within the SAM envelope, employing a mix of surprise, decoys, and ECMs, but mostly relying on aerobatic flying and complex teamwork to reduce losses. The IAF also attempted various methods of semi-standoff attacks with *Shrike* anti-radar missiles, electro-optical *Walleye,* and HOBO gliding bombs, and the very fast medium altitude toss-bombing (*Kela*) technique to launch munitions and egress before the anti-aircraft missiles reached the aircraft. But all of these proved to be technologically deficient, and the targets were missed all too often.

By contrast, a real advance was using unmanned aircraft as decoys. Flying before or during air strikes the drones caused the enemy to waste time and ammunition on the wrong targets while simultaneously exposing themselves to discovery. The decoys used in the 1973 war had proved their great potential, even though the opportunity to capitalize on their effectiveness had been missed. But having learned their value the IAF broadened its arsenal of decoys. Newly developed, unpowered *Shimshon* (Samson) gliding decoys, along with older *Telem* decoys, were launched by the attacking aircraft in the 1982 takedown, successfully luring the Syrians to reveal the positions of their missile batteries[[20]](#endnote-20) and to expend missiles uselessly.

Improved Electronic Counter Measures were obviously important to protect aircraft flying within the range of enemy SAMs. One of the problems revealed by the 1973 war had been that the available ECMs were fairly effective against older *SAM-2*s, only slightly effective against the later *SAM-3*s, and totally ineffective against the latest *SAM-6*s. Evidently the US ECM effort was too slow to keep up with the rapid pace of Soviet SAM innovations. It was time for local efforts. During the 1973 fighting a burnt-out *SAM-6* seeker head had been retrieved on the Golan Heights on the second day of the war. Another still intact seeker was retrieved on October 24 from the Canal front. Both were sent to *Rafael*, whose countermeasures’ team immediately started working at a furious pace to develop specific jamming and deception electronic countermeasures against the *SAM-6*, then the most effective Soviet anti-aircraft missile.

Those electronic countermeasure devices were designed, engineered, tested, and manufactured in a few months instead of years, and were delivered to the air force in the spring of 1974 – too late for the October 1973 war but ready for the next.[[21]](#endnote-21) At the same time, old US-made electronic-countermeasure pods that had failed in 1973 were modified with some new electronics, and they too turned out to be highly effective against the *SAM-6*s. However, the constant threat was that the enemy would acquire a new system impervious to the existing ECMs. Maintaining viable ECMs requires a constant effort to collect information on the latest enemy systems, find their limitations, and then develop the capabilities required to jam or confuse them. As with the Israeli drone industry, Israel invested heavily in this field and still does.

An even better solution is not to have to fly into the danger zone at all, but that requires munitions that can reach targets from beyond the enemy’s effective interception range. Despite all the disappointments with the standoff munitions it first received from the US, the IAF invested heavily in this field, purchasing various US-made electro-optically guided and anti-radiation missiles (collectively called *Egrof*, Fist) with a color suffix to indicate the specific munition, e.g. *Egrof Yarok* (Green) for the *GBU-15*, *Egrof Khum* (Brown) for the Israeli Tadmit, *Egrof Tzahov* (Yellow) for the modified AGM-62 *Walley*e, and so on.[[22]](#endnote-22)

By 1982 the air force had integrated *AGM-78* *Standard* anti-radiation missiles (code-named *Egrof Sagol*, “Purple Fist”), which were technically superior to the *AGM-45 Shrike* received a decade earlier, both in their range and because they were programmed to keep flying toward the targeted radar even if its operators switched it off. Previously, it had been enough for radar operators to briefly stop radar emissions to deprive the *AGM-45*’s homing guidance and to restart them when the radar dish had rotated to another bearing, to divert the attack. But with the *AGM-78* this tactic would fail because the missile was programmed to continue on its initial track, so the entire radar had to be moved—impossible to do in seconds. The *AGM-78* was so effective that the 69th *F-4* *Phantom* squadron was specifically dedicated to employ them, with air crews trained in their use; eventually the 69th would launch some thirty *AGM-78s* during operation *Artzav 19* in 1982.

The air force also availed itself of the proximity of the SAMs to Israeli territory– it would not be flying across the seas to a distant target, as all the targets were just up the road. To add to the small number of expensive air-launched variants, both the *AGM-45* and *AGM-78* air-launched missiles were drastically modified into ground-launched missiles. This started with the mounting of *AGM-45*s on WWII vintage M3 halftracks, to obtain an 11km range system introduced at the end of the 1973 Yom Kippur War as a stopgap measure. Later their range was increased by adding booster rockets, which had been developed and manufactured locally and very quickly. The boosted *AGM-45 Kilshon* (Pitchfork), developed and tested within two weeks, used converted M-4 *Sherman* tanks as the launching platforms, yet another use for that forty-year-old mainstay; the missiles could attack targets up to 60km away.

In 1977 the more capable *AGM-78* *Keres* (Hook), introduced with a more elaborate truck-mounted triple launcher, had a longer range and interim inertial guidance to hit SAM radars whose operators had stopped emitting between launches, precisely to throw off anti-radiation munitions. But this was a case of a rapid, economical, and seemingly clever innovation that failed in combat. While dozens of *Kilshon* and *Keres* missiles were fired at Syrian SAM batteries, they failed to destroy any; evidently with ground-launched missiles the initial trajectory angles were just too flat. It was fortunate for the air force that the air-launched radar-killers proved sufficient.

Also essential, it was determined, were electro-optical guided munitions, which allowed aircraft to deliver their munitions accurately while remaining beyond the range of the Soviet 23mm anti-aircraft cannons and portable infrared missiles with which the Syrians were amply supplied. (There has never been any Western anti-aircraft cannon even remotely as cost effective as the Soviet 23mm in its twin or quad configurations).

The air force employeda mix of homegrown and US supplied guided munitions that could be launched from some distance from the target. What the air force called the “loitering attack method” was optimal for standoff weapons, of which it had a useful variety: the US-made AGM-62 *Walleye* and the GBU-8 *HOBOS* were older guided but unpowered bombs, which glided down to their targets within modest standoff ranges.[[23]](#endnote-23) The *Tadmit,* locally developed by *Rafael,* was also a glide bomb manually guided from the launching aircraft.[[24]](#endnote-24) Zeev Bonen, then *Rafael’s* CEO, was well aware of the pressing need for standoff munitions and ordered the conversion of one of the company’s production lines to manufacture *Tadmit* standoff munitions exclusively, supplying the IAF with the first unit as early as the end of 1974.[[25]](#endnote-25) This marks *Tadmit* as a precursor to the *Iron Dome*: it too was developed very quickly by ignoring normal procurement, development, and manufacturing procedures and practices to provide a rapid solution to a major threat.

A small fraction of *Tadmit* bombs were directed to their targets by Weapons Officers on board C-130 aircraft that were thought better suited to accurately deliver the bombs to their targets than the *F-4 Phantoms,* in which the descending glide bomb had to be observed through a tiny cathode-ray tube. To train crews in the use of the new electro-optical munitions, a US simulator was employed at Eglin Air Force Base from 1978, with the program extending into 1982.[[26]](#endnote-26)

The Orchestra – Sella’s Computer Revolution

All the capabilities accumulated would not suffice if the entire operation could not be precisely coordinated from start to finish. The various capabilities had to be combined in a common integrated action plan that would enable all the myriad parts to work together in exactly the correct sequence and with precise timing. But as the envisaged IAF operation grew in size and complexity, its preplanned coordination in the manner of a well-rehearsed orchestra would impose increasing rigidities in the plan implementation, evoking fears of a repeat of the *Dugman* and *Tagar* failures.

Acquiring real-time intelligence with a rapid planning cycle to exploit it would only partially reduce the timelapse between acquisition of the targets and strikes against them. If the pilots and aircraft waited for orders on the ground and needed to study them in depth before takeoff there would still be a considerable delay. Therefore, the best solution was to have aircraft already in the air waiting for targets that would be provided in such a way that the pilot did not need much time to study and implement. But doing this with up to a couple hundred aircraft in the air would require a constantly updated picture of the overall situation of both enemy and friendly forces.

When the British invented the centralized aerial battle control system that had saved them in the summer of 1940, the control was done manually. The IAF, established and initially manned mostly by veterans of the Royal Air Force, adopted the same system, with the commander in charge sitting on a balcony overlooking a large room containing a big table with a large-scale map of the Middle East on which women conscripts manually moved around small tags, each representing an aircraft with all its details (type, armament, fuel state, current altitude., current speed) manually written on it.[[27]](#endnote-27) Until 1973 this method had proven successful, but it became clear it could not keep up with the much faster tempo and far greater complexity of operations. The IAF needed new capabilities, a new plan to exploit them, and a new way of commanding the operations.

On the morning of June 9, 1982, a few hours before Operation *Artzav 19* started, Col. Aviem Sella, then head of the operations branch directly under air force chief MG David Ivry, was in his underground headquarters awaiting the moment he had been preparing for ever since the 1973 war. “There are many different components to this story,” Sella later said, “and their common denominator is that they all rose from the largest manufacturer of motivation – failure... the air force had been insulted.” Born in 1946, in the air force since 1963, Sella flew Israel’s first *F-4E* *Phantoms* during the War of Attrition, shooting down five *MiG-21s*, including one flown by a Soviet pilot in the ambush operation of July 30, 1970. Sella was not mentally prepared for the 1973 defeat inflicted by the SAMs.

Very soon after the fighting ceased in 1974, young Sella was assigned to IAF headquarters with the rank of major and given the large task of finding ways of suppressing the air defenses that had proved so formidable. Chief of operations Amos Amir formed six different teams to think through as many aspects of the overall problem: electronic warfare, intelligence, training, ordnance, and more. Sella moved among them, sometimes to listen, sometimes to lead. Though only a major (hardly a senior position in the IDF, with its few stars) Sella found himself in charge of the single most important air force initiative.

One of Sella’s first and arguably hardest tasks was to change the IAF mindset that saw strong opposition of many pilots to the very idea of focusing on fighting the SAMs.[[28]](#endnote-28) The Old Guard still thought only of air battles—the test of quick instincts, endurance, thorough knowledge of the aircraft on both sides and of their limits, with a willingness to push those limits and take risks, all of which did indeed yield the air combat superiority Arab air forces could not overcome, and which caused them to rely so largely on Soviet-supplied air defenses. What the Old Guard could not accept was that it was their own superiority as pilots that had driven the other side to rely on the missile defenses that had defeated the air force in 1973—hence it was not a problem that more air-combat superiority could possibly cure.

In the immediate aftermath, another group kept arguing that the defeat had been caused by the sequence of disastrous last-minute reversals in attack priorities, so that the solution for next time was to stick to the plan and add more self-protection for more combat aircraft rather than diverting air force funding to missiles, drones, and supporting aircraft.

Sella, himself a deputy squadron commander during the Yom Kippur War, immersed himself in the subject and won over the senior officers for his ideas, which he presented in an internal 1975 document, “Missile Combat – Aerial Warfare against SAM batteries,” which developed a previous publication on the subject by Eytan Ben-Elyahu, an *F-4* *Phantom* squadron leader who would go on to become IAF chief.

Sella further promoted the idea that anti-SAM combat warranted the same methodological approach and resources as air-to-air combat, laying out a detailed breakdown of the solution. First, avoid detection via proper flight-profile planning (normally ultra-low entry); second, break the SAM radar lock-on with maneuvering and radar-confusing “chaff”; and, third, disable the SAM radar with electronic countermeasures and skilled use of radar-warning receivers and jammers, and by raising air-crew awareness and skills with SAM battery scale models, illustrations, and even full-size mockups at every IAF airbase, so airmen could practice identification and attack runs every time they flew their landing approach. He also suggested establishing special ranges with simulated SAMs, a very costly training aid.

To implement Sella’s vision, the air force had to add another layer of command and control capability; plans were still based on the meticulous, centralized planning that had been so successful with *Moked* in 1967 but had failed in 1973 when the plans could not be adapted to changing circumstances. The new layer allowed the central air command center to adapt or change plans even when the aircraft were already in the air in the midst of operations. A new five-step workflow emerged under Sella’s leadership:

1. Strike formations go on loitering routes in front of but out of range of the enemy’s SAM array.

2. A specialized intelligence team acquires and relays real-time intelligence on the array of SAMs, recording their movements and pinpointing their positions.

3. That team transfers its synthesis backed up by aerial photographs to the anti-SAM command post.

4. The latter relays the position of each SAM battery to the loitering aircraft best positioned to attack that particular battery.

5. The aircraft then launch standoff electro-optical munitions at the SAM batteries, which are vectored to strike their fire-control centers.

The command post established to coordinate the successive attacks against the SAM batteries would have to command and control flights of up to 200 aircraft at the same time, in addition to land-based platforms and EW assets. Having designed the new plan, and the command post that would execute it, Sella was appointed to direct its lean staff, comprised of an intelligence officer, an air traffic control officer, and a specialized planning officer for each one of the three SAM regiments of the Syrian air defense network, as well as an electronic warfare officer. Once established in the IAF’s underground command headquarters, the staff attempted to implement Sella’s five-step process in a trial run against a mobile SAM battery. The test failed, and that failure pointed to the urgent need to computerize the entire workflow, hardly an everyday challenge when only the most routine processes were computerized.[[29]](#endnote-29)

The tightly scheduled attack plan, with all the different ground as well as air units involved – from drones, decoys, and helicopters to the large number of fighter-bombers – could not be coordinated and controlled with the old manual methods. Parameters could have been memorized, but there were just too many variables. Moreover, once the operation started, updated instructions for men and machines would be needed in seconds—much too fast for instant human recalculations of the entire strike plans.

Computer control was essential because the planners had to anticipate that three or four attack waves would be needed to destroy the vast, varied array of Syrian air-defenses, each flown by aircraft armed with different weapons to attack each one of their separate components (radars, missiles, launchers, command posts, mobile anti-aircraft cannons, and towed AA gun mounts). They had to simultaneously process the locations, weapon loads, and fuel status of all air force aircraft, and the nature and location of all the targets, thereby allowing continuous optimization of the attack by matching aircraft to targets.[[30]](#endnote-30) Any delay would create a dangerous air traffic problem, diminish the element of surprise, and expose dozens of attacking aircraft to air defenses.

By then mainframe computers had been in standard use in all modern countries for almost two decades, but there was no standard program, or set of programs, that was at all suitable to command and control such a complicated plan of operations. Furthermore, the cost estimate for a tailor-made program (it was all hand-coding then) killed the idea of computerizing the IAF’s command and control.[[31]](#endnote-31)

Ironically it was again the ace fighter pilot, Major Aviem Sella, who initiated the effort to acquire a digital command and control system, named *Periscope;* the air commanders in their deep bunker would “see” the air battle through it. Having studied computer science during his prescribed mid-career university education leave, Sella was convinced he knew everything there was to know about computers. Armed with the cocky attitude of a typical fighter pilot, Sella went directly to air force chief MG Benny Peled to tell him that the air force had to be computerized. This occurred in 1974, many years before email or Google, when computers were still seen as merely computational machines, not the core of operating systems. Hence, Sella was told that the computerization of air operations was neither necessary not possible. Undeterred, he went on to search for ways to realize his vision. What he needed was a program that could integrate and continuously update in near real time all essential data into the ongoing operational plan, such as the exact location of a just-moved Syrian missile launcher or the weapon load of a specific fighter at a given moment.[[32]](#endnote-32) It would all become very ordinary later on, at least for the US and a few other advanced armed forces, but at the time it was certainly a macro-innovation without precedent.

He received some good advice when he witnessed an artillery command exercise and asked Amnon Yogev, a reserve artillery officer working at the Weizmann Institute, how his branch coped with the challenge of directing the simultaneous firing of many artillery guns and rockets against a large number of targets of varying types, many mobile. Yogev referred Sella to Zvi Lapidot, a director in the institute’s computational department and a reserve signals officer of an artillery battalion, who was working on a computerized command project for the Artillery Corps. Sella requested a meeting with the president of the Weizmann Institute (an august figure in Israel), and promptly convinced him to assign a team of computer scientists to work under his direction to develop an integrated operational system for the air force. One was duly formed and set to work, and they were not Weizmann’s rejects but rather the A-team. The Weizmann Institute Computer Science department had acquired its first computer in the 1950s, when even telephones were scarce in Israel, and had developed an advanced capability in that field.

Sella had not changed the minds of his more than skeptical superiors; he had simply gone ahead, never asking nor receiving authorization, let alone a budget, from the air force. The lack of any money was not an obstacle to start the project, as the scientists simply remained on the Weizmann Institute’s payroll. After six months of hard work, the prototype program for the intended system was ready. Sella went to the air force chief, Peled, and persuaded him to visit the institute with him to “see something.” One day in the summer of 1975 Peled arrived at the Weizman Institute, just when the power was cut off. Peled did not storm off but waited patiently for the power to be restored. He spent two hours examining the system before declaring “we need this, as it is, by tomorrow.” Within a week, a truck had come to take the bulky mainframe computer from the Weizman Institute to the air force headquarters bunker. There were no formalities, no paperwork, no bills to pay – it was just a matter of unloading the bulky computer from the truck.

As compared to the manual display board of 1973, *Periscope* belonged to a different era. It integrated, instantaneously, the action of individual “systems,” for example, a single fighter-bomber, into a super-system orchestrated centrally that could follow up initial strikes with ad hoc strike orders for loitering aircraft hunting for mobile surface-to-air missiles. It could do so on the basis of continuously updated information received from drones, ground radars, airborne command centers, individual fighter aircraft, and more. The most dangerous SAM batteries were the mobile ones that could move every ten minutes—much too fast for the command structure and intelligence of the air force of 1973. But in 1982 the Syrian SAM network was faced with an air force that could redirect its aircraft, weapons, countermeasures, and decoys within seconds.[[33]](#endnote-33)

The *Periscope* system induced a complete mentality change in the air force, and rather quickly. With that, its internal organizational structure also changed. The system did not really centralize everything—its development generated the realization that it is neither possible nor desirable to command and control all air combat, all close air support sorties, all reconnaissance and transport missions, as well as to coordinate the fight against the SAMs, all from one and the same control center.[[34]](#endnote-34)

Considerable training was required to enable all the components of the IAF capable of implementing the new concept. A full-scale, operable model of a *SAM-6* battery was set up in Hatzor airbase, and there were models of Soviet early warning radar at every IAF airbase, also at an electronic aerial range. David Ivry, the air force commander, decided that each new fighter pilot was to perform at least one practice run against Syrian *SAM-2* and *SAM-3* batteries in South Lebanon, but without any firing. That way every pilot in the designated anti-SAM squadrons would be familiar with the theater of operations and the tactics developed to destroy SAM batteries. In addition, every four months, the IAF conducted a large-scale exercise centered on SAM suppression. Those exercises were nicknamed *Torpedoes* and included extensive use of simulated Syrian anti-aircraft units, and later of simulated combat over Lebanon against the actual SAM batteries, without the Syrians becoming aware of what the IAF was up to.

Action

As to what actually happened between 16:00 and 18:00 on June 9, 1982, even now the specifics remain secret, perhaps because of a single technical detail.[[35]](#endnote-35) But there is no doubt that the day started with reconnaissance and electronic-intelligence sorties, backed by ground and air-launched decoys that duly aroused Syrian SAM batteries, revealing their positions. All known SAM positions were relayed to the air force command center and the parameters were loaded into the Periscope program.

*Scout* drones then verified the SAM location and status prior to attack, with four electronic warfare aircraft up to provide barrage jamming against Syrian radars.[[36]](#endnote-36) At that point the fighter-bombers of the strike force went up to hold loitering positions at different altitudes, with *F-15*s and *F-16*s armed with air-to-air weapons flying top cover to fight off any Syrian fighters that tried to intervene against the stacked fighter-bombers. The strike force consisted of 24 *F-4 Phantoms* armed with anti-radiation and electro-optical precision-guided munitions, supplemented by *A-4* *Skyhawks* and Israeli-made *Kfir* fighter-bombers armed with both cluster and ordinary bombs.[[37]](#endnote-37) Their presence was precautionary; in case the Syrians jammed the anti-radiation missiles or employed some unknown Soviet countermeasure against the electro-optical munitions, the *A-4*s and *Kfirs* would resort to classic dive-bombing.[[38]](#endnote-38)

At the peak of the operation, a hundred Israeli aircraft were in the air, armed with different munitions for different missions, so that whenever an attack plan for any particular set of targets was generated, based on information processed by the *Periscope* program, an optimized “strike package” could be made up by selecting aircraft from those already in the air and waiting. The hostile and friendly aerial picture and aerial traffic control was provided by Israel’s array of ground-based radars, their operators talking directly to the pilots. A year before the war these had been reinforced with the arrival of *E-2C* *Hawkeye* airborne radars employed as forward air-traffic controllers for the loitering fighters, to keep their various formations properly stacked until each had its turn to launch an attack, based on their proximity to a verified SAM battery location. The *E-2C*s also served to extend the range of radar coverage beyond the reach of Israel’s radars high on Mount Hermon and could also relay radio communications if needed.[[39]](#endnote-39)

As the attack unfolded, whenever a Syrian radar was switched on, *AGM-78*s would be launched, usually destroying it. When a visual or radar contact revealed the location of a SAM battery, it was promptly attacked by one or more *F-4*s armed with *Tadmit* or *GBU-15* remote-controlled gliding bombs, usually aimed at the battery’s fire-control-center. A-4 *Skyhawks* and *Kfirs* with cluster bombs would follow up to destroy the launchers of “headless” batteries.

During the two hours of *Artzav 19,* the Syrian SAM batteries in Lebanon remained stationary, so that the much-practiced ability to hunt mobile batteries was not needed. But in the following days, when SAM batteries, including *SA-8*s, moved at night into South Lebanon they were destroyed within hours.[[40]](#endnote-40) It was only then that the drones fully realized their potential – during *Artzav 19* they had mostly served to verify the validity of battery location data just prior to attack, to make sure they had not suddenly moved or been destroyed.[[41]](#endnote-41) But during the night of June 9 the *Scout* drones played a crucial role in hunting the formidable *SA-8*s. The latter were found alongside the other SAM batteries the Syrians sent into South Lebanon under cover of the night; with *Periscope* guidance and real-time imagery from the drones, the command post directed the “shooters,” the airborne fighter-bombers, to destroy the moving batteries, providing the pilots with updated and exact locations.

As head of the IAF’s operation branch, Sella had the privilege of seeing the conversion of his concept into an operational plan, *Artzav 19,* as well as its actual implementation in war, using the computer-assisted command system he himself had introduced into the air force just a few years earlier.[[42]](#endnote-42) It was, in fact, the first computerized war operation attempted anywhere. It was also the first time the air force deviated from its much-valued unified unitary command and control directly by the air force commander, because of the expectation that important events would happen at a frantic pace in warfare compressed to just a few hours, leaving no time for staff deliberations. Instead, air force commander MG David Ivry limited himself to supervising air-to-air operations and appointed Sella to directly command the takedown of Syrian air defenses, by overseeing the functioning of *Periscope*.[[43]](#endnote-43)

A visitor to the underground air force command center would have been greeted by the odd sight of an ultra-orthodox Jew in a typical black suit and hat: Menachem Kraus, the only member of the Weizmann Institute team who actually knew how to operate the mainframe computer on which the Periscope software ran. Having never served in the IDF (exempted as a full-time cleric), Kraus did not even have a common soldiers’ minimum-security clearance, let alone the more demanding one needed for the ultra-secret command center, and Sella had to convince his chief that Kraus was critical for mission success.

Sella later recounted that while the operation was in full motion, every few minutes Kraus raised his hand and turned his fingers to signal “how many” batteries destroyed while Sella, sitting across the command room, would raise his fingers in response to inform him of the number destroyed up to that moment. When it was all over, Kraus crossed the corridor to Sella’s office to shake hands, covering his eyes to avoid having to look at all the young women soldiers along the way (in the summer heat the air conditioning could not keep up at full occupancy, so dress was informal).[[44]](#endnote-44)

*Artzav* 19 in June 1982 was a watershed event in the history of warfare. It was the first battle fought under computer command for all practical purposes; it was also the first battle, aerial or otherwise, in which unmanned aerial vehicles, or “drones,” had a major, arguably decisive role.

1. Avneri, *Ha’Mahalumah,* 18. [needs full citation] [↑](#endnote-ref-1)
2. Sella interview. [↑](#endnote-ref-2)
3. Shmuel Gordon, *Thirty Hours in October* (H) (Tel-Aviv: Ma’ariv Books, 2008), 426. (H) [↑](#endnote-ref-3)
4. Gil Shani, “Coming down from the heavens,” *IAF Magazine Online*, October 25, 2004. (H) *Zahavan* <http://www.iaf.org.il/1424-22879-he/IAF.aspx> [↑](#endnote-ref-4)
5. Gordon, *Thirty Hours in October*, 428 – 431. [needs Hebrew translit. title] [↑](#endnote-ref-5)
6. The MQM-105 *Aquila* UAV had already demonstrated useful capabilities when it was suspended in September 1985 because it failed 21 of the 149 performance specifications, many necessarily trivial. Not an uncommon way of stopping macro-innovation that (by definition) lacks extant users to defend it. [↑](#endnote-ref-6)
7. A stripped-down *Firebee* (*Shadmit* in the IAF) was used as a target drone by air defense units. [↑](#endnote-ref-7)
8. “The *Telems* arrive at the UAV squadron,” *IAF website.* (H) http://www.iaf.org.il/3626-4953-he/IAF.aspx http://www.iaf.org.il/3626-4953-he/IAF.aspx. [↑](#endnote-ref-8)
9. Too modestly for some; Technion graduate Abraham Karem emigrated to the US to become the “drone father” with the winning *Predator* design via his first *Albatross*, then *Amber,* experiencing bankruptcy before his rebirth as a General Atomics acquisition. [↑](#endnote-ref-9)
10. Dobster continued at the IAI, developing UAVs for the US (*Pioneer* and *Hunter*), the widely exported armed decoy *Harpy* and other UAVs. Eyal Birnberg, “Eye Contact,” *IAF Website* (H). http://iaf.co.il/Shared/Library/Controller.aspx?lang=HE&docID=18389&docfolderID=1102&lobbyID=50 [↑](#endnote-ref-10)
11. Shani, “Coming down.” [needs Hebrew translit. title] [↑](#endnote-ref-11)
12. Shani, “Coming down.” [needs Hebrew translit. title] [↑](#endnote-ref-12)
13. “The first UAV squadron,” *IAF Website*. (H) http://www.iaf.org.il/4968-33518-he/IAF.aspx http://www.iaf.org.il/4968-33518-he/IAF.aspx [↑](#endnote-ref-13)
14. 9K33 *Osa or Romb*. NATO reporting name SA-8 *Gecko*. [↑](#endnote-ref-14)
15. Cohen & Globerman, “Most targeted killings have been carried out by IDF UAVs.” [first names, source?] [↑](#endnote-ref-15)
16. David A. Fulghum and Robert Wall, “Israel Starts Reexamining Military Missions and Technology,” *Aviation Week & Space Technology*, August 20, 2006, https://web.archive.org/web/20061218215607/http://www.aviationnow.com/avnow/news/channel\_awst\_story.jsp?id=news%2Faw082106p2.xml; “Israel sets combat drones against missile launchers in Gaza,” *World Tribune*, May 8, 2007. http://www.worldtribune.com/worldtribune/07/front2454229.238888889.html [↑](#endnote-ref-16)
17. Amnon Barzilay, “The IAI has developed a UAV for the interception of ballistic missiles,” *Globes*, August 6, 2006. (H) At: http://www.globes.co.il/news/article.aspx?did=1000119023 [↑](#endnote-ref-17)
18. Aviel Magnezi & Yoav Zaitun, “The wing which was torn off a UAV carried a new kind of navigation component,” *Ynet,* January 29, 2012. (H) At: http://www.ynet.co.il/articles/0,7340,L-4182254,00.html [↑](#endnote-ref-18)
19. “The IAF’s new UAV *Kochav* becomes operational,” IAF Website November 10, 2015. (H) At: <http://www.iaf.org.il/4427-45608-he/IAF.aspx>. [↑](#endnote-ref-19)
20. On gliding decoys see Meir Finkel, “IAF Build Up Leading to Mole Cricket 19 (1982-1973),” *IDF Journal Bein Ha’Ktavim* no. 20-21 (2021), 105 (H). Martin Van Creveld, *The Age of Airpower* (New York: Public Affairs, 2011)*,* 230. [↑](#endnote-ref-20)
21. Gordon, *Thirty Hours in October,* 427. [needs Hebrew translit. title] [↑](#endnote-ref-21)
22. Finkel, “IAF Build Up,” 106-109. [needs Hebrew translit. title] [↑](#endnote-ref-22)
23. Ivry, “Destroying the Syrian SAM array*,”* 71. [needs full citation on first mention, Hebrew translit if orig in Hebrew] [↑](#endnote-ref-23)
24. Gordon, *Thirty Hours in October*, 428. [needs Hebrew translit. title] [↑](#endnote-ref-24)
25. Finkel, “IAF Build Up,” 106-109. [needs Hebrew translit. title] [↑](#endnote-ref-25)
26. Finkel, “IAF Build Up,” 110-111. [needs Hebrew translit. title] [↑](#endnote-ref-26)
27. Gordon, *Thirty Hours in October,* 282. [needs Hebrew translit. title] [↑](#endnote-ref-27)
28. Gordon, *Thirty Hours in October*, 91-92. [needs Hebrew translit. title] [↑](#endnote-ref-28)
29. Finkel, “IAF Build Up,” 94. [needs Hebrew translit. title] [↑](#endnote-ref-29)
30. Ivry, “Destroying the Syrian SAM array*,*”70. [↑](#endnote-ref-30)
31. Finkel, “IAF Build Up,” 94. [needs Hebrew translit. title] [↑](#endnote-ref-31)
32. Ivry, “Destroying the Syrian SAM array*,*”69. [↑](#endnote-ref-32)
33. Gordon, *Thirty Hours in October*, 458; Ivry, “Destroying the Syrian SAM array,” 70. [needs Hebrew translit. title] [↑](#endnote-ref-33)
34. Sella, interview with the authors. [↑](#endnote-ref-34)
35. Ivry, “Destroying the Syrian SAM array,” 71; Van Creveld, *Age of Airpower*, 230. [↑](#endnote-ref-35)
36. Uri Milstein, “The *Artzav* effects: how Israel destroyed the Syrian missiles and the Soviet Doctrine,” *Ma’ariv*, June 4, 2016. http://www.maariv.co.il/news/israel/Article-544311 [↑](#endnote-ref-36)
37. Michael Bar Zohar and Nissim Mishal, *No Mission is Impossible* (NY 2015), 201. [↑](#endnote-ref-37)
38. Finkel, “IAF Build Up,” 109. [needs Hebrew translit. title] [↑](#endnote-ref-38)
39. Avneri, *Ha’Mahalumah,* 60-61. [↑](#endnote-ref-39)
40. Finkel, “IAF Build Up,” 98. [needs Hebrew translit. title] [↑](#endnote-ref-40)
41. Finkel, “IAF Build Up,” 101. [needs Hebrew translit. title] [↑](#endnote-ref-41)
42. A year earlier, on June 7, 1981, Sella was chief of operations when the IAF destroyed Iraq’s Osirak nuclear reactor in “Operation Opera.” [↑](#endnote-ref-42)
43. Finkel, “IAF Build Up,” 112-113. [needs Hebrew translit. title] [↑](#endnote-ref-43)
44. Kraus and his three team members, Amnon Yoge, Izhak Ben Israel, and Zvi Lapidot, were awarded the prestigious Israel’s Defense Prize. [↑](#endnote-ref-44)