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Computers in Air Defence

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1. AIR DEFENCE

With man's mastery over the third dimension – the near atmosphere and space – it has become increasingly necessary to protect oneself not merely from attacks from land and the sea but, more importantly, from attacks from the air. This was recognised even during the World War II and a rudimentary air defence capability was sought to be established by the manual (visual) surveillance and the anti-aircraft guns. The advent of radar signified a major advance in air defence technology and techniques. Rather than depend on visual observation and the hazards and limitations thereof, it became possible with radar to detect the presence of flying objects at much great distances. The PPI display of a conventional air-surveillance radar permits an operator to scan the sky for several hundreds of kilometers all around. Early radar-based air defence systems were dependent on human observation and decision making for detecting targets, identifying them, deciding on interception strategy and for recovering the interceptor after completion of his mission. This was feasible because, with a radar range of between 200 to 400 kilometers and aircraft speeds in the range of 500 kilometers per hour, upto 30 minutes warning was available before the target was overhead.

2. COMPUTERISATION

In the pre-computer days, identification of friend or foe was done taking into account available flight plans. IFF codes and other diverse information was used to the extent possible. Assessment of threat, likewise, had to be qualitative and semi intuitive rather than systematic and quantitative. Even tracking a single aircraft among a diversity of targets required a good deal of skill. Weapon allocation to neutralise the threat had to be done on the basis of simple thumb rules rather than systematically, quantitatively and logically. How well an interceptor could be guided and controlled

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in response to evasive and or misleading maneouvres by the target, depended entirely on the skill and experience of the controller. Recovery of the interceptor has again to be managed using adhoc, qualitative and subjective methods. Therefore, consistently good quality response could not be assured. While expert controllers could be depended upon to operate with maximum effectiveness and efficiency under nearly all circumstances, it was extremely difficult to improve the performance of the mediocre. The crucial question was: 'could one somehow achieve performance approaching that of an expert controller even from a controller with average or below average skills?'

The important contribution of computerisation in air defence was the facility that it provided of:

(a) enunciating air defence procedures and strategies in clear, quantitative unambiguous terms,

(b) assessing their validity and merit both in the abstract as well as in specific (hypothetic or even in real life) situations and, finally,

(c) incorporating them into software which, subsequently, would behave with the utmost reproducability, consistency, reliability and efficiency.

Consider for instance the strategy to be adopted for intercepting an aircraft in the sky. The computer visualised the profile to be followed by the interceptor as consisting of a fixed (say upto 16) number of segments. Depending on the situation in each case the program determines the parameters defining each of these segments on the basis of various criteria: minimum time, minimum fuel or any other relevant consideration. The machine then makes several (say upto three) alternatives available to the controller leaving the final choice to him. During interception, it would not flood him with details and instructions ahead of time. It would give these in steps, each a few seconds before it is actually required to be communicated to the pilot. It keeps continuously reassessing the situation and recomputes the profile whenever the target behaviour changes significantly. This would be accomplished by suitably modifying the still unexecuted segments of the profile. The controller would not even be aware that such a recomputation has taken place, because he was not informed about these segments ahead of time. A much more significant advantage is also obvious: the quality of profile computation is now assured, irrespective of the personal experience, intelligence and competence of the controller. The below average controller can therefore be helped to respond as well as an expert would. The only assumption is that the strategy incorporated into the profile generation software is as good as that adopted by an expert controller.

This advantage alone is adequate justification for the induction of computers into air defence. Quite apart from this, recent developments in aircraft technology have made computerisation of air defence systems inescapable. With today's supersonic air craft, the warning time available between detection and attack can be as little as a few minutes – clearly too short for meaningful human response. A computer, on the other hand, can respond even within such short times.

3. AIR DEFENCE FUNCTIONS

Let us now consider how a computer system implements the various functions of air defence. The following is an enunciation of some of the common characteristics of commercially available air defence systems:

3.1 Tracking

The first pre-requisite for engaging a target acquired by the radar is that it should be possible to track it. A computerised air defence system acquires target data primarily from 3–D radars equipped, either with hardware or software video extractors. It accepts information regarding range, azimuth, height and IFF codes of the targets detected. Similar information is accepted also from gap filling radars and neighbouring air defence systems. (It would even be possible to incorporate information from visual observation, if available). All this data is converted into a common coordinate system and correlated. By making a scan to scan comparison of the target position, plots pertaining to each individual target are linked and tracks are generated alongwith speed, bearing, height and other details. Uncorrelated plots (which may be the result of static or slow moving objects) are eliminated. Track information is extrapolated in case echoes are missed during individual scans. The information so analysed is presented in a properly human engineered form, so that the operator is able to 'take it in' at a glance. Selective masking of information is also possible (for example of all friendly aircraft of all aircraft outside a particular height range) for easy readability. Information regarding targets headed for areas covered by neighbouring Defence Stations can automatically be communicated to them.

3.2 Identification

Information regarding available flight plans and IFF codes is used to identify whether a given target is a friend or an unexpected intruder. Aircraft within flight corridors can be classified as friendly.

3.3 Threat Evaluation

All possible areas that may be under attack by the intruder are identified and the threat arising to each of them quantified using target height, speed, etc. It is also possible to identify specific points of importance which could fall within the range of the intruder and are therefore threatened. Warnings can be sent to all of them, automatically.

3.4 Weapon Allocation and Control

Various alternatives such as surface to air missiles, interceptor aircraft and anti-aircraft guns may be available for deployment. Depending on available information regarding the hostile target, the disposition of defensive weaponary available and their readiness status, trial interceptions are worked out and the times required for interception in each case are arrived at. The system can implement one out of the several such possibilities, depending upon the choice of the controller. For this, it assembles the profile out of standard segments (such as climb, acceleration, zoom, turn, etc.). The aim is to position the intercepter as close as possible to the expected interception point. Segment data is displayed step by step, just at the times when specific instructions are required to be communicated to the pilot. Corrections are made on line to account for manoeuvring by the target as well as deviations in the interceptor implementing earlier instructions. (An essentially similar procedure can be adopted even with respect to missile interception, except that the reaction times in this case require to be much smaller). The fuel consumption of the aircraft is also computed step by step and kept track of throughout; an interception can be aborted if recovery is to become impossible due to fuel limitations.

The profile computation can be organised to permit a variety of 'final' approaches to the target: head on, broad side on or end on. An appropriate one can be chosen to ensure minimum probability of detection by the target's radar.

3.5 Recovery

After successful (or aborted) interception, the interceptor is recovered, using a similar procedure aimed at computing an efficient profile. The relevant parameters are: fuel availability, distance to recovery bases and the coordinates of the interceptor. If recovery to home base is not possible (say due to fuel limitations), recovery is made to any other base.

4. SIMULATION

All these are indeed significant capabilities which make computerisation very attractive. There is a further benefit that computerisation provides; the performance of the system can be demonstrated, tested and evaluated without any aircraft even having to be air borne. It is possible, using simulation techniques, to provide aircraft data to the air defence system in real time in exactly the same manner as a radar does. This can be done for any predetermined flight exercise, of arbitrarily high complexity. Further, this simulation can be done by a separate program on the same system. Alternatively, the exercise can be preplanned and information regarding hostile and unknown tracks can be computed and dumped on to a storage device (disk or tape). When this is played back, the system would treat it exactly as if it were live data and react to it appropriately.

Additionally, it is possible to record earlier real, life episodes and play them back on the system to do a post mortem evaluation of performance or to train novice operators on difficult situations. It is even possible to provide consoles on the systems for the 'target', and the 'interceptor' They could then have an 'engagement, and sharpen their respective skills in a war game, without ever leaving the ground!

There can be facilities for input and updating of environmental information such as metereological data, base status, flight plans and so on without interrupting regular system operation.

Needless to say, it is important to ensure that the target is detected. An air defence system can hardly deal with a target that it does not know about. To ensure a high probability of detection it is customary, for obvious reasons, to mount the radar heads on locations of high elevation. While this improves visibility, it also raises the problem of ground clutter.

5. AIR BORNE DEFENCE SYSTEM

Despite the increasing coverage provided by radars of today, warning times are becoming uncomfortably small, due to increasing aircraft speeds. The obvious answer to the need for greater coverage is to base the radar at even greater heights than the terrain would permit: i.e. on flying platforms. Radars located at such heights would be able to look considerably beyond the borders, right into enemy territory and detect threat almost from the point of its origin, thereby greatly increasing the time available for meaningful reaction. Such radars have necessarily to look down and need very special and advanced visual pattern processing techniques to detect moving targets in high clutter. This is the manner in which air borne warning and control systems (AWACS) operate. It has been stated that one air borne system is nearly as effective as 20 ground–based systems. A single AWACS can look over an area greater than 500 thousand square kilometers and can track ships, fixed installations such as off shore production platforms, features on the ground as well as aircraft. The technique adopted for clutter removal is to compare pictures seen in two successive scans and essentially eliminate all features that are common between these scans. This should be a straightforward, even if tedious procedure. This would require a memory with adequate capacity to store enough pixels (individual points or 'cells' of a picture) to ensure a reasonable resolution (of the order of 10 meters or so). What makes it complicated is the fact that the two pictures would not correlate easily because of the movement of the observation platform and the curvature of the earth. The computational load is such that even the most powerful super computers can get over loaded. Special array processors have to be used, taking advantage of the fact that the computation is largely repetitive. Much of the information is processed on board. Defensive steps can then be initiated to counter any agressive moves that are detected. Instructions relating to this are then conveyed to ground–based Defence Stations. Such air borne systems, with the enormous computational loads they demand, could not even have been dreampt about, let alone realised, without computers.

Two precautions are most important under such circumstances: electronic-counter-counter-measures and encryption of communication. Here again, computers have a major role to play.

6. THE INDIAN SCENE

An air defence system comparable to commercially available state-of-the-art systems has been developed under funding from the Department of Electronics by a group of organisations headed by the Tata Institute of Fundamental Research. This effort was based on purely indigenous know how. All the hardware and software were designed and developed locally. After successful trials, the know how for this system was transferred to Electronics Corporation of India Limited. Commercial production and induction of these systems into active use would greatly enhance the Defence capabilities of this country, given the geopolitical realities it has to contend with.

7. ADVANTAGES AND DISADVANTAGES

There are several advantages of computerisation in air defence. We have already mentioned those of consistency and quality. Quality can be further improved over a period of time as the user group acquires experience with the various strategies that have already been implemented.

Subject to the target being detected by the sensor, one can, with a high degree of confidence, assume that it will be engaged and successfully intercepted.

The intricacies of the calculations involved in the various steps of air defence activity are clearly beyond the capability of an operator, particularly at times of stress. A computer is a great help in this regard; what is more, there is a further quantitative advantage. It is possible to deal with several hundreds of targets at a time and also carry out large numbers of simultaneous interceptions. In fact, the capability of modern computerised air defence system is such that it becomes very difficult and almost impractical to test them by live exercises. Simulation has to be resorted to.

Computerisation also permits integration of information provided by a variety of sensors. This makes it possible to interlink a number of radars and exchange information between them, realising an efficient command, control and communication network.

It is commonly thought that computerised air defence systems have reached such a high degree of efficiency that they are unlikely to be called upon for actual use in combat. Intruders perforce fly at tree top heights to avoid detection. Consequently, use of a computerised air defence does not eliminate the possibility of attack, it places the enemy in a position of great disadvantage by forcing him to fly at low altitudes, thereby increasing his risk as well as reducing fuel efficiency and range considerably.

8. CONCLUSION

To conclude, computerisation of air defence systems has brought about qualitative and quantitative improvements to the defence capabilities of countries using it. The main limitations of computerised air defence pertain not so much to those of the computer but to the other components: the sensors, the communication systems and the human links. There is scope for further automation by way of eliminating the fallible controller-to-pilot-to-aircraft link and establishing a direct link between the control computer and the control system of the interceptor aircraft. This would permit faster response by reducing the loop delays and also minimise errors of communication and interpretation. However, this also raises the problem that this reduces the scope for human overseeing of the decision-making and execution process.

One would notice that most of the functions that the computer is called upon to perform are straightforward and mundane. The machine is hardly if ever called upon to use 'intelligence' Advanced techniques such as Artificial Intelligence and expert systems are yet to make significant inroads into the air defence scene. This is not very surprising; computerisation in such a vital area has to take a conservative approach.

The main risk of computerisation is that, in a very broad sense, it 'stereotypes' responses to given situations. This makes it easy for the enemy to anticipate such responses and therefore adopt approaches which maximise the probability of his success. This process of one-up-manship can exist even in a non computerised situation; however, it becomes much more of a guessing game there because of the unpredictibility of human reactions.

A further disadvantage of computerisation is that changes to existing strategies become slower to evolve and implement. Faced with an unorthodox situation, a human controller makes suitable on the spot responses with matching initiative and innovativeness. Atleast, he would be quick to learn from such experiences and incorporate in his own strategy the necessary changes to surmount such problems. The human operator in a computerised system has to operate at a more superficial level. He cannot initiate changes to the system on his own. Implementing changes of strategy into computer software, should this turn out to be necessary, would require extensive effort in making the modifications, testing them fully and, most importantly, certifying that the new version of software is bug free. This can certainly not be done within a matter of days, say while a short war is in progress.

This brings us to the other important and all-pervasive question of reliability of software. Despite spectacular advances in software engineering and computer science, these have not progressed to a stage where sophisticated software systems can easily be certified to be totally reliable. Unpredictable performance in unanticipated situations cannot be completely ruled out.

Despite these, the advantages of computerisation and the progress of weapons technology are such that Defence systems have to depend increasingly on computerisation in the decades to come.