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# CHALLENGES OF AIR THREAT DETECTION IN INDIA'S CONTEXT

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In the coming decade, India will confront the growing threat from the Stealth aircraft and Drones in addition to the existing threats from the Ballistic and Cruise missiles. Their designs and flight characteristics are focused to avoid or delay their detection which reduces the reaction time of air defences and probability of their destruction.

## STEALTH AIRCRAFT THREAT

Our Northern neighbour has developed a fifth generation air dominance fighter J-20 with stealth characteristics. The J-20, a midair-refuelable, missile-capable jet designed to fly far beyond China's borders, was for years kept in top-secret development by the Chinese. It was first showcased to the world by China during US Defence Secretary, Mr. Robert M. Gate's visit during Jan 2011. It has been operationalized since then and twenty+ are in service. After solving the engine related issue, Chinese are expected to undertake the serial production of the aircraft.

Another state owned Chinese company Shenyang Aircraft Corporation is developing a midsized twin engine fighter FC-31 with stealth features. Its prototypes conducted a maiden flight in Oct 2012 and again in December 2016. In November 2018, an Aviation Week article revealed that the FC-31 programme has received government funding and is being sought after by both the PLANAF and

PLAAF. It may also be offered for export, as an alternative for those countries that cannot purchase American F-35.[1] Chinese are also known to be engaged in developing stealth long range bomber (H-20). It is estimated in the US annual congressional report of 2016 that the H-20's may carryout first flight in the early 2020s, with production possibly beginning around 2025.[2]

## Characteristics of Stealth Aircraft

An intruding aircraft can be detected by its radar, Infrared and acoustic signatures. For radar detection, reflected radio waves from the aircraft are also picked up by the source radar (air borne or ground) which leads to its radar detection. The range depends on the transmitted power, height of the aircraft, the radar horizon of the ground radar, and effect of extraneous clutter / interference.

The IR signatures too can lead to detection of the airborne/ground targets. This mode of detection is normally employed by the aircraft. Aircraft generate heat from their engines as well through frictional heating with the air. The nose and leading edges become hot, more so when flying supersonically. This can make detection easier. This is why stealth planes stay subsonic even when they are able to fly supersonically or have super cruise capability without switching reheat.

Modern fighter aircraft are equipped with Forward Looking Infrared (FLIR), for enhancing all-round situation awareness. It uses a passive thermo graphic camera, so that they do not give out any radiation of their own, unlike radar. As the IR attenuates in the atmosphere, the range of detection by this mean is not very large.

All aircraft emit specific acoustic signatures. The relevant literature suggests that acoustic signatures can be processed to detect the aircraft. This being a passive system would not be prone to the threats of anti-radiation missiles but, acoustic detection has not developed to an extent that this can be universally used to detect the combat aircrafts. In US however, customs and border protection force use it for detection of illegal activities like smuggling of drugs/criminal transit / human trafficking etc across the Northern borders. The sound emitted by the low flying aircraft is picked up by the Acoustic Seismic Detection System (ASDS) which detects the presence of the aircraft and its approximate location by triangulation. For obvious reasons, it is not suited for detecting the fighter aircraft unless these approach at low level.

Stealth aircraft have been designed to reduce the radar, IR signatures to avoid detections. The aircraft design aims to reduce the radar cross section. US F22 is known to be an example of perfect stealth but, changes in design has raised F22 cost to an astronomical level which even America has found it unaffordable and therefore, it has developed F-35, a less stealthy aircraft and a cheaper practical version. Likewise, the Northrop B-2 Spirit, and latest B21 Raider also fall in the genre of Stealth bombers which are designed for penetrating dense anti-aircraft defences. Other aircraft under development such as Chinese J 20, J 31and Russian SU 57 (Pak-FA) are not as stealthy as F-22 but, these aircraft still would be difficult to detect and even if detected the ranges would be so low to enable any credible response by the air defence. Russia and China are also developing stealth bombers, the details are not in public domain.

[1]http://www.globaltimes.cn/content/743700.shtml

[2]https://media.defense.gov/2018/Aug/16/2001955282/-1/-1/1/2018-CHINA-MILITARY-POWER-REPORT.PDF

## Radars for Detection of Stealth Aircraft

Stealth design as mistakenly believed does not make the aircraft invisible, rather the technology simply delays detection due to the reduced cross section on certain radar frequencies. Radar absorbent material coatings which have carbon black particles or tiny iron spheres on every surface of the stealth fighter further help in concealing the aircraft by absorbing the radar energy with minimal reflection.

**Use of Low Frequency Radars (LFRs).** Radars operating on low frequencies can detect despite the coating of the IR absorbent material, as the absorbent coating is not thick enough to absorb the low frequencies in the metric band and below, so target aircraft reflects such radio frequencies despite its stealth features. However, the reflected signal displayed has poor azimuth discrimination due to large beam width and poor range resolution of the detected pick up. Thus VHF and UHF band radars cannot be used for aircraft tracking but, these can provide good early warning for activation of air defence weapons. Our northern neighbour's J-20 fighter is not even fully stealth could thus, it can be detected by one of several UHF/VHF radars which India too possesses. However, these radars due to the design limitations do not offer long detection ranges and cannot thus be used to detect deep inside the territory of the adversary.

Another report which raises questions about the stealthy state of J-20 is that SU 30 MKI could actually track J 20 during its flight in the Indo- China border. This affirms the belief that unlike the US's F-22 and F-35 stealth jets, the J-20 doesn't have all aspect stealth. A US expert however, believes that, it is possible that the Chinese are flying the J-20 with radar reflectors attached to enlarge and conceal its true radar cross section during peace time operations, just as the USAF routinely does with the F-22 and F-35.Hence, challenge of J-20 cannot be brushed aside and counter measures surely are needed to tackle the threat.

**Over the Horizon Radars.** These radars have detection ranges of thousands of km and allow surveillance of very large territories but, are not suited for tracking aircraft threats due to poor resolution. These require large powerful transmitters and huge antenna (antenna dimension is in miles) and are very expensive. The HF frequency used in this radar returns to the earth after bouncing from the ionosphere. US and Canada have deployed these radars. Even Australia and China have deployed one radar each.

**Passive (Multi-static/Bi-static) Radars**. These are known to be better in detecting the stealth aircraft than the mono-static radars. Such a system typically uses low frequencies (broadcast TV and FM band). At these frequencies, it difficult to control the aircraft's signatures.

**Quantum Radars.** Quantum radar might eventually provide a capable mean of detecting stealth fighters and bypassing electronic warfare capabilities of the adversary's aircraft. A quantum radar functions by using a crystal to split a photon in to two entangled photons. The radar beams one half of the entangled pair outwards, and monitors the corresponding effects on entangled partner. If the beamed particles hit say a stealth fighter, the effect on the beamed photon would be visible on the un-beamed partner photon as well, as a ping. The photons which register a 'ping' are sorted out from the unaffected photons to form a sort of radar image. Quantum radars will make the stealth technology ineffective. The Quantum technology is still at the laboratory level even though many countries are engaged in the research.

### Infrared Detection

IR detection has application in the airborne sensors rather than ground based sensors. Infra-Red Search and Track systems (IRSTs) of the fighter aircraft can be used against stealth aircraft as well, because aircraft surface heats up due to friction with the air. The two channels IRST carries out detection by comparing the difference between the low and high channel. It is fitted to the MiG-29 and Su-27 aircraft. The French Rafale, the Euro fighter and the Swedish Gripen also make extensive use of IRST. This not to say that IRST can be used to detect the adversary's aircraft at the ab-initio stage but, it would be used during engagements to know about the adversary, aircraft position to take advantage of the tactical situation.

### Acoustic Detection

The acoustic detection could be employed to detect a Low Flying Aircraft (LFA). The Sound radiated by LFA was used for their detection, tracking and classification by the developed Acoustic Seismic Air Detection (ASAD) system which determines the direction by correlating the detection from more than one detector of the system. US uses this system on the Northern border to check the entry of the smugglers / drug/ human trafficking. The system can also be used as the early warning system and can replace the visual detection by the operators who are also in some places deployed along the border to fill in the gaps in the radar system. The acoustic library of the system can help in distinguishing the type ie whether transport/ helicopter / fighter aircraft.

## BALLISTIC AND CRUISE MISSILE THREATS

India nuclear doctrine declares no first strike capability and would resort to a massive debilitating strike in response only. Our neighours in the North and West have capability and sizeable arsenal of nuclear ballistic and cruise missiles. It is incumbent that we have credible capability to detect their launches well before these enter our airspace and target our country. Such a capability will at first enable us to detect them, initiate action to neutralize them and finally take an appreciate decision to use the strategic weapon.

The chart below indicates their characteristics and the difficulties involved in their detection and interception:-

Key Characteristics of Ballistic and Cruise Missiles[3] :-

| Characteristics | Ballistic | Cruise Missile |
|---|---|---|
| Range | From Low to very high<br>Up to 15000Km | Mostly 1000Km to<br>4000km |
| Altitude | High -Easily detectable | Low - Hard to Detect |
| Precision | Low – around few<br>hundred meters | High – A few meters |
| Speed | Up to 25000 Km at impact<br>Hard to intercept | Around 1000km<br>Possibility of intercept exist |

[3] https://epthinktank.eu/2017/09/29/understanding-nuclear-weapons-and-ballistic-missiles/

All ballistic missile trajectories consist of three phases—boost, midcourse and terminal. The boost phase is defined as the part of the missile's flight from the time of launch until it stops accelerating under its own propulsion system, typically the first 60 to 300 seconds of flight.

It is ideal to destroy the missile in the boost stage, but, the window of opportunity is relatively small, Air borne laser alone could accomplish it. But capability as on now does not exist from far away distance.

In mid-course phase of a ballistic missile trajectory follows a more predictable flight path, there is more time for ballistic missile defence elements to track and engage the target. Example: Aegis BMD.

The terminal phase of flight starts when the missile re-enters the Earth's atmosphere, generally lasting less than 60 seconds. A layered defence approach is normally followed. After attempting mid course interception, terminal phase missile interception is attempted if the threat is not already neutralised. Example THAAD, Arrow. This approach requires early detection and tracking of the ballistic missile by combined use of Satellite-Based Infrared systems (SBIRS) and Ground based system (GBS). The SBIRS programme is designed to provide early warning of missile launches, and simultaneously support other missions including missile defense, technical intelligence and battle space awareness on 24/7 basis.[4,5]

The system comprises of IR sensors in a satellite which can detect the missile launches in its area of observation. The purpose of the Infrared sensor is to acquire the ballistic missile in the early stages of the flight. A tracking infrared sensor in the satellite is designed to follow missiles, warheads, and other objects such as debris and decoys during the middle and later stages of flight. US, Russia, positively have the space based missile detection capability. Its availability with China can be strongly expected due their recent advancement in space technology.

The space based system is supplemented by a follow on ground- and sea-based early warning radars to track the target missile and intercept it. Both US and Russia have ground based ballistic missile tracking systems. US has Ballistic Missile Early Warning System (BMEWS) system deployed in the Northern hemisphere and other areas. These are deployed at Colorado-United States, Thule- Green land, Clear-Alaska, Yorkshire-UK, Trinidad, and New Jersey and provide overlapping cover of 3000km against ballistic and cruise missile threats. These altogether form part of the ground based interceptor system which will detect and destroy the incoming ICBM in the space in the mid-course interception. Russia in comparison has chain of eight radars for early warning of the ballistic missiles and aircraft. These are phased array radars which have claimed detection range of 6000 km and are huge structures. As on 2017, eight such radars are operational.[6]

[4] http://www.lockheedmartin.com/news/press_releases/2009/0602ss-sbirs.html

[5] www.losangeles.af.mil/News/Article-Display/Article/734759/sbirs-geo-5-6-contract-awarded/

[6] http://tass.com/defense/981965

[7]

*Voronezh-type radar*

### Missile Detection Challenge for India

The nation faces significant threat from the nuclear armed ballistic and cruise missiles. India plans to intercept the threat at the terminal phases. After the Kargil war of 1999, DRDO is engaged in developing a Ballistic Missile Defence (BMD). We have also contracted Russia for purchase of five S-400 BMD systems. India has bought three Green pine radars from Israel which are being used in conjunction with BMD by DRDO.[8] Green pine radar has the range of 500km and can track targets flying with speed of 3000m/s. DRDO has upgraded these to Swordfish LLTR, an Active Electronically Scanned Array (AESA) radar to track the threat. The Swordfish LLTR currently has a range of 600 km - 800 km which DRDO is in the process of upgrading it to 1,500 km.[9]

Currently, DRDO relies heavily on radar systems for testing its BMD performance and even S 400 when inducted will depend for detection on the integral radar for detection of threat. A missile travelling at 5ooo m/s could cover 600 km in less than two min. This does not give adequate reaction time particularly when direction of approach of the incoming missile is not known. Therefore, a credible system would need space based early warning system with follow on ground radar based system to track the incoming ballistic missiles. This is especially necessary as we

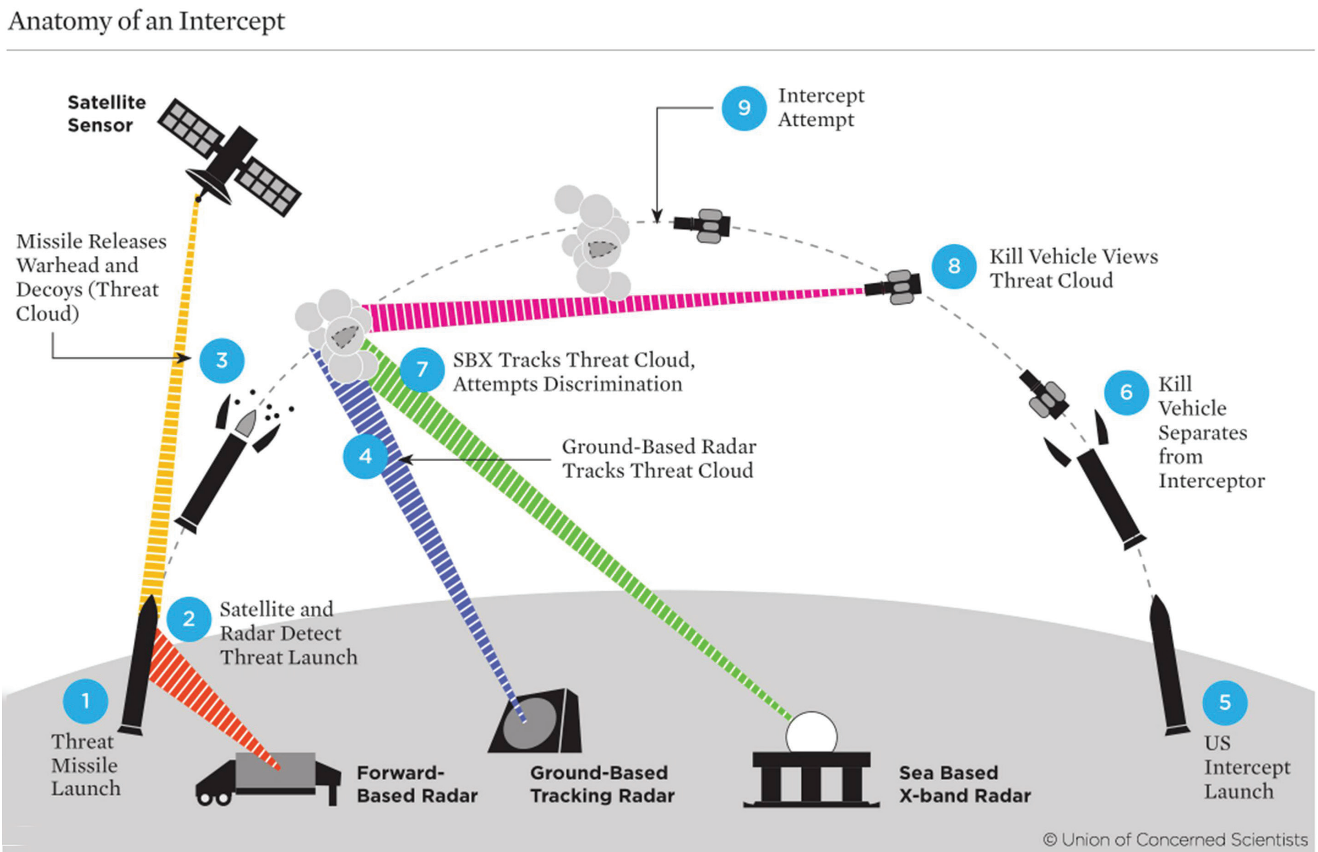
[7] Ibid

[8] https://www.globalsecurity.org/wmd/world/india/bmd.htm

[9] https://www.domain-b.com/aero/mil_avi/miss_muni/20090306_successful_missile.html

must detect enemy's ballistic missile launches as we take steps to neutralize these and then initiate response as per our second strike nuclear policy. Acquisition of this capability will deter our adversary to attempt first use of the nuclear weapon.

Clearly, as missiles and counter measures become more advanced, we need for more advanced sensors and weapons systems to effectively mitigate the threats.

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**Detection of the Cruise Missiles**. Defence against an attack by a cruise missile is similar to tackling low-flying manned aircraft and hence, most methods of aircraft defence can be used for a cruise missile defence system. Cruise missiles fly at low level and can be detected by the same conventional radar which also detects the aircraft. AWACS, tethered radars surely provide relatively better detection ability against the cruise missiles because their low level detection ability. Similarly, air defence weapons which are conventionally employed against the aircraft can be used to neutralize the cruise missiles with a caveat that not all threats can be detected and neutralized. India's indigenous Akash missile defence system and Barak-8 a long-range anti-air and anti-missile naval defence system developed jointly by Israel Aerospace Industries (IAI) and the DRDO is claimed to possess the capability to engage the aerial targets like fighter jets and cruise missiles.

[10] https://www.ucsusa.org/sites/default/files/images/2016/07/nuclear-weapons-m-how-missile-defense-works.jpg

### Detection of Drone Threat

The large and medium size drones have the radar cross-section matching manned aircraft therefore; can be detected by the conventional radars. Large/medium/mini UAVs while particularly flying at low level may evade detection. Most of these would be detected by the AEW aircraft, AWACS and tethered radars. We could use conventional weapons which are employed against the manned aircraft. Recent shooting down of three drones by IAF after Balakot strike in the western India proves this view. Low flying drones can be detected by establishing early warning network which includes radar, acoustic or visual observation by dedicated observers. Very small drones like quadcopter etc once spotted can be neutralized by the sharp shooters and /or using drone frequency disruptive devices.

### Conclusion

In the coming decade, the spread of fifth generation aircraft with the stealth characteristics in the aircraft inventory of our adversaries would create detection difficulties for our air defenses since existing radars would have reduced detection ranges precluding initiation of threat mitigation action. The low frequency radars, passive / OTH radars can detect such threats. While these radars too suffer from resolution problem but, early warning from these will enable the Air Defences for initiation of appropriate tactical actions. The advent of Quantum radar when developed in future would revolutionize the radar technology. It could detect all threats including the stealth aircraft which in time to come may reduce focus of air forces to acquire the stealth aircraft, as stealth designs also bring its wake some operational limitations.

For credible detection of ballistic and cruise missiles we would have to think of developing space based IR detection of the ballistic missiles if it does not exist already (not in public domain). As regards to cruise missiles and drones, the detection techniques employed to detect low flying aircraft will be equally effective for cruise missiles and drones. AWACS, tethered radars could detect these threats in same way as in case of manned aircraft.



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