आज़ादी का अमृत महोत्सव
आज़ादी के 75 वर्ष

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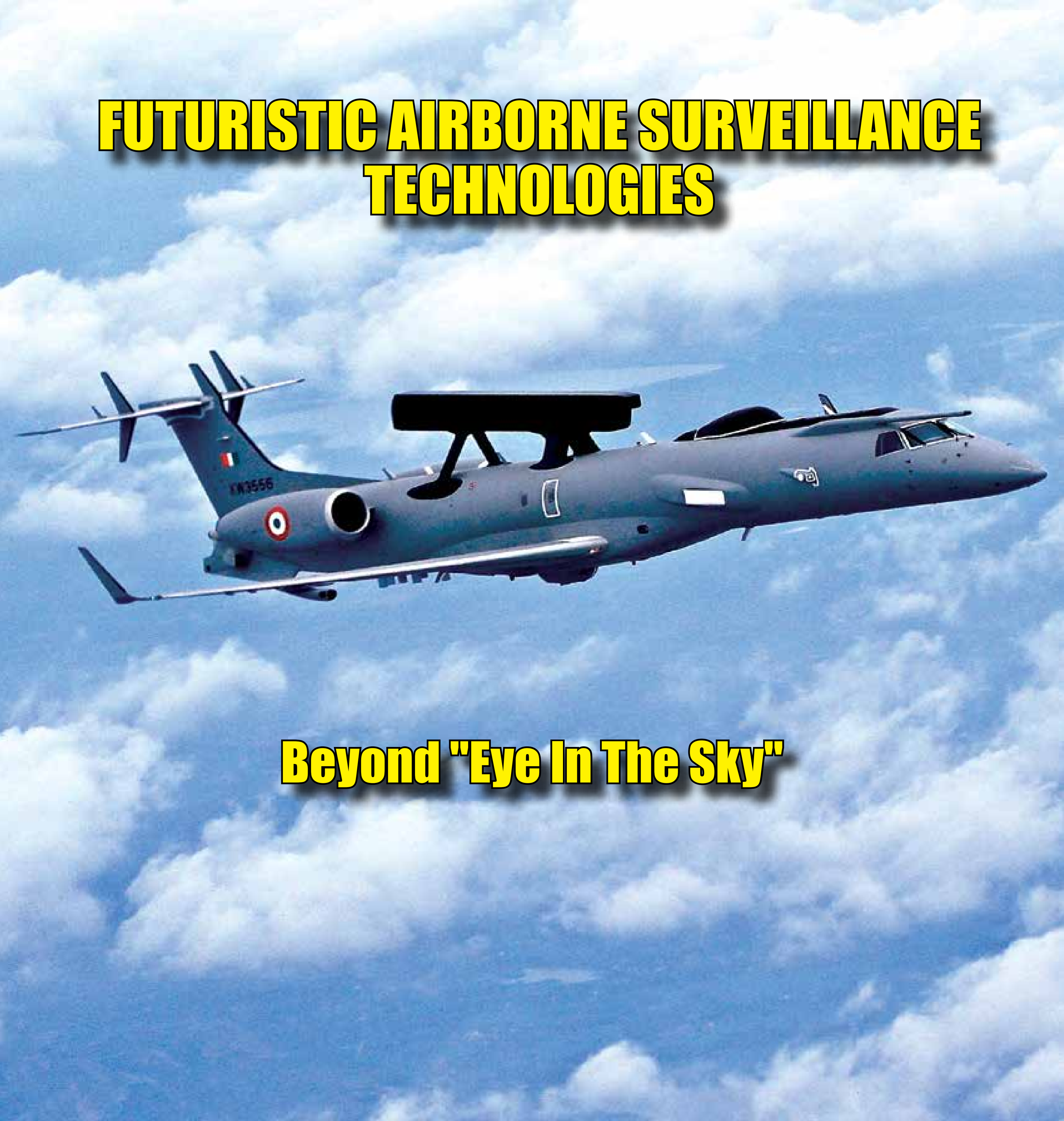

FUTURISTIC AIRBORNE SURVEILLANCE TECHNOLOGIES

Beyond "Eye In The Sky"

Technology Focus focuses on the technological achievements in the organization covering the products, processes and technologies.

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From the Desk of Guest Editor

As brought out in the previous issue (April 2021), the Centre for Airborne Systems (CABS) has delivered two India's own Airborne Early Warning and Control System, Netra to Indian Air Force. Completion of this programme and the capabilities and expertise developed and established through this programme, has paved way for the design, development and delivery of next-generation airborne surveillance systems such as Advanced Air Borne Early Warning and Control System, and Intelligence, Surveillance, Targeting and Reconnaissance (ISTAR) system for IAF and Maritime Multi-Mission Aircraft (MMMA) for Indian Coast Guard. These have necessitated improvements to existing capabilities and also bringing up new capabilities, and technologies.

In tune with this, in the current issue of *Technology Focus*, it is proposed to bring out a brief glimpse of the upcoming technologies and systems aimed at such programmes.

I am confident that this issue of *Technology Focus* will also be equally interesting and thought-provoking.

Happy reading…!!

MS Easwaran
Distinguished Scientist
Director (CABS)

FUTURISTIC AIRBORNE SURVEILLANCE TECHNOLOGIES

The development of an indigenous Airborne Early Warning and Control System (AEW&C) was taken up by DRDO & Indian Air Force in 2004. On 26th January 2017, the AEW&C was flown for the first time in the Republic Day Fly Past. Netra, as the name given during the FlyPast, was in tune with the operational environment as envisaged. On 14 February 2017, the Netra was handed over to the Indian Air Force. The previous issue of Technology Focus was dedicated to the Netra system, its operational requirements, configuration and the various sub-systems developed for the Netra. This issue of Technology Focus discusses various systems, sub-systems and the technologies incorporated in the Netra and various technical facilities established at CABS to realise the mission AEW&C System. In 2004, the critical technologies to support the development of such a complex system were not available indigenously. For instance, while the development was envisaged for an active array radar system, the basic building block namely the Transmit / Receive Module was yet to be matured. Electronics and Radar Development Establishment (LRDE) had just taken up the development of an active array radar system on the ground as a technology development project. Similar was the case with technologies for every subsystem. However, a major decision was made to persist with Indigenous technologies for the critical systems such as primary radar, IFF, etc., and also to develop the requisite software in-house.

The Development Challenges

Globally, it can be seen that the AWACS/AEW&C systems have hitherto been developed/integrated by an OEM of the aircraft. For instance, in the US, M/s Boeing is the main contractor for the AWACS, the former USSR the A-50 was developed by M/s Beriev aircraft company. In the case of Erieye, the two main integrators were M/s SAAB & M/s Embraer both manufacturers of aircraft. The exception to these are the Indian AWACS from M/s ELTA, and Indian (DRDO) development of AEW&C. Also further, in the case of Indian AWACS procured from M/s Israel, M/s ELTA the prime contractor is a major defence industry having all the infrastructure and resources within itself to take up the development of such complex system and is part of Israeli aircraft industries. M/s ELTA had the experience of delivering such a complex system to other countries before taking up the Indian contract. In contrast, for the indigenous development in India, DRDO was the only agency capable of taking up this development work and this was the first of the kind. Further, DRDO with its charter to do research, design and development, although geared up for the same, was not having a mandate to take tasks such as post-delivery support, maintenance, etc. In the case of most of the systems developed this was not a handicap, as DRDO was able to identify a production agency owing to quantities required and were able to transfer the technologies to the appropriate production partner and thereon the production partner was tasked with delivery and post-delivery support in quantities.

However, in the case of the AEW&C system, this concept did not work as the quantity required was only three. Further, at the time of launching the programme, the procedures also did not permit to engage the private industry as a partner. Hence, there was no choice but for DRDO to handle the development, and production of the system/ subsystems, integration, qualification, test and evaluation as well as delivery and post-delivery support. The development approach taken up was to get a fully modified and certified aircraft from the OEM M/s EMBRAER and then install the mission systems designed and developed by the various Indian agencies to produce the complete AEW&C system. Further owing to the classified and protected nature of mission systems, it was not possible to send the mission systems to M/s Embraer for installation at their premises. Hence, the first order of business was to finalize the proper interface requirements with the aircraft vendor in the form of an Interface Control Document (ICD).

Qualification and Certification

In light of the previous experience with the ASP programme, a conscious decision was made to get the aircraft with modifications certified by the OEM as per FAR 25 requirements. The contract specified that the certification to be done by M/s ANAC, the Brazilian certification agency for the civilian aircraft. While this strategy enabled the aircraft with all modifications to be fully certified to the international safety norms, on the other hand, the aircraft modification also consisted of certain changes that were typical to a military aircraft and ANAC was not empowered to certify. These typically were Air to Air Refueling, Additional APU/Power System, Internal Fuel tank and related distribution system and safe separation of Chaff and Flare Dispensing System.

As regards mission system qualifications, one of the main challenges were in the certification of the Active Array Antenna Unit (AAAU) which was one of the major structure of the radar system. As a structure, the AAAU was critical to the safety of the aircraft, but, as a functional unit, it was one of the major subsystems for radar and IFF. As a structure, the certification and acceptance of this unit had to be done by ANAC before the same is accepted for installation in aircraft. However, as an overall unit including structure, the Centre for Military Airworthiness and Certification (CEMILAC) & DGAQA were to be responsible for the overall certification and clearances.

The certification of the aircraft by ANAC also required several components of mission systems to be made available to the OEM to enable them to certify the aircraft for flight safety. As many as 300 Customer Furnished Equipment (CFE)'s consisting of AAAU mock-up, SATCOM Radome, Communication, ESM, CSM antennas, MAWS sensors, CMDS components, fabricated cables, special connectors, etc. were dispatched to OEM in a time-bound manner to enable the OEM to complete the overall certification. These involved, exporting these items through multiple countries and reimporting through various clearances.

The systems were installed and powered on without any hitch. M/s Embraer along with IAF & CEMILAC carried out the complete safety of flight evaluation for EMI/EMC effects of mission system on aircraft avionics.

Flight Test and Evaluation

In the case of procurement of such a system, the OEM responsible for the delivery has all the requisite wherewithal to conduct the flight evaluation as per plan. Generally, the OEM has dedicated pilots, test teams, that are directly part of OEM and a plan and process which is controlled by his QA teams. However, in the case of this indigenous development, the clearance for the aircraft as well as the system is to be given by CEMILAC & DGAQA, the flight evaluation is carried out by FTE's and pilots from AFPT & ASTE respectively.

Hence the major challenges in this area include, coordinating the varied agencies for flight requirements, clearance for the flight from RCMA, DGAQA, Arrangement of target and flying support from ASTE, and of course designers for the appropriate readiness of the system. This is further complicated by the requirement of different types of targets and emitters to be organized. These challenges were appropriately handled by CABS, DRDO to ensure successful operationalization of AEW&C, thereby leading to its induction to IAF.

Maintenance and Support Challenges

Last but not least is to ensure the maintenance and support post-delivery of the system. Several factors are affecting the overall process. For one DRDO is not mandated for providing post-delivery support. In most of the cases of DRDO developed product, the technology is formally transferred to an identified production agency which in turn becomes fully responsible for the delivered items in terms of support and maintenance in all respects. In the case of AEW&C, only a limited number were required (only three), it was not possible to identify any formal production agency for the system as a whole. Hence DRDO had to devise a new strategy to enable the maintenance and support of the systems. Accordingly, a qualified agency named as Engineering and Life Support Agency (ELSA) has been identified through competitive bidding where M/s BEL had emerged as the best fitting to the laid down requirement at the most competitive cost.

Emerging Scenario and Challenges

The AEW&C programme has paved way for complete self-reliance and has established capability and confidence in the country towards the entire airborne surveillance system requirement. The Spinoff IFF system is another major achievement. Today India is one of the very few countries that have achieved these capabilities.

With the "Make in India" emerging as the future strategy for the development of defence technologies there is an immediate need to evolve a strong and friendly policy towards combining the strengths of the Govt. research agencies such as DRDO, etc. with those of industry as well as institutes to enable the country to become truly self-reliant and global player in major defence technologies and systems.

Netra - Spin-off IFF Mk XII (S) System Variants

IFF Mk XII(S) system is a major spin-off technology from the AEW&C system. The IFF Mk XII(S) variants as available in the international market are in single box configuration whereas the IFF system developed for AEW&C is in distributed configuration due to the platform requirement. While the development of the IFF system for AEW&C was in progress, requirements of the IFF Mk XII(S) system for tri-services with IAF as the lead agency were projected. Since this technology existed as a spin-off at CABS, DRDO, a proposal was initiated for its development.

However, it was required to develop and qualify the single box IFF Mk XII(S) system variants through Production Agency (PA).

Following this, CABS initiated the development of the prototype of single box IFF Mk XII(S) system variants as available in the international market in the following configuration by initiating the identification of the Production Agency (PA):

- Long Range Interrogator
- Long Range Combined Interrogator Transponder (CIT)
- Transponder

Integration and Evaluation

The IFF Mk XII(S) system variants in various configuration have been integrated on various platforms of Mission Mode and Technology Demonstrator (TD) projects being pursued by different DRDO Labs as detailed below:

QRSAM

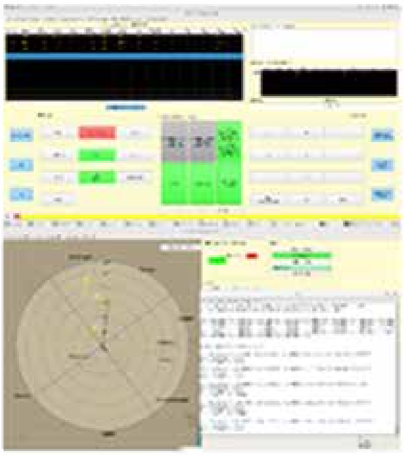
The IFF Mk XII(S) Medium Power Interrogator from the PAs along with the Electronically Scanned Antenna Array(ESAA) has been integrated with Battery Multi-Function Radar (BMFR) and Battery Surveillance Radar (BSR) of the QRSAM system. Three systems has already been delivered to Electronics and Radar Development Establishment (LRDE). The DRDO evaluation has been completed and User trials are to start shortly.

Rustom 2

The IFF Mk XII(S) transponder manufactured by the PA has been qualified as per the Rustom 2 roadmap. The unit along with the associated antenna and interface software with MPCC has been integrated with the platform and is being flown as form fit equipment in the ongoing trials.

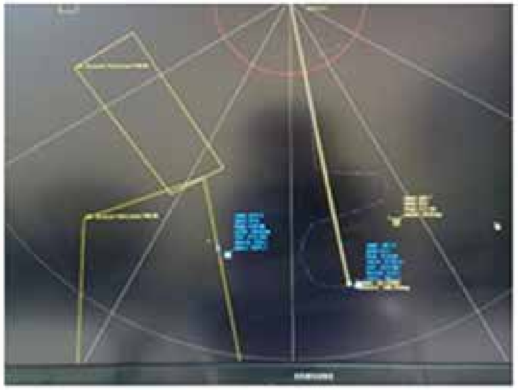
IFF Antenna on platform

Interrogator & other LRUS



Integrated Test Result

IFF Mk XII(S) System on QRSAM



IFF Mk XII(S) System on Rustom 2

Aerostat

The IFF Mk XII(S) high-power interrogator along with the associated antenna has been integrated with the aerostat of Aerial Delivery Research & Development Establishment (ADRDE) and tested satisfactorily.

LCA Mk 2

The IFF Mk XII(S) CIT in split configuration has been qualified and integrated at Air Rig of ADA for its transponder functionality. The unit has been tested and integrated with AESA of LRDE for LCA Mk 2.

ADTCR

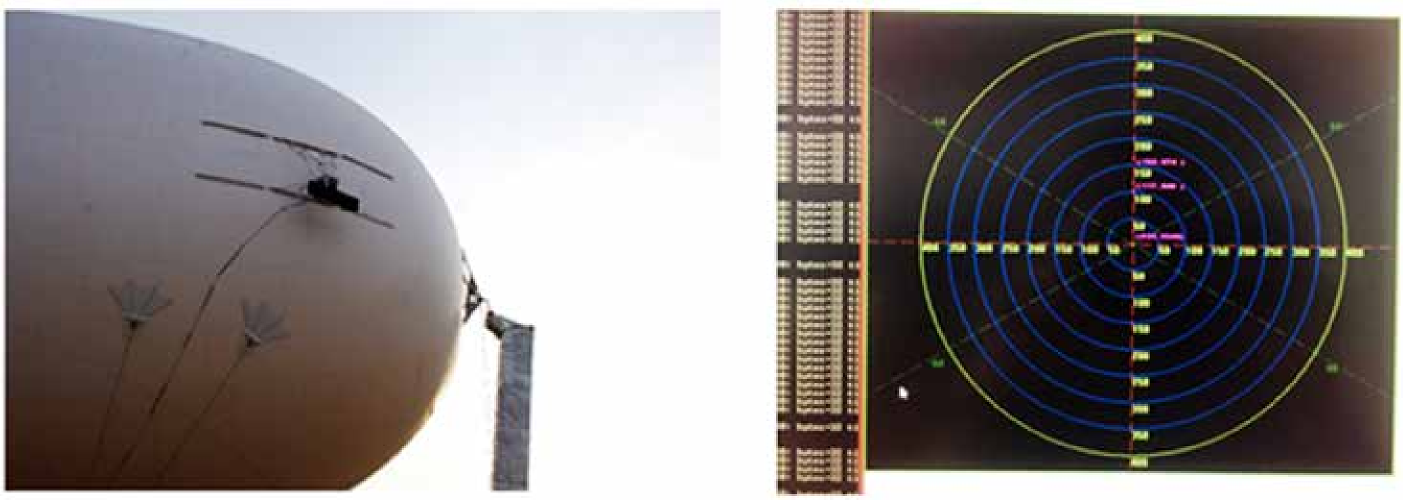
The IFF Mk XII(S) high-power Interrogator has been integrated and tested with the radar simulator of LRDE and ready to be integrated with the actual platform.

MRSAM

The IFF Mk XII(S) high power interrogator in 19" rack configuration with M-scan feature along with the 2.2m planar antennae has been realized and tested in stand-alone mode at CABS in the rooftop facility. It is ready to be integrated with the MRSAM Radar system at RCI on the platform.

Besides the above requirements that have already been realized and/or integrated with the intended platform, there are requirements of IFF Mk XII(S) system variants projected by various DRDO Labs for the upcoming project listed below:

- ⌘ LRSAM (LRDE)
- ⌘ AMCA (ADA)
- ⌘ UCAV (ADE)
- ⌘ Aerostat (ADRDE)



IFF Mk XII(S) System on Aerostat

CIT in Split configuration

Antenna Panel & Interrogator for MRSAM

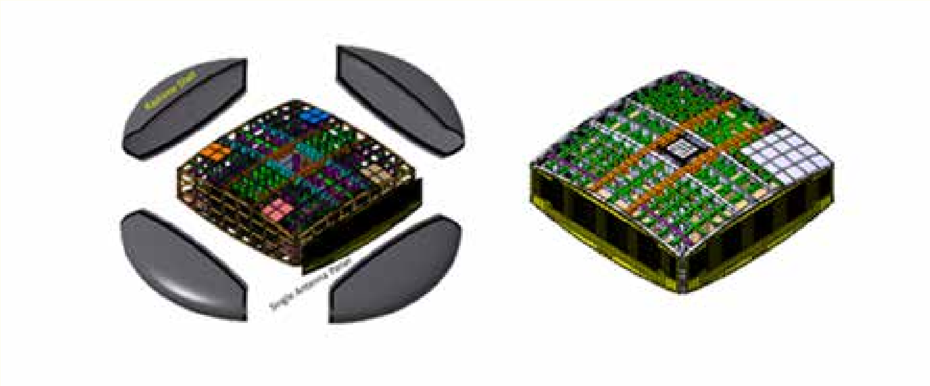
Critical Technologies Developed for Airborne Force Multipliers

CABS has designed and developed state-of-the-art Digital Airborne Active Electronically Scanned Array (DA2ESA) for primary & secondary radar for surveillance for Advanced AEW&C-MkII indigenously. The most critical component/system is the dome antenna mounted on top of the aircraft carrying the AESA for primary and secondary surveillance radar. This entails to development of some of the critical components and technologies namely structure of the dome, the liquid cooling system for airborne use, the composite radome technology to meet the aerodynamic, Strength and EM requirements, State-of-the-art TR modules, compact and efficient power modules, the necessary digital hardware and software for functioning of the system, etc. The critical technologies developed are:

Dome mounted on top of the aircraft

Dome structure

The Dome of ellipsoidal shape with dimension of 10.2m diameter X 2.2m height is arrived at with approximate weight of dome including electronics is around 12.5 tons. The integrated antenna panel of dimension 5.95m X 1.6m for both Primary and secondary radar. The size of one composite Radome shell configuration is 7209 X 2126 X 1787(h) mm.



View of the metallic and composite radome structure

Structural Design and Development

- Completion of structural analysis
- Stack analysis, interference analysis

Final assembly jig

Dome structure assembly

◇ Completion of the metallic dome

The prototype of metallic structure has been realized. The necessary jig has been realized considering the profile requirements of the dome

Composite Radome

Design and development of composite radome was quite a challenging task as it has to provide aerodynamic elliptical shape as well as covering for antenna from environmental damages with required transparency to electromagnetic waves. This design is capable of withstanding bird impact load as per FAR-25 regulations. Composite radomes are realized using the nickel male tool.

Electronics Component Design for AESA

The AESA is realized with digitized multi-channel outputs to achieve reconfigurability of the Array for the latest algorithms.

TR Modules for PR: STRMM, a state-of-the-art for primary radar is the critical element of AESA that is being developed for the DA2ESA. For PR requirements, seven modules are housed in the single STRMM. GaN-based amplifiers are used to obtain increased efficiency. To realize one side of the AESA Array 238 numbers of STRMM's are required.

TR Modules for IFF: The IFF array is configured to be an AESA-based system. Therefore, L-band TRMM (LTRMM) is realized with GaN-based amplifiers. The LTRMM's are liquid cooling systems and heat dissipation requirements have arrived accordingly.

Channel Receiver & Digital Electronics (CRADE): Single CRADE is used for sub-array. The CRADE is designed with a dual superheterodyne receiver and gives out digitised IF. The CRADE's are liquid cooling systems and heat dissipation requirements have arrived accordingly.

Realized composite radome & integration with metallic structure

Antenna: Considering the power aperture product and taking into account the microwave aspects the antenna has been designed to meet the operational specifications. To have complete 360 degree coverage with the least scan loss effects and to meet PR specifications, a 4-panel configuration has arrived. CABS has realised Jigs and fixture for the assembly of antenna panels and based on these, four numbers antenna panels have been machined and assembled and meet the requirements.

Probe Design: Suitable probes have been designed for each PR and SSR element. The designed probes adapt well with the cavity-backed slot antenna by providing a good return-loss profile for the bandwidth of operation.

Power Supply Units: For each sub-array, one power supply has been designed to take care of the supply power needs of 8 STRMM's and a single CRADE. The power supply units are liquid cooling systems and heat dissipation requirements have arrived accordingly.

Cooling System Study

Coolant Selection: Liquid Cooling System (LCS) is adopted for dome electronic cooling and Poly Alpha Olephene (PAO) has been used on coolant. Various tests are conducted in NABL accredited laboratories for its thermal properties, corrosiveness and found that the coolant meets the requirements.

Cold Plates: Vacuum brazing technology that gives seamless permanent joints is adapted to the cold plates. Cold plates that are thermally efficient, less weight at the same time meeting the structural requirements are designed, developed and had undergone qualification tests successfully. These are realized in numbers to ascertain the process. Cold plates are stacked in racks in which STRMMs, CRADE, power supply units are housed and tested for their operational performance. Results obtained from the thermal studies are experimentally validated.

Piping Layout

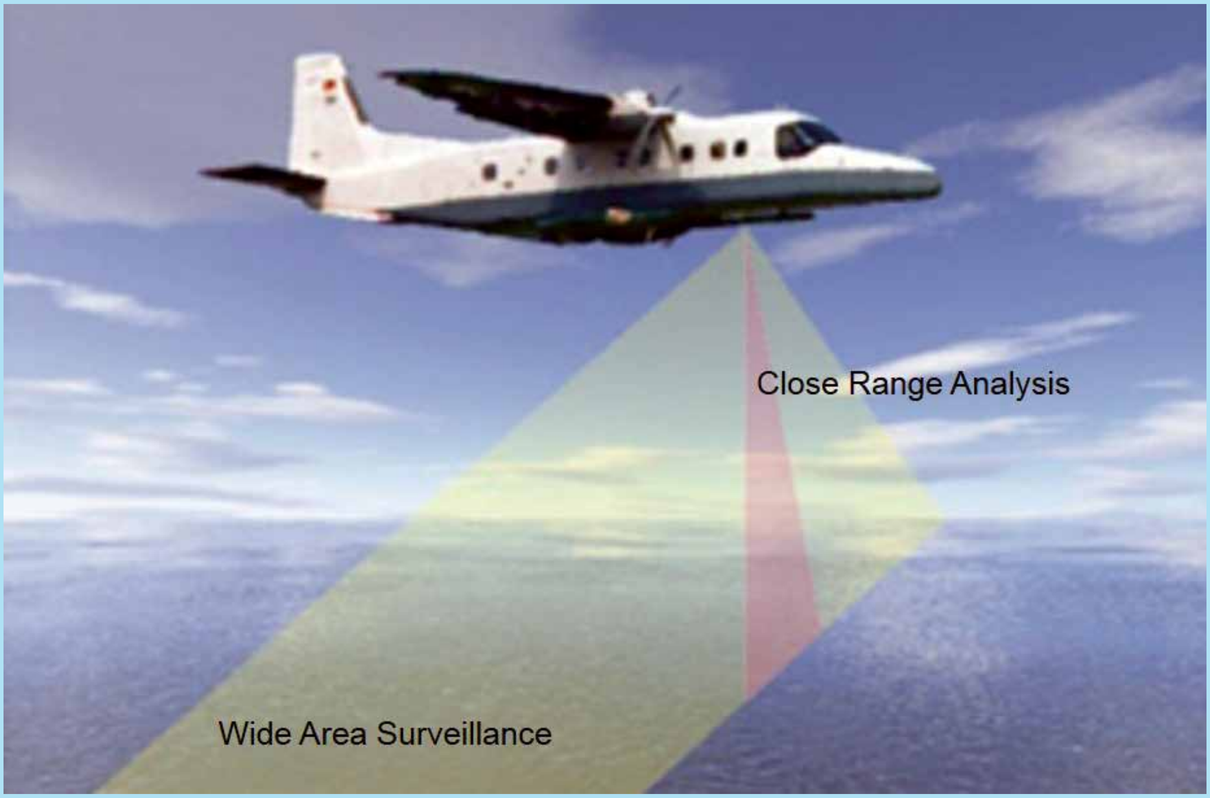
To study the pressure losses associated with routing and bends, a detailed CFD analysis was carried out and to benchmark, the analysis, full scale of half diagonal piping layout that simulates the bends inside the dome is realized as water flow network and the results are compared.

Pollution Surveillance Using Multispectral Sensors

CABS has been identified as a Nodal Agency for the development of 6 Multi Mission Maritime Aircrafts for the Indian Cost Guard (ICG). One of the primary roles of MMMA is pollution surveillance. Oil spills account for a majority of the pollution in a maritime environment. These spills may be due to accidents or intentional. Understanding the characteristics of the spill like thickness distribution, the chemical composition of the oil, etc is important for oil spill response and clean-up. As oil in water is highly dynamic due to seawater and wind, the oil spills must be detected along with its thickness distribution. Bonn's agreement on the oil spill provides a comprehensive oil spill identification scheme. A set of multispectral sensors bundled and christened as Pollution Surveillance Suite (PSS) is used for detection, classification and identification of maritime pollution. The PSS provides effective pollution surveillance in terms of oil slick detection, identification, quantification, classification. The integration of the PSS with a mission management system and multifunctional tactical console enhances its capabilities. The tight integration of the PSS as a subsystem into the MMS turns it into a powerful autonomous mission-ready suite for pollution surveillance applications. The PSS suite has the following multi spectral-sensor system for effective pollution surveillance in terms of oil slick detection, identification, quantification, classification and documentation:

Side Looking Airborne Radar (SLAR) working in X-band is the primary sensor for far-range detection of oil spills on the sea surface. The detection of oil spills using a SLAR is based on the principle that surface films of oil dampen the capillary waves of the sea surface, which in return leads to a reduction of the radar backscatter signal.

IR/UV Line Scanner for mapping of the oil distribution on the



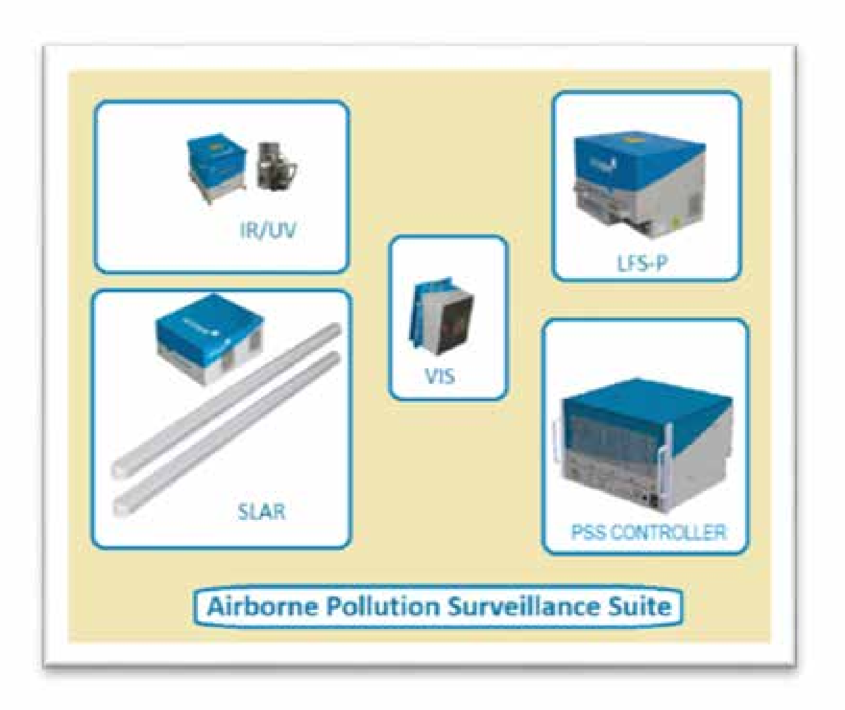
sea surface and calculating its extent. The IR/UV line scanner is a passive bi-spectral sensor that is usually sensitive in the thermal infrared and the near-ultraviolet with a field of view of 90°. It is a two-channel passive detector, which is sensitive in the wavelength range of 0.28 µm to 0.38 µm (UV) and 8 µm to 12 µm (IR).

VIS Line Scanner for colour mapping of the oil on the water surface for securing evidence and documentation. The system is used for the acquisition of georeferenced red/green/blue composite images. These images can be used for documentation and more exact volume estimations based on oil colour codes.

Laser Fluoro Sensor (LFS) is an active laser-based nadir-looking remote sensor for oil type classification and measurement of oil film thickness and is based on oil fluorescence spectra.

Microwave Radiometer (MWR) for measuring the thickness of Oil>50µm. These sensors have to be integrated into a single central command and control unit called the PSS controller. This unit controls the sensors as a single suite and post-processes the output of each of the sensors to provide the required information.

The MMS developed by CABS follows an open architecture approach providing NTP service (both query and broadcast mode) and navigation data service. It also provides capabilities of state management, health monitoring, etc. The sensors of PSS have been tightly integrated with the MMS through defined protocols. The MMS also integrates with the Multifunctional Tactical Console (MTC) for providing command and control functionalities to the operator according to a unified operating concept. All the sensors for the mission can be commanded similarly and display the data from the sensors



AESA-based Maritime Patrol Radar

Maritime surveillance is an important force multiplier for ICG. The Maritime Patrol Radar is the primary sensor in maritime surveillance as it provides forces with critical information such as small floating object/small boat detection, vessel detection and classification, coast imaging, coastal activity picture, search and rescue, etc. These capabilities are achieved by operating the same MPR in different modes. Active Electronically Scanned Array (AESA) has become the backbone of such next-generation radars. The main characteristics of this MPR are:

Beam Agility: AESAs are capable of instantaneous beam steering. A typical example is that the beam looks in a particular direction can be scheduled arbitrarily based on sea states, ranging from benign to harsh. Beam Agility also helps in priority-based tracking of hostile targets.

Seamless Mode Interlacing: In surveillance, radar may be required to operate in different modes in different directions/volumes. In the coast, for example, an MPR may be required to do detection on the seaside and imaging on the land side. State-of-the-art AESA, built on GaAs TRMs, SoC system controllers, high fidelity ADCs, provides the required agility in waveforms, signal processing and beam agility to interlace different modes.

Sub-array Beam Forming and STAP: The most important mode of MPR, the small sea surface target detection requires meticulous signal processing to remove clutter and detect a target. AESA with multichannel receivers enable multichannel beamforming. This helps in clutter cancellation via the simultaneous spatial and temporal treatment of clutter returns. This is known as Space-Time Adaptive Processing (STAP). STAP is hailed as the only advanced signal processing tool for small target detection in harsh sea conditions.

Hardware of MPR

RF Frontend: Sea surveillance radars are generally developed in X-Band owing to their smaller size and characteristic sea clutter returns. X-Band AESA with the above-mentioned capabilities typically has more than 1000 sub-components. The elements of the AESA are energized by GaAs-based TRMs for higher power efficiency and state-of-the-art integrated Phase Shifters and Attenuators enabling Azimuth and elevation scan.

Digital Beamformer and Receiver: Subarray digital beamforming as mentioned earlier is achieved by multiple receive channels powered by high fidelity, high sampling rate ADCs. Each channel has a precise, 6bit phase and attenuation control for channel balancing.

Low Noise X-band Exciter: This subsystem of MPR, provides stable, coherent, and low phase

Rooftop testing of MPR

noise, high spectral purity X Band drive; Stable Master Oscillator (STAMO) to X-Band AESA unit. Besides, it generates spectrally pure LOs for the receiver, clock for coherent frequency-agile waveforms for ECCM.

Radar Processing Unit: This unit is the core signal processer for the radar. The state-of-the-art RPU is designed using the High-Performance Embedded Computing (HPEC) Processors with 2200 TFLOPS. This system is capable of simultaneous processing of 6 channel high bandwidth IQ data to perform STAP.

Electro Optic / Infra-Red (EOIR) System for Maritime Surveillance

CABS has developed EO/IR system for airborne applications with M/s Tonbo Imaging as the industry partner. The unit is called Avenger S50.Avenger-S50 is an airborne 4-axis mechanically stabilized electro-optical payload for aerial and naval surveillance. It captures images simultaneously in the visible, SWIR and MWIR spectrum providing imagery that gives greater situational awareness. It can be used in the belly up / down position of the aircraft. It also has a laser range finder and a laser pointer.

The Key Features of this System are:

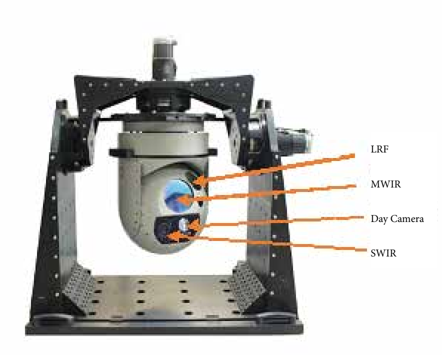
- Four-axis gyro stabilized
- <10μ rad stabilization accuracy
- < 5 mrad pointing accuracy
- Simultaneous display of 4 HD videos
- Integrated video tracker
- Slew to cue
- Geo referencing
- Geo Pointing
- Extensive BITE
- Weight <55Kg ; Power <380 W (28V)
- Dia ~ 390 mm; Height ~ 490 mm
- Handgrip control

Its applications include:

- Long range surveillance platform for aerial and naval platforms
- Electro-optical director
- Remote control weapon station
- Avenger-S50 is a EO / IR mechanically stabilized package for surveillance from airborne platforms

The EO / IR payloads are:

- Cooled MWIR thermal imager
- SWIR Imager
- Low light CMOS HD colour camera
- Laser range finder
- Laser Pointer
- GPS
- Integrated inertial sensor
- Digital magnetic compass
- External interface to an NMEA compatible GPS

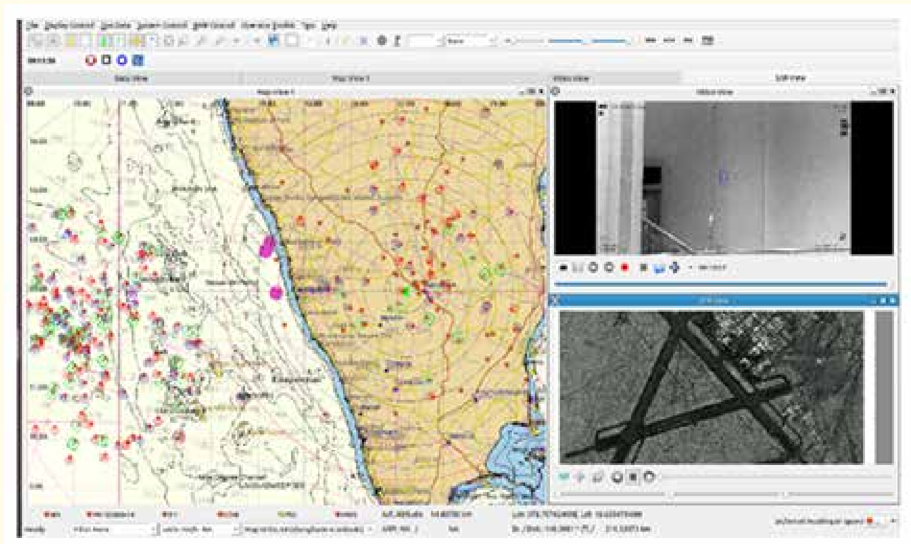


Integration with CABS Mission Management System and Multi-Functional Tactical Console (MMMA)

Mission Management System(MMS) is considered as the heart of an Maritime Patrol Aircraft (MPA). It is a distributed control system for all the sensors and tactical Consoles. Multi-functional Tactical console (MTC) is an ergonomically designed, re-configurable console with multiple monitors installed on the MPA. It is used to command and control various sensor suites installed on the aircraft. Real-time maritime and air situation picture is displayed on monitors of MTCs.

EOIR has been integrated with Multi-Functional Tactical Console (MTC) through MMS. MTC sends command and control messages through Mission Management System (MMS) and MMS will forward to the EOIR system. EOIR response messages are sent to MTC via MMS.

Video streams are available in H.264 encoded Ethernet format. Ethernet video streams are directly accessed from MTC and handgrip controller.



Integrated Display of EOIR video in MTC

Low Speed Wind Tunnel Testing and Data Analysis for Decision Making

CABS, being the nodal agency for the development of indigenous airborne surveillance systems, is also responsible for the evaluation and selection of the potential aircraft (platform) for the surveillance role. The selection considers the aerodynamic evaluation post-modification and suitability in meeting the minimum performance, flying and handling qualities of the aircraft for the mission and regulatory requirement.

The installation of various antennae changes the aerodynamic characteristics creating incremental changes in the performance, stability and control of the aircraft. Initially, the candidate aircraft's basic aerodynamic characteristics are estimated using the lower order aerodynamic models. With the help of the engine characteristics and this aerodynamic model, the performance measures are checked with the quoted numbers by the OEM. In that aerodynamic model, the expected incremental changes due to the installation of various antennae of different dimensions are added and the performance values are re-evaluated for suitability of the selected candidate aircraft. After finalizing the candidate aircraft, the design of a wind tunnel model for the testing is carried out.

The design of the wind tunnel model requires identifying the suitable scale considering the blockage ratio in the test section area of the chosen wind tunnel. Then the geometrically-scaled model of the candidate aircraft is designed for the force and

Wind Tunnel Model inside the Tunnel

moment measurement with suitable provisions for installation and varying the location of the different antennae in a modular way. The structural integrity of the model for the expected aerodynamic loads inside the tunnel is ensured by the design and material used for the model fabrication.

The wind tunnel model is tested at all the expected operational aerodynamic angles and the force and moment data obtained are analysed. The longitudinal, lateral-directional characteristics of the basic aircraft and the modified aircraft are checked. Aerodynamic models are developed in the linear ranges of the aerodynamic angles. The aerodynamic performance is evaluated with the revised estimates of the aerodynamic coefficients obtained from the wind tunnel testing. The stability characteristics of the modified aircraft are evaluated. From the data obtained by varying the location of the antenna on the aircraft, the near-optimal location of the antennae from the aerodynamic performance and stability viewpoint is identified. Further, to restore the stability of the modified aircraft as that of basic aircraft, the need for additional aerodynamic fixes is also estimated.

Audio and Data Management System

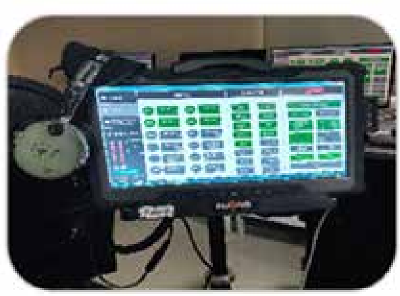
CABS has designed and developed an Audio and Data Management System (ADMS) for mission communication applications for surveillance platforms. ADMS is a VOIP-based system. It integrates the routing of audio and data between onboard crew members within aircraft as well as between aircraft to ground station through radios. It interconnects all communication technologies regardless of radio band, frequency and hardware.

The system is scalable from one to several operators and becomes a center piece in remote-controlled setups from single radio to complete operations. It allows control of all internal communication on board, with features such as platform-independent, record and playback. The modular architecture of ADMS is such that, it can be used by Army, Navy, Air Force with optimized SWaP-C hardware components.

The ADMS consists of four major sub-modules:

CUIP

CCCU



CUIP with ADMS Client Application

Radio controller

- Command and Communication Control Unit (CCCU)
- Radio Gateway Unit (RGU)
- Communication User Interface Panel (CUIP)
- Radio controller Unit (RCU)

Command & Communication Control Unit (CCCU) routes the voice and data over ethernet based on the selected mode of communication. CCCU acts as a server of the communication software. CCCU has two intelligent boards with internal memory and a separate power supply for each.

Radio Gateway Unit (RGU) is one of the ADMS core building blocks and provides a seamless interface between radios and telephony assets using open standards VOIP. It converts the audio from radios and other analog channels to standards-based Voice over IP (VoIP) which can be streamed to any compatible device via the LAN.

Communication User Interface Panel (CUIP) is a user-friendly interface, like a softphone, implemented on a COTS 10.4" rugged MIL-STD tablet, with 1 HDMI port, 4 USB ports,1 Gigabit Ethernet port. It allows the user to control the radio parameters, have an intercom and communicate from air-to-ground as well as ground-to-air. The Client Human Machine Interface is displayed on the CUIP. It provides users with the ability to access and control radio, telephony, intercoms and fax systems, both local and remote, using a single intuitive graphical user interface. Soft PTT functionality during normal mode operation is also provided.

Radio Controller Unit (RCU) is mainly used for controlling the VHF/UHF radios through RS422 and Digital IO's, configuring the various VHF/UHF radio parameters such as frequency of the main channel, presets, modulation, guard channel, Tx power and squelch, etc., based on the TCP/IP commands received from the Mission System Controller. RCU shall be used for recording the IP RTP audio packets and store the audio files on a local hard disk.

ADMS integration setup

ADMS LRU Rack

Salient features of ADMS:

- Onboard intercommunication of operators
- Audio routing between connected entities
- Data routing between connected data-enabled entities
- Radio control and configuration of connected radios
- Radio relay Functionality
- Mission audio recording
- Air-to-Ground and Ground-to-Air audio/video conferencing
- Onboard and off-board data and textual conversations
- Onboard Video conferencing
- Fax facility from air-to-ground
- Secure and non-secure voice communication
- Scalable and platform-independent

AI in Futuristic Airborne Surveillance Systems

Growth of AI

Artificial Intelligence (AI) has penetrated all areas including gaming, image recognition, speech, automotive, natural language processing, medical and military. Of late, all the advances in AI are propelled by deep learning, which is a sub-field of machine learning which further is a sub-field of AI. Deep learning involves training Artificial Neural Networks (ANNs) with many layers that hierarchically extract features from the input.

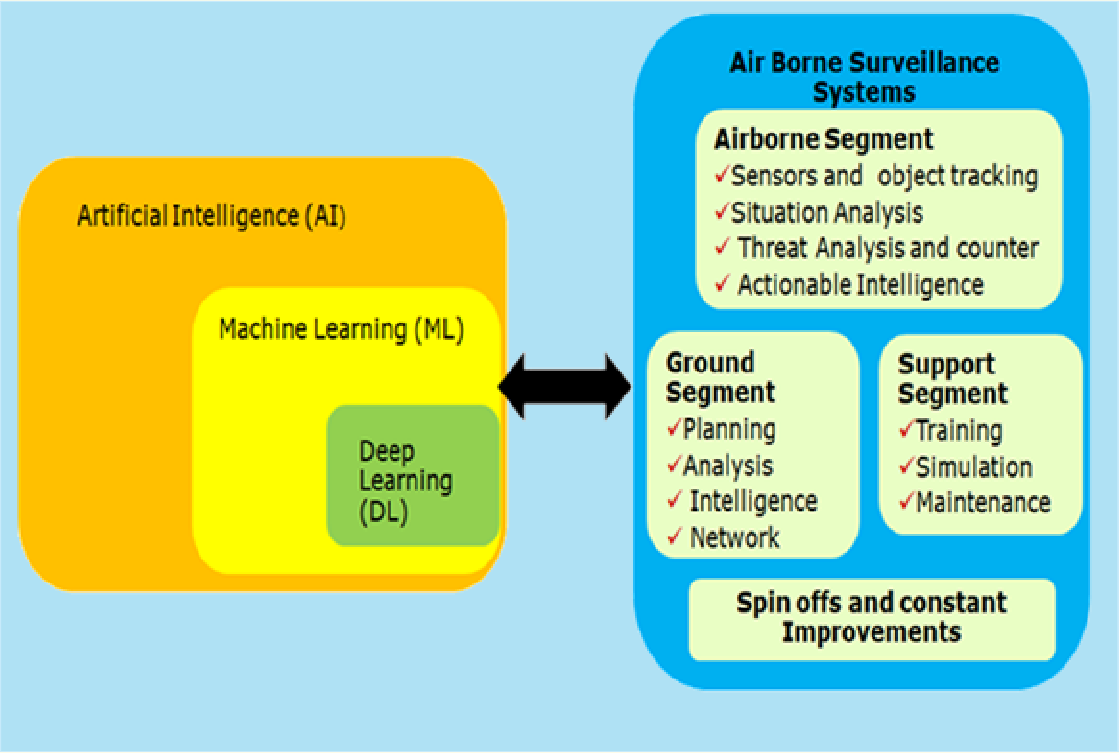
The usability of AI and deep learning in all these fields is exemplified by its capability in detecting hidden patterns efficiently and accurately. The military uses of AI are projected to be impacting all modern combat battlefield elements. AI is being increasingly used in all the areas of airpower namely control of airspace, strike, air mobility and Intelligence Surveillance and Reconnaissance (ISR). Thus, in the future AI will find its place in airborne surveillance systems in all aspects of the Find, Fix, Track, Target, Engage and Assess (F2T2EA) process.

The key enablers for the success of AI are the availability of larger datasets, the power of big data analytics to handle the growing data volume, the power of Graphics Processing Units (GPUs) for training larger networks and matured algorithms and toolchains.

However, the adoption of AI techniques to airborne systems is challenging as enough training data is never available. Also, the development applications should be robust and lightweight amenable for real-time implementations. The opacity, evaluation of these techniques in the battlefield and perpetual upgrades also pose challenges. Additionally, military doctrines have to be rewritten for providing autonomy for the machine to take critical decisions.

AI for Airborne Surveillance

Any typical network-centric airborne surveillance system will have multiple sensor and communication links tightly integrated by a mission and data management system on an airborne platform for performing multiple missions. Exploiting such a network-centric complex system of systems involves cohesive operation multiple airborne, ground and support segments. This involves state-of-the-art sensors, communication links, integration of human in loop elements, simulation facilities, interfaces to



AI Ecosystem for Airborne Surveillance

military networks, planning, analysis, intelligence gathering, training and effective maintenance. AI facilitates improvement in each of these areas of airborne surveillance and the ecosystem.

The application of AI to these areas is as follows: These areas are generic and can be interpreted in the context of a specific sensor (e.g. Radar, EO/IR, AIS, IFF, ESM, etc.) or group of sensors.

Predictive Maintenance for Mission Aircraft –Typical applications include integrated mission system, diagnostics and predictive analytics in-ground rigs and aircraft power system/routing.

Some of the tools used are Multi-Instance regression, Random forest, Support Vector Machines (SVM).

Automatic Target Recognition (ATR)- Typical applications include object detection, object recognition and classification, EO, IR, SAR, ISAR images, High range resolution (HRR)/RS profiles, Image tagging.

Some of the tools used are Convolutional Neural Network (CNN), Variation Auto-Encoder (VAE), Recurrent Attention Models (RAM) and Generative Adversarial Networks (GAN).

Object Tracking and Fusion- Typical applications include association and tracking of high maneuver airborne targets, Association and tracking maritime targets, Ground Moving Target Tracking (GMTT), Fusion of EO and IR images, Fusion of SAR and EO Images, passive tracking of CSM, ESM and Fusion.

Some of the tools used are CNN, Siamese networks, Long-Short term Memory Networks (LSTM), Variation RNN (VRNN).

Object Identification- Typical applications include SLAR oil spill segments, ship name reading, vehicle license plate reading.

Some of the tools used segmentation, CNN, You Only Look Once (YOLO), Single Shot Multi-Box Detection (SSD), Variation Auto-encoders (VAE).

Threat Detection- Typical applications include Airborne-flight routes, Maritime-sea lanes, Maritime terrorism, Land-Military formation, Oil rig protection, VA/VP protection.

Some of the tools used are dynamic stochastic networks, instability score, VRNN.

Active Phased Array Antennas- Typical applications include collimation in presence of mutual coupling, Estimation of failed antenna elements based on Range-Doppler maps, Automatic pattern correction to combat failures.

Some of the tools used are CNN, Deep-Reinforcement Learning (Deep-RL).

Simulation and Training- Typical applications include situation prediction during a loss of sensor pick up, intelligent air combat simulation for pilot training, training simulated pilots in OTS, Battlefield management solutions.

Some of the tools used are Air Combat Simulation Models, Multi-Agent Reinforcement Learning, Multi-Objective Reinforcement Learning.

Sensor Processing- Typical applications include HRR, SAR/ISAR image formation processing, Estimation and tracking of Radar signals (ESM), Non-homogeneity detector STAP applications, Garble processing in IFF.

Some of the tools used are LSTM, Auto-encoder networks, CNN.

Intelligent Planning Stations - Typical applications include strategy planning, strike planning, resource planning.

Some of the tools used are big data analytics tools, Apache Hadoop, Apache Spark, inbuilt machine learning.

Intelligent Data Nodes- Typical applications include flight data analysis, Maritime Doman Awareness (MDA), Integrated ASP, mission computers.

Some of the tools used are Big data analytics tools, Apache Hadoop, Apache Spark, Inbuilt machine learning, Feature fusion.

Human Machine Interface (HMI) - Typical applications include Voice-activated commands, speech-to-text conversion, Smart Maps. Some of the tools used are RNN, LSTM

The penetration of AI in airborne surveillance systems will provide faster, efficient and accurate systems. It will provide the operator with aids compressing planning and decision-making time. One important aspect that AI adds to the gamut is precision as against mass. This is achieved by aiding the human being with a "global view" of the situation being perceived. CABS has created the necessary eco-system for the development and deployment of AI techniques in airborne surveillance and will incorporate feasible technologies into future products.

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Upcoming Airborne Force Multipliers

Multi-Mission Maritime Aircraft

The state-of-the-art Multi-Mission Maritime Aircraft (MMMA) shall be equipped with the latest technology sensors and armament to provide enhanced surveillance and interdiction capability in the exclusive economic zone and search and rescue capability in the Indian Search and rescue region. It shall be a multi-role system, for maritime surveillance, search and rescue, interdiction and pollution surveillance as primary roles. Besides, it also can perform secondary roles such as cargo and personnel transportation and air ambulance for medical evacuation. Its flight characteristics shall be adapted to the maritime patrol flight profiles, with excellent maneuverability at low altitude and outstanding mission performance.

The MMMA mission system includes a complete suite of surveillance sensors, a comprehensive communications system for voice, data and image transmission, and the Fully Integrated Mission and Data Management System (IMADMS) for tactical command, control, data processing and display.

The IMADMS is a flexible system, developed by CABS, with a modular, scalable and distributed architecture, that integrates, presents and controls information coming from the mission sensors and aircraft navigation systems. It enhances situation awareness, facilitates decision making and improves the operational efficiency of the mission.

CABS has been identified as a nodal agency by MoD for carrying out the development of indigenous six such MMMA systems for ICG.

Mission Systems of MMMA

The Mission systems of MMMA shall comprise of state-of-the-art sensors such as AESA based Maritime Patrol Radar, Identification Friend or Foe (IFF), Electro-optics/Infra-Red (EO/IR), Pollution Surveillance Suite (PSS), Communication Support Measure (CSM), Automatic Identification System (AIS), Data links for both Line of Sight (LOS) and Beyond LOS communication & Mission Communication System (MCS). All these sensors shall be command and controlled by distributed MMS and present the maritime domain awareness/picture to the operators on Multifunctional Tactical Console (MTC). It shall also provide the same to the ground data terminals through communication links.

AESA Based Maritime Patrol Radar

The primary sensor for MMMA, maritime patrol radar is AESA-based radar mounted on the belly of the aircraft. It is used for the detection, tracking and imaging of air and sea-based targets. It operates in various modes such as Air to Air, Air to Sea, Moving Target Indicator

(MTI) in sea and ground, Range Signature (RS), Synthetic Aperture Radar (SAR) Beacon and Weather modes. It provides seamless mode interlacing, improved time budget for classification and identification modes and also provides better time-on station.

IFF

IFF is a secondary cooperative sensor that provides the identification and height information of targets equipped with a suitable transponder. The information provided is used to identify the targets as friendly or non-friendly in the surveillance area.

The system has been built as per ICAO Annexure X/STANAG 4193 with Mode-S (level2) capability. The system also caters to secure modes IS1 (the mode- 4) and IS2 (mode-5).

IFF

PSS

PSS is used for the detection, identification and classification of oil spills.

The PSS system consists of

- **Side Looking Airborne Radar (SLAR)**- Far Range detection of the oil spill (60-80 Kms at 3000 ft)
- **UV/IR Line Scanner–** Near range investigation in Thermal Infrared and near Ultra Violet region
- **VIS scanner–** Near range in vestigation in the visual region
- **Laser Fluoro sensor (LFS)** – for oil type classification and thick ness of oil film.
- **Microwave Radiometer** –for measuring the thickness of oil > 50 mm

Airborne Pollution Surveillance Suite

EO/IR

The EO/IR sensor helps in imaging of targets of interest.

It comprises of HD day camera, thermal imager, Short wave Infrared (SWIR) imager, laser range finder and Laser pointer. The sensors can operate simultaneously depending on the daylight/weather conditions and display HDMI images to the operator.

It has the features of geo-pointing, Geo-referencing and video tracking also.

AIS

The Automatic Identification System (AIS) is an automatic tracking system used on ship and by vehicle traffic services for identifying and locating vessels by electronically exchanging data with other nearby ship, AIS-base stations and aircrafts equipped with AIS.

Features of AIS are:

- Surveillance to improve situation awareness
- Application to vessel traffic services
- Aids to navigation
- Information distribution services like weather reports, safety-related information.

Medium Wave AIS

CSM

The CSM System shall search, intercept and record communication signals over a wide range of frequencies and perform the required analysis for in-flight operations. CSM system performs the spectral search, direction finding, location fixing, monitoring, analysis and digital recording of communication signals. A multichannel audio recording of communication is also done on-board for post-flight analysis. It is capable of searching till 3 GHz and do direction finding till 1.2 GHz.

Data Links

The data from maritime patrol radar, IFF, AIS and CSM are downlinked to the ground stations and tactical control data uplinked to the MMMA system. Communication between the MMMA system and Ground Exploitation Stations (GES) is through 'C'-Band LOS Link and 'Ku'-Band SATCOM Link.

MCS

The Mission Communication System (MCS) provides Air-to-Air and Air-to-Ground V/UHF voice communication. It also provides integrated control of all onboard communication sets and intercom for all mission operators and the flight crew.

MMS

MMS is the heart of the MMMA system and provides all features namely, command and control, integration of mission sensors, tactical, navigation and communication system. It has following features

- Scalability
- Distributed architecture
- Redundancy and fault tolerance

- ARINC, 1553, RS-232, RSS-422 and Ethernet Interfaces.

MTC

The MMMA system comprises three reconfigurable, triple display Multifunctional Tactical Consoles (MTC) capable of operating in any of the designated modes. The MTC will display the Recognizable Maritime Picture (RMP) of the overall scenario perceived by the various sensors to the mission operator via the MMS. The same RMP is also communicated to the ground station via the data links. MTC also receives health information from all the systems periodically and displays health status to the operator. It has following features.

- Generic, modular software architecture
- Reusable plugin based architecture for sensor interfaces
- Highly extendable for additional sensors

Intelligence, Surveillance, Targeting and Reconnaissance

Planning attacks against mobile targets is dynamic and highly time-critical, as the time duration available for targeting is extremely small. Dynamic and time-critical targeting capability is therefore essential to drastically reduce the sensor to shooter time through improved situational awareness, along the frontiers and in insurgent afflicted regions. The need of the hour is to provide near-real-time intelligence inputs to decision-makers. Intelligence, Surveillance, Targeting and Reconnaissance (ISTAR) system provides such dynamic and time-critical targeting capability and contributes significantly to meet the nation's security goals. ISTAR system links several battlefield functions together to assist a combat force in employing its sensors and managing the information they gather. The information is gathered using very high-performance sensors in addition to the deployed human resources. Intelligence is the processing, exploitation, analysis, interpretation and dissemination of the information gathered. The capabilities of the sensors are selected based on the operational requirements. The ISTAR role is categorised based on the platform used namely, space-based, airborne manned aircraft, uninhabited aerial vehicles, or shipborne. Further, they are also classified as strategic, if the system is used for strategic Intelligence gathering or as tactical if it is used for tactical intelligence gathering.

The ISTAR systems used worldwide include Sentinel (ASTOR) of UK JSTARS of USA, Shadow R1 of UK, ISR MMA of Israel, etc. The ISTAR acts as an element in the Net-centric warfare. As AWACS provides air-to-air and air-to-sea surface surveillance, the ISTAR complements the AWACS role by providing Air-to-ground surveillance to aid in precision strikes. ISTAR thus provides dynamic and time-sensitive targeting capability and contributes significantly to meet the Nation's security goals. It will aid in limiting the scale and complexity of undetected hostile threats. It has multi-spectral surveillance capability to detect, locate and monitor irregular forces.

The role of the ISTAR system shall be for carrying out intelligence gathering, surveillance, reconnaissance and targeting by day and night from stand-off ranges. The ISTAR system will be operated at high altitudes from large stand-off ranges and will be used for intelligence processing, exploitation and dissemination and generation of the common operating picture. ISTAR aircraft will be simultaneously networked with the airborne network, ground-based network and the command and control network.

The ISTAR aircraft will be a system of systems that comprise airborne and ground segments. The airborne segment comprises of mission Systems such as AESA-based Synthetic Aperture Radar/Ground Moving Target Indicator (SAR/GMTI), Electronic Intelligence (ELINT) and Communication Intelligence (COMINT), Electrooptical/IR imagery sensor (EO/IR), Communication datalinks in Wideband Line of Sight (LoS), Beyond LoS and Very/Ultra High Frequency (V/UHF) links and Self Protection Suite (SPS).

Mission Maritime Aircraft (MMMA)

Intelligence, Surveillance, Targeting and Reconnaissance (ISTAR)

Advanced AEW&C

DESIDOC thanks Dr Reena Sharma, Sc 'G', Shri Y Maheshwaran, Sc 'F' of Centre For Airborne Systems (CABS) for bringing out this issue of *Technology Focus*.

डेसीडॉक द्वारा प्रकाशित

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