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ADS-B Technology With GPS Aided Geo Augmented Navigation

TanmaySenapati[1], Mahesh Ramachandran[2], Shivam Sharma[3], Kalimuthu.K [4]

*Department of Electronics and Communication, SRM University

Abstract: - Automatic Dependent Surveillance-Broadcast (ADS-B) is being rolled out as the next generation air transportation systems for communication protocol. The ADS-B will play an essential role in the protection of the two billion people travelling across by 2015 as estimated by the Federal Aviation Administration (FAA). Due to the recently published proof of concept attacks, it becomes one of the most ever pressing topics especially with the deadline for mandatory implementation in most airspace.

The main focus of this paper is on the critical need for practical implementation of the ADS-B technology and how it can be used to monitor the air traffic over Indian Air Space. The launch of the GAGAN Satellite (INDIA's Satellite Based Air Traffic Management System) by ISRO and Airport Authority of India(AAI) is the first step towards fully incorporating this technology .The authors have pointed out the urgent need for transition from the currently used radar based navigation system to ADS-B technology using GAGAN for making the air travel safer and efficient.

Keywords:-ADS-B,GNSS,GAGAN,Radar, FAA, NextGen.

I. INTRODUCTION

The Federal Aviation Administration(FAA) estimates that the rising number of flights and passengers will overwhelm the current Air Traffic Control (ATC) by 2015 leading to increase in delays, higher costs and greater environmental impact. With increased traffic,very light jets,unmanned aerial vehicles and commercial space flight in the near future, there is an imminent need to be proactive in upgrading the national airspace system.To meet this challenge the FAA is rolling out the NextGen- Air Traffic Control system called the Automatic Dependent Surveillance-Broadcast(ADS-B). ADS-B enables the widespread use of Satellite Based GPS technology.It provides air traffic controllers information that will make air craft efficiently navigate through the congested airspace. Automatic Dependent Surveillance Broadcast(ADS-B) is all about communications between aircraft and also between aircraft and ground. Both are vital in terms of ensuring safe flights and efficiency in terms of fuel use, time and emissions.ADS-B is an integral part of the planned efficiency drive towards 2020.Developed and certified as a viable low-cost replacement of conventional radar, ADS-B allows ATC to control and monitor airplanes with greater precision and over a larger percentage of earth's surface that has ever been possible before.For example, large expanses of Australia, Hudson Bay in Canada, currently without any radar coverage are now visible on ATC screens of strategic replacement of low cost ADS-B receiving stations.ADS-B is one of the most important underlying in the plan to transform ATC from the current radar- based surveillance to satellite- based global positioning system(GPS) surveillance.The acronym can be broken as, Automatic- always ON and requires no operator intervention, Dependent- it depends on a accurate GNSS signal for position data,Surveillance- It provides "Radar-like" surveillance services. ADS-B allows aircrafts to determine their exact location through GPS Satellite.That information is broadcast back to other nearby ground stations and ADS-B ground stations which relay the information back to Air Traffic Controllers.Additionally, a signal with flight, weather and data is broadcast back to the plane.

With increase in number of passengers,air-accidents,delays, fuel consumption there is an urgent need for shifting from Radar-Based Navigation to Satellite Based Navigation. ADS-B provides update 12 times faster than that of radar. Hence, there is an urgent need to bring Satellite Based navigation technology and ADS-B helps us in achieving this. There are clear benefits of using ADS-B technology over Radar Based Navigation. It includes surveillance in non-radar areas, more direct routes which save fuel, better coordinated take-offs and landings.

The 1978 crash of Air India Flight 855,1996 Charkhi-Dadri mid- air collision,2010 Mangalore crash, dis-appearance of MH370 are some of the incidents which stresses the need of GPS-based navigation system. The first step towards incorporating this type of surveillance in India is the GAGAN(GPS aided GEO-augmented navigation system) by

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ISRO(Indian Space Research Organization) along with AAI(Airport Authority of India).GAGAN is India's first GPS satellite which will put India on the 4th position globally after USA,Russia and Europe.GAGAN will provide air traffic management over the Indian Air Space stretching from Australia to South Africa.

This paper gives an overview of using GAGAN along with ADS-B technology to manage the Indian Air Space.This will make the ever increasing aviation industry more efficient and safer.Since ADS-B technology is already being adopted some countries, it is thus required that India also starts using the ADS-B technology along with its first GPS satellite-GAGAN.

II.ADS-B

The Federal Aviation Administration and the European Administration EUROCONTROL has named ADS-B as the successor of radar. ADS-B is a new surveillance technology designed to help modernize the air transportation system. It provides foundational technology for improvements related to the Next Generation Air Transportation System (or NextGen).NextGen refers to the effort of the U.S. Federal Aviation Administration (FAA) to transform the air traffic control (ATC) system to support a larger volume of airplanes more efficiently. Developed and certified as a viable low cost replacement for conventional radar. ADS-B allows ATC to monitor and control airplanes with greater precision and over aFar larger percentage of the earth's surface than has ever been possible before. Every aircraft projects its velocity and position using the on-board GPS. The information is broadcasted in message form periodically by the ADS-B OUT. The message broadcasted will be received by the Air Traffic Control Systems on the ground level and other aircrafts by ADS-B IN.

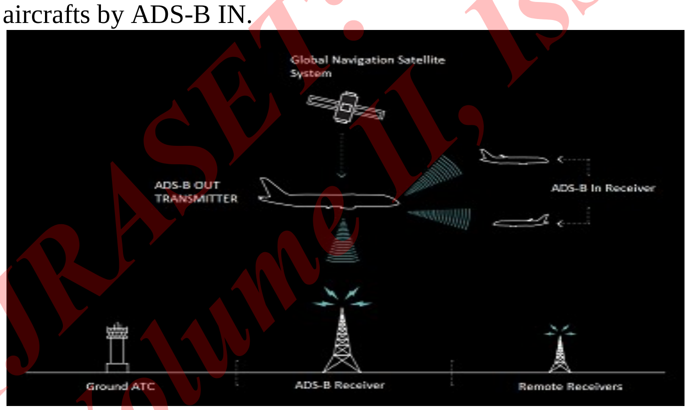

Fig.1 Working of ADS-B

A. WORKING OF ADS-B

ADS-B uses a combination of satellites, transmitters, and receivers to provide both flight crews and ground control personnel with very specific information about the location and speed of airplanes in the area. From the airplane perspective, there are two aspects to ADS-B. ADS-B Out signals are sent from the transmitting airplanes to receivers located on the ground or in other airplanes. The ADS-B Out signals travel line-of-sight from transmitter to receiver ADS-B Out signals are received by ATC ground stations for display of traffic to air traffic controllers. ADS-B Out signals are also received by other airplanes in the vicinity of the transmitting airplanes. After Reception of the ADS-B signals by the receiving airplane, the lateral position (latitude and longitude), altitude, velocity,and flight number of the transmitting airplane are presented to the receiving airplane pilot on a Cockpit Display of Traffic Information (CDTI). The received ADS-B Signal is called ADS-B In. The maximum range between the transmitting Andre planes is greater than 100 nautical miles (nmi), allowing the CDTI to display traffic both near and far.Navigation satellites send precise timing information that allows airplanes equipped with global navigation satellite system (GNSS) or GPS receivers to determine their own position and velocity. Airplanes equipped with ADS-B Out broadcast precise position and velocity to ground ADS-B receivers and to other airplanes viaa digital data link (1090 megahertz) along with other data, such as the airplane's flight number and emergency status. ADS-B Receivers that are integrated into the ATC systems on the ground or installed aboard other airplanes (i.e., ADS-B In) provide users with an accurate depiction of real time aviation traffic.Unlike conventional radar, ADS-B works at low altitudes and on the ground so that itcan be used to monitor traffic on the taxiways and runways of an airport. ADS-B is also effective in remote areas where there is no radar coverage or where radar coverageis limited. ADS-B uses two data links, a 978 MHz UAT (Universal Access Transmitter) and a 1090 MHz extended Squitter. UAT involves installation of a hardware, therefore, general aviation in EUROCONTROL and Federal Aviation Administration use this whereas commercial aircrafts use 1090 MHz

There are three modes currently in use in the civil aviation i.e. Mode (A, C and S).

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Table 1

Parameters	MODE A	MODE **C**	MODE S	ADS-B
Message Length	12 Bit	12 Bit	56/112 Bit	112 Bit
Frequency	1030/1090 MHz	1030/1090 MHz	1030/1090 MHz	1090 MHz
Uses	Identifying	Altitude Determination	Multiple	Multiple

Comparison of different modes

Aircraft localisation has been relying on radar based systems. There are two conventional methods for the radars i.e primary surveillance radars and secondary surveillance radars.

Primary Surveillance Radars(PSR) are independent and work without the cooperation from the aircrafts with high frequency signals. In contrast to PSR's secondary Surveillance Radars were used in the Air Traffic Control before ADS-There are three modes in case of SSR i.e Mode A, Mode C and Mode S. Table 1 compares the characteristics of the three modes with the ADS-B.

In case of Mode S, there are two message lengths 56 bit and 112 bit whereas ADS-B uses only 112 bit message length, surveillance of Mode S is priced at $5.5 million and the cost of ADS-B is around $3 million.

In case of ADS-B, every aircraft collects their own data such as velocity and position using the measurement devices. The ADS-B infrastructure is very cost effective when compared to the conventional Primary Surveillance Radar (PSR) which is currently being used.

There are three benefits of ADS-B. Firstly, the GPS positions reported by ADS-B are more accurate than the current radar positions and more consistent. This means that in the Instrument Flight Rules (IFR) closer aircraft spacing can be used than the present, which provides much needed capacity improvements in congested spaces.
Secondly, ADS-B surveillance is much easier and less expensive to deploy than the ground radar. This means that the airspace which previously had no radar and only procedural services can now have the benefits of ATC services.And finally, since ADS-B is a broadcast service and can be received by other aircrafts as well as the ATC on the ground, it offers the aircraft to have an accurate and inexpensive traffic awareness of other nearby aircrafts.

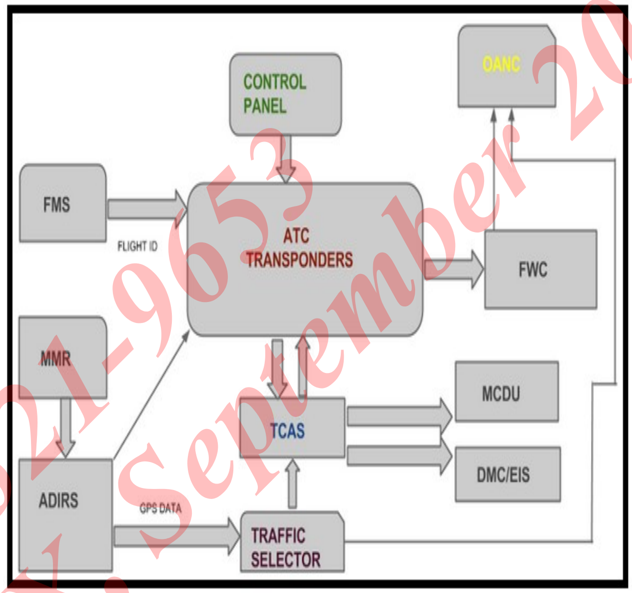

Fig. 2 Architecture of ADS-B

B. ARCHITECTURE

ADS-B OUT needs:

- ATC transponders AT D0-260 standards.
- Additional wiring associated with peripheral equipment,
- MMR in hybrid architecture with GPS capability.

CURRENT STATUS: -Aircraft currently flying in Europe are generally well equipped for the transition to ADS-B OUT as the prerequisite ATC transponders Mode S (DO-260) are already required to meet the former enhanced surveillance mandate. Aircraft greater than five years of age and operating outside of Europe are more likely to need a new transponder in order to
Achieve ADS-B capability.

ADS-B IN:

- TCAS capable
- Additional wiring

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- Traffic selector in cockpit
- EIS2 capable
- On-Board Airport Navigation System.

C.APPLICATIONS OF ADS-B

ADS-B GROUND APPLICATION:-ADS-B Out offers several benefits to ground-based ATC. In radar areas, it canbe used by ATC to supplement 5- and 3-nmi en-route separation services. Whereno other radar or surveillance is available, it can be used by ATC to provide thatseparation services.For airport surface surveillance, ADS-B Out provides ground control with a picture of all airplanes and vehicles on the ground. In the terminal area, ADS-B Out could enable 2.5-nmi separation in-trail approaches, 2-nmi separation for dependent parallel approaches, and separation during independent parallel approaches for runways spaced more than 4,300 feet apart.

ADS-B IN BORNE APPLICATION:-ADS-B In offers potential benefits across all domains of flight, from departure toarrival (see “ADS-B in various domains of flight” on this page). It provides situationalawareness of other airplanes and vehicles on the airport surface and situational awarenessof other airborne traffic, such as assistance in finding targets outside the cockpit window using the CDTI. ADS-B In could also enhance situational awareness on approach, allowing continued approaches using the CDTI after initial visual acquisition. Airborne spacing applications facilitate increased capacity and efficiency in a number of ways. Enhanced sequencing and merging enable precise delivery of airplanes to the meter fix for subsequentcontinuous descent approaches; in trail procedures assist airplanes in moving tooptimal operational altitudes in remote areas; and enhanced crossing and passingoperations assist airplanes in flying optimal flight routes and speeds. ADS-B In alsoenables airplane crews to assume responsibility for separation from up to twoother airplanes through delegated enroute separation. In this scenario, the controllerretains responsibility for separation from other airplanes beyond the two the crew has assumed responsibility for.

ADS-B AROUND THE WORLD: -ADS-B activity is increasing around the world. ADS-B benefits the aviation industryby means of the decreasing the cost of providing services and increasing the operationalefficiency and capacity of the regional air transportation system.It also reduces the risk of lives of billions of people flying across the world daily.

III.DIFFERENCE BETWEEN RADAR and ADS-B SURVEILLANCE.

Before the widespread use of radar for air traffic control in the 1950s, an aircraft’s position was calculated by the crew and the information was relayed to ATC by radio.As radar technology came into existence it gave controllers a picture of the airspace around them.The Primary SurveillanceRadar (PSR) showed the aircrafts as dots on screen. With the help of MODE C transponder the controllers could assign a four digit code to the dot on the screen allowing them to identify each dot as a particular aircraft. This was known as Secondary Surveillance Radar (SSR). Adding MODE S transponder gave each dot an aircraft-specific identifier tied to the aircraft registration number as well its altitude.

All of this technologywas to locate the aircraft from the point of the Air Traffic Controllers, who could then manage the traffic. This approach worked well for areas under air traffic control but did nothing for areas without radars. As the skies are becoming more congested, a system for real traffic awareness for the pilots became a necessity. Hencethere a need to shift from the present radar based navigation to a new system. Hence it leads to the advent of new technology which is satellite - based navigation which is ADS-B technology.

TYPE	Independent	Cooperative
Primary Surveillance Radar	Surveillance data received by radar	Does not depend on aircraft equipment
Secondary Surveillance Radar	Surveillance data received by aircraft	Requires aircrafts to have a working a ATCRBS transponder
Automatic Dependent Surveillance (ADS-B)	Surveillance data received by aircraft	Requires aircrafts to have a working ADS-B function

TABLE II Analysis of Radar and ADS-B technology

Primary surveillance radar does not require any cooperation from the aircraft. It is robust in the sense that surveillance outage failure modes are limited to those associated with the ground radar system. Secondary surveillance radar depends on active replies from the aircraft. Its failure modes include the transponder aboard the aircraft. Typical ADS-B aircraft installations use the output of the navigation unit for navigation and for cooperative surveillance, introducing a

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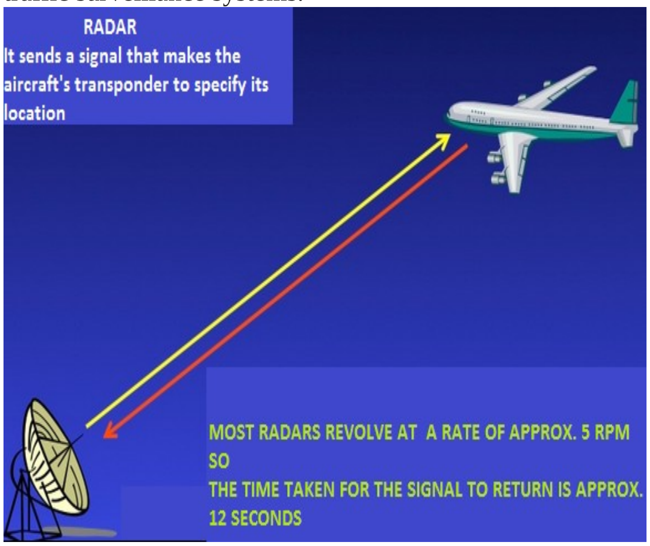
common failure mode that must be accommodated in air traffic surveillance systems.



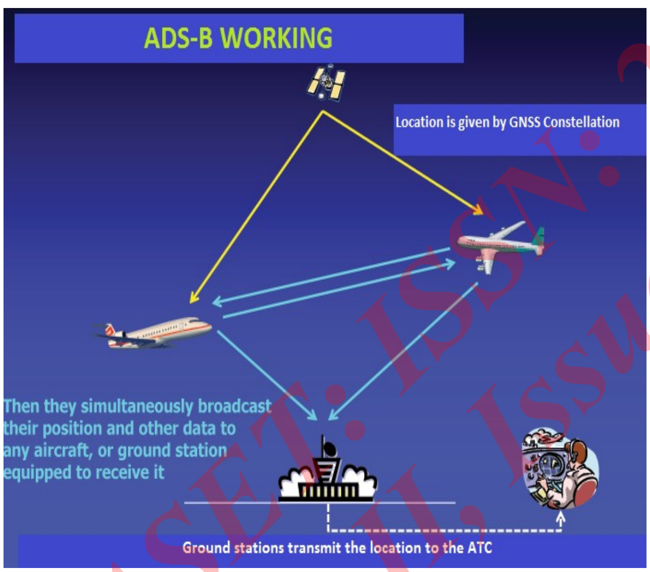


Fig. 3Difference between ADS-B and RADAR

Far different from radar, which works by bouncing radio waves from fixed terrestrial antennas off of airborne targets and then interpreting the reflected signals, ADS-B uses conventional Global Navigation Satellite System (GNSS) technology and uses a relatively simple broadcast communication link. Also unlike radar, ADS-B accuracy does not degrade with range, atmospheric condition or target altitude and update intervals do not depend upon the rotational speed or the reliability of mechanical antennas. The time taken by these mechanical antennas to accept and send the signals from the transponders is approximately 12 sec which leads to loss of real time information. With ADS-B technology, the information from the GNSS about its position and other data is constantly broadcasted to the air traffic controllers and the nearby aircrafts which leads to real time awareness for the pilots and the controllers. The ADS-B technology also provides coverage in non- radar regions which increases the efficiency of the aviation industry. The cost of setting up a ADS-B ground station is much lesser than any of the existing radar technology. With ADS-B technology, we can have more direct routes that shorten flight times and fewer delays. The technology provides more information in the hands of the pilots who will have air traffic control data on their display screen right in the cockpit and the pilots will only guide them whereas in radar the information is in the hands of the controllers which then again have to send this information to pilots through data links. This leaves a lot of work to be done by the controllers and also leads to confusion between the pilots and controllers.

IV. GAGAN(GPS AIDED GEO –AUGMENTED NAVIGATION)

To Provide Satellite Based Augmentation System Services over India and neighbouring regions the GPS Aided Geo Augmented Navigation (GAGAN) - a Satellite Based Navigation System (SBNS) is being launched by the Union Ministry for Civil Aviation. This system is expected to provide enhanced navigation performance for critical applications like Civil Aviation, Marine Navigation, Train & Road Transport, Precision Farming, Search and Rescue (SAR) operations, Surveying and Mapping (Geodetic and Geodynamic), Mining etc.

GAGAN is a planned implementation of a Satellite Based Navigation System developed by Airports Authority of India (AAI) and Indian Space Research Organisation (ISRO), to deploy and certify an operational SBAS for the Indian Flight Information Region, with expansion capability to neighbouring Flight Information Regions (FIRs). When commissioned for service, GAGAN is expected to provide a civil aeronautical navigation signal consistent with International Civil Aviation Organization (ICAO) Standards and Recommended Practices (SARPs) as established by the Global Navigation Satellite System Panel (GNSSP). ICAO has endorsed Global Navigation Satellite System as Future Air Navigation System (FANS) for civil aviation.
The project involves establishment of a full complement of Satellite Based Augmentation System (SBAS) consisting of 15 Indian Reference Stations (INRES), 3 Indian Navigation

Land Uplink Stations (INLUS), 3 Indian Mission Control Centre's (INMCC), 3 Geo-stationary Navigation in C and L bands and with all the associated Software and Communication links.

A. NEED FOR AUGMENTATION:-

- Current GPS constellation cannot support requirements for all phases of flight.
- Accuracy is not sufficient (even with Selective Availability off, vertical accuracy>10m).
- Availability and continuity must be met.

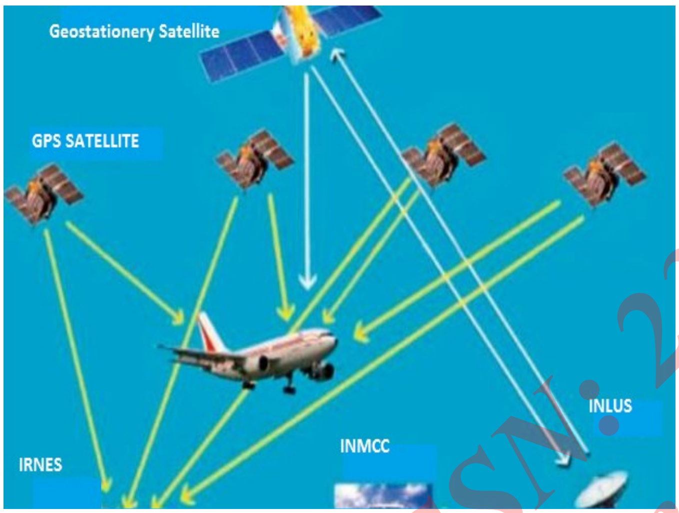


Fig.4Operations of GAGAN.

B. Working of GAGAN

The Global Navigation Satellite System (GNSS) data is received and processed at widely dispersed INRES which are strategically located to provide coverage over the required service volume. Data is forwarded to the INMCC, which process the data from multiple INRES to determine the differential corrections and residual errors for each monitored satellite and for each predetermined ionosphere grid point (IGP). Information from the INMCC is sent to the INLUS and uplinked along with the GEO navigation message to the GAGAN GEO satellite. The GAGAN GEO satellite downlinks this data to the users via two L-band ranging signal frequencies (L1 and L5), with GPS type modulation, to improve the accuracy and availability and provide integrity. GAGAN will provide augmentation service for GPS over India, Bay of Bengal, South-East Asia, and Middle East expanding into Africa. GAGAN will be compatible and interoperable with other SBAS systems such as the Wide Area Augmentation System (WAAS) of USA, the European Geostationary Navigation Overlay Service (EGNOS) of European Union (EU) and the Multi-functional Satellite Augmentation System (MSAS) of Japan. It will fill the gap between the European EGNOS and the Japanese MSAS to provide seamless air navigation service across regional boundaries.

V. 1996 CHARKHI DADRI MID-AIR COLLISION

Mid-air collisions are one of the deadliest disasters that can happen in the aviation industry. The 1996 Charkhi Dadri Mid-Air Collision is one such incident. It occured on the 12 November 1966 over the village of Chakri Dadri to the west of New Delhi, India.The aircraft involved were a Saudi Arabian Airlines Boeing 747-100B en route from New Delhi to Dhahran, Saudi Arabia and Kazakhstan
Airlines IIyushin II-76 en route from Shymkent Kazakhstan, to New Delhi. The collision took place at 14,000 feet over the Indian Air space which claimed the lives of 349 people on board which included 289 passengers and 23 crew members in all. Both the aircrafts were being guided by the Delhi ATC.

There are a series of events which lead to such a disaster.The Kazakhstan Airlines which was flying into New Delhi was flying at an altitude of 23,000 feet initially whereas the Saudi Arabian Airlines was flying at an altitude of 10,000 feet over the same airspace.The Delhi ATC asks the Kazakhstan airlines to descend to an altitude of 15,000 feet and maintain it till any further notice whereas the Saudi-Arabian airlines was asked to climb to 14,000 feet and maintain it. But the Kazakhstan Airlines kept descending below 15,000 feet to 14,500 feet and 14,000 feet and lower. This leaves us with two aircrafts which are at the same altitude and heading in the opposite direction over the same airspace. The radio operator of the Kazakhstan Airlines realized then that they had flown much below their assigned altitude of 15,000 feet and hence asked the pilot to climb to climb to 15,000 feet. Had the radio operator not asked the pilot to climb up the Kazakhstan Airlines would have flown below the Saudi Arabian airlines. But it was rather too late and then the left wing of Kazakhstan Airlines crashes into the two engines of Saudi Arabian Airlines which leads to third- deadliest air disaster ever.

The flight data recorders of Kazakhstan Airlines and Saudi Arabia Airlines were decoded by investigators in Moscow and Farnborough,England respectively. The investigators cite many reasons for such a fatal accident. The ultimate cause was held to be the failure of Kazakhstan Airlines pilot to follow ATC instructions, cloud turbulence and communication problems. The report also

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suggested a serious breach in operating procedure to the lack of English language skills on the part of Kazakhstan pilots. This lead to communication problems between the ATC and the pilots. Furthermore, Indira Gandhi International Airport did not have a Secondary Surveillance Radar which provides additional information regarding aircrafts identity and altitude by reading transponder signals. The aircrafts were also not equipped with the Traffic Collision Avoidance System (TCAS) which alerts the pilot of a possible collision.

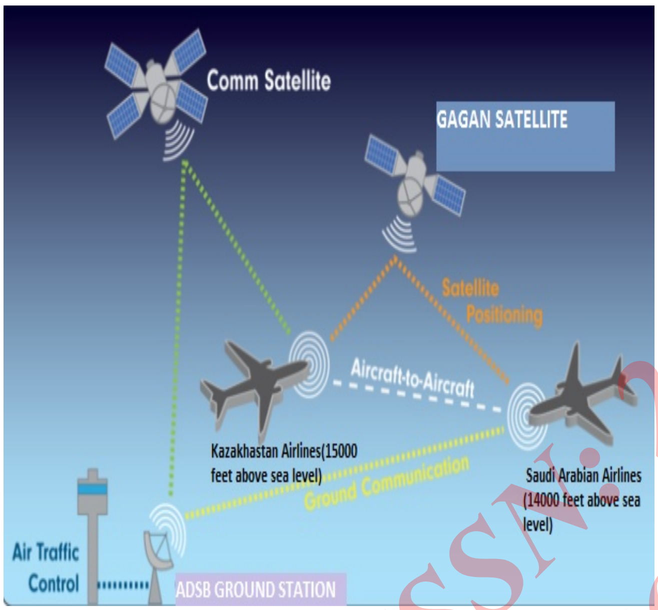

Fig. 5 1996 Dadri-Chakri incident could have been avoided with ADS-B technology.

As we reflect upon that fateful day, 18 years ago we need a new technology which does not lead to such accidents in the future. The technology that can be adopted is ADS-B with GAGAN satellite. This incident could have been avoided by using this technology. Both the flights could have known their position from the GAGAN satellite and with the help of ADS-B technology and information regarding its position, altitude and velocity could have been broadcasted to both the aircrafts and the Delhi ATC.Hence this would have led to avoidance of collision as both the aircrafts could have about each other'saltitude, position and altitude and hence pilots could have easily adjusted their altitude. This could eliminate the problem of the language of English which was cited one of the major reasons of collision as the pilot of Kazakhstan airlines would have known about the approaching Saudi-Arabian airlines by the GAGAN satellite in its Cockpit Display System(CDS) and would have conveniently adjusted its position say for example, to 16000 feet. The reason of cloud disturbance being a factor could be easily avoided as the aircraft would know about it and all its nearby position, altitude by GAGAN satellite and hence acted accordingly.Hence with see that by adopting ADS-B technologies with GAGAN satellite the lives of 349 passengers could have been. There is an urgent need to adopt this technology as it would make the air travel safer and efficient.

VII.LIMITATIONS

ADS-B provides a lot more beneifts than the presently used Radar system. The limitation is that the frequency is shared with all Mode A, Mode C and Mode S transponders as well as TCAS and other users. The frequency is already near saturation in the busiest airspaces, yet the "Extended Squitter" message is twice the length (112 bits) of a standard 1090 response (56 bits), and it can take up to 5 transmissions per second to send a fully populated 1090ES ADS-B Message. 1090 ES is not bidirectional and therefore cannot support Flight Information Services (FIS) or aircraft-to-aircraft TCAS-like services. Furthermore, the 978 MHz which is used in ADS-B technology is the least profitable technology for manufactures. UAT requires a dedicated transceiver in each aircraft, while 1090ES only requires software modification to existing Mode-S transponders.Line of sight (LOS) is also one of the major drawbacks in the ADS-B technology. For this ADS-B

Link Augmentation System (ALAS) is being introduced which is alternative flight path for the ADS-B.

VIII.CONCLUSIONS

The paper suggests the ADS-B technology is intended to transform ATC by providing more accurate and reliable tracking of airplanes in flight and on the ground. The ADS-B technology will make air travel safer, efficient and greener for the environment.ADS-B is in the upstages of a roadmap vision up until 2020 and has been updated by NextGen.It is clearly seen that ADS-B technology is much better than the currently used Secondary Surveillance Radar(SSR) as it provides better accuracy,cheaper cost and give a more up to date picture of the airspace.The launch of the GAGAN satellite by ISRO along with AAI adds benefits to this technology as it can be used be together to reduce the conjunction over the Indian airspace. The paper highlights the urgent need of incorporating all the flights operating over the Indian airspace and elsewhere to equip their fleets with the ADS-B technology which along with the GAGAN will make the skies

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a lot safer to travel.The authors have made an attempt to point out the benefits of this technology by describing the 1996 CharkhiDadri Mid-Air Collision which could have been avoided by the ADS-B technology along with the GAGAN satellite. Hence we can say that with the increasing number of passengers travelling by flights it is required to make our air travel more efficient and safer and at the same time eco-friendly.ADS-B technology provides us with this and hence it necessary to upgrade to this technology so that no other air disaster occurs and lives of billions of people are safe.Countries like Australia have already adopted this. Many Accidents can be avoided if India uses it in the future and it also reduces fuel which helps in having a greener environment.

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