

FACILITATION OF SBAS TECHNOLOGY FOR ADOPTION AS A MEANS OF NAVIGATION IN AFRICA'S AVIATION SECTOR

BY

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OUTLINES

- About NIGCOMSAT-1R
- NigComSat – 1R Hybrid COMSAT and Coverage
- Introduction to Global Navigation Satellite System (GNSS)
- Introduction to Satellite Based Augmentation System (SBAS)
- Global and Regional Satellite Based Augmentation System (SBAS) across the world (Operational and Planned).
- Illustration of Regional Satellite Based Augmentation System
- NIGCOMSAT-1R NAVIGATION PAYLOAD: Africa's Contribution to SBAS
- Multilateral Cooperation Efforts
- Needs Assessment of SBAS in Africa
- SBAS Approach Coverages and Plans
- SBAS Flight Demonstration using NIGCOMSAT-1R
- Benefits in Aviation Sector
- SBAS Demonstration and Non-Aviation Sector with Value Added Services & Applications
- Conclusion
- References

ABSTRACT

The importance and application of global navigation satellite systems (GNSS) has never been greater; there is increasing demand for both commercial and government projects as an emerging technology for adoption; indeed, owning and operating a GNSS facility has become a matter of national esteem especially as it concerns Satellite-based augmentation system (SBAS). SBAS; a less ambitious system than GNSS is a satellite-based system that aids a Global Navigation Satellite System (GNSS) in providing further accuracy, integrity, availability to positioning, navigation, and timing for professional use and application in critical sectors that involves safety of life (SOL) and precise positioning i.e Aviation and Non-Aviation sector which requires verified performance with integrity. This technical session and presentation provides insights and progress being made in African continent with an SBAS flight demonstration to sensitize stakeholders towards acceptance and adoption of SBAS technology for its many benefits including non-aviation sector.

SATNAV EXPERTS AGREE GNSS CAN BE A CYBERSECURITY ISSUE WITH ITS VULNERABILITIES.

- ❖ The Global Navigation Satellite System (GNSS) is a cyber infrastructure that allows users with a compatible device to determine their position, velocity and time by processing signals from satellites.
- ❖ The ability of GNSS devices to determine the real-time location of persons, vehicles fixed and/or moving assets makes this technology suitable for tracking, surveillance, monitoring as well as search and rescue missions.
- ❖ After the First World War, radio time signals offered alternative technology for determination of the Greenwich Time and longitude at sea for maritime navigation . The first manifestation of new technology capable of usurping the super accurate mechanical chronometers occurred in 1904, when the United States Navy began to experiment with the transmission of radio-time signals as an aid to the determination of longitude (Davies, 1978). The challenge for precision continued with Naval Navigation systems, which depends on electromagnetic waves travelling at 300,000,000 m/s, where one microsecond error in a vessel's time will result in 300 metres of navigational error.....
- ❖ For further reading on history, trends and regional developments of GPS (GNSS)/SBAS, pls click on the link below:

<https://ieeexplore.ieee.org/document/6145156>

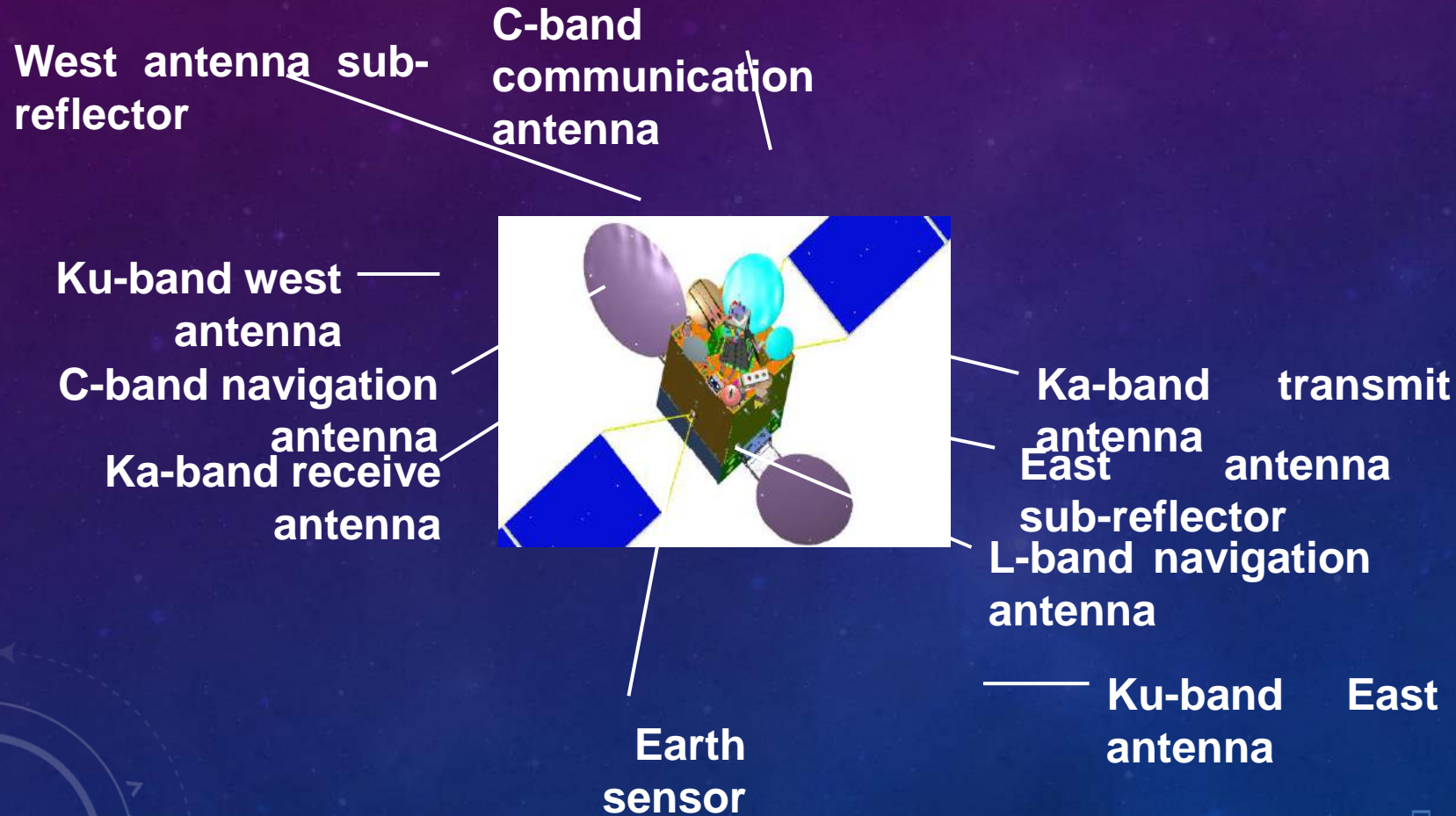
<https://stm.bookpi.org/RDER-V11/issue/view/26> Chapter 4 to 6 (Pages 41 to 85).

<https://stm.bookpi.org/AAER-V16/article/view/2001>

ABOUT NIGCOMSAT-1(R)

- Nigeria's first communication satellite (NIGCOMSAT-1), a quad-band high powered satellite with navigational capability and capacity was launched on 14th May, 2007.
- NIGCOMSAT-1 was Africa's first contribution to the Global Navigation Satellite System as regional Satellite-based Augmentation System (SBAS).
- It was however de-orbited on the 10th of November, 2008 due to an irreparable single point of failure on-board the satellite.
- All broadcast, telecommunication services being offered by the satellite including strategic navigational plans and objectives were disrupted.
- The **NIGCOMSAT-1R**, is the insurance replacement for NIGCOMSAT-1 satellite launched on 19th December, 2011.

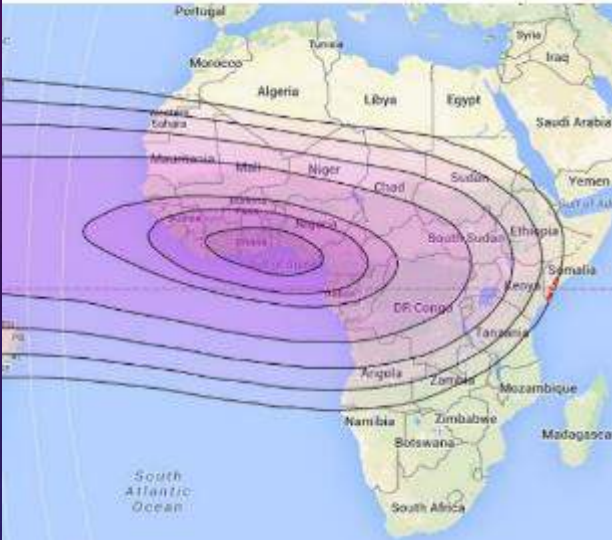
NIGCOMSAT-1R



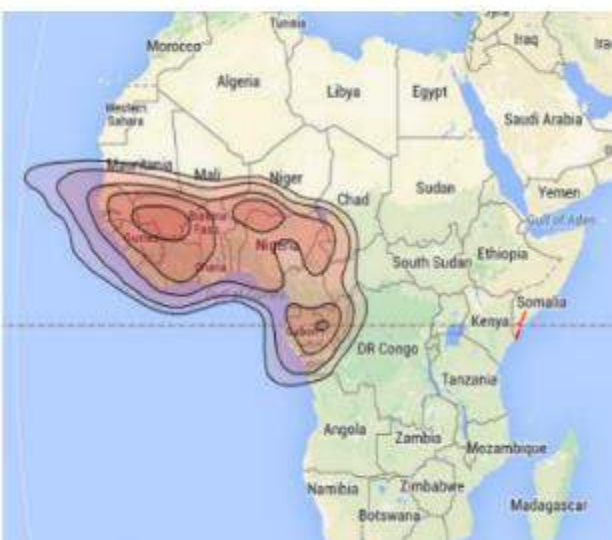
□ The satellite is located at 42.5 degree

NIGCOMSAT-1R SATELLITE FOOT PRINT

C-Band Ecowas 1 beam



Ku-Band Ecowas 1 beam



Ku-Band Ecowas 2 beam



Ku-Band Asian (Kashi) beam



NIGCOMSAT-1R SATELLITE FOOT PRINT

Ka-Band Nigeria Spot beam



Ka-Band South Africa Spot beam



Ka-Band Europe Spot beam



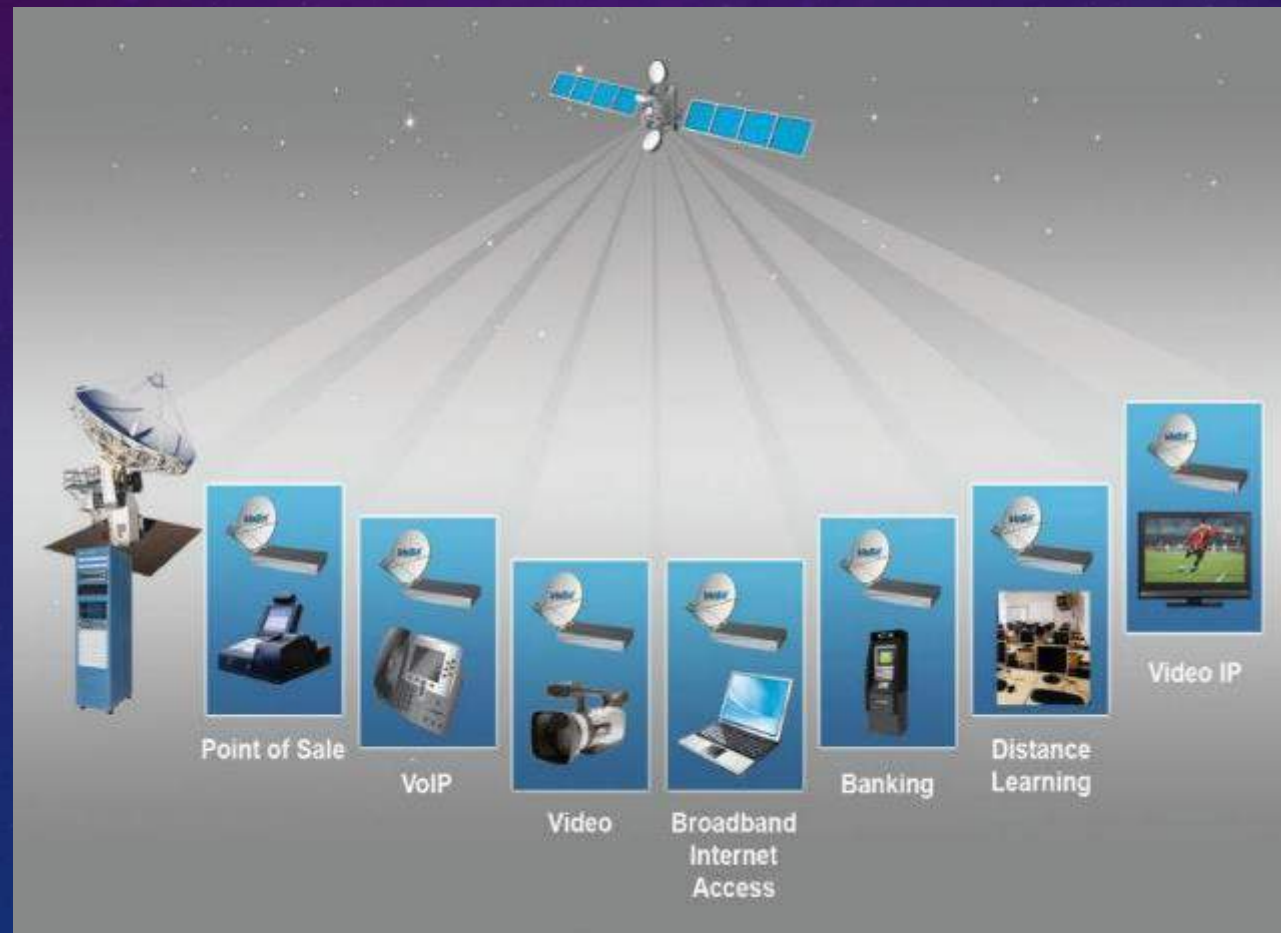
L-Band Navigation Payload L1 beam



BEYOND NIGCOMSAT'S TRADITIONAL RANGE OF SERVICES IS SATELLITE-BASED NAVIGATION CAPABILITY.

NIGCOMSAT

...African Rooted
Globally Positioned



INTRODUCTION

WHAT IS GNSS?

- The Global Navigation Satellite System (GNSS) is the infrastructure that allows users with a compatible device to determine their position, velocity and time by processing signals from satellites. GNSS signals are provided by a variety of satellite positioning systems, including global constellations (GPS, GLONASS, Galileo, BeiDou) etc.

GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS)

System	No. of Satellites	Nominal Altitude (Km)	Orbit Inclination i ($^{\circ}$)	Initiation and Current Operational Capability
GPS	32 satellites (31 Operational, 1 in Maintenance) 12 th July, 2017)	20,200	55	Initiated 1973 by USA, 1995(FOC)
GLONASS	27 Satellites (23 Operational, 2 under checks, 1 inflight tests phase and 1 spare) (12 th July, 2017)	19,000	64.8	Initiated by Russia in 1975, 1996(FOC) 2011 (Restarted Modernization)
GALILEO	Presently 18 satellites (13 Usable, 1 Not Available, 2 Testing and 2 Under Commissioning) (11 th July, 2017) (30)	24,000	56	Initiated by EC in 2000, 2014(IOC). Galileo Initial Services achieved in 2016 (FOC) expected 2021 tentatively
BEIDOU (COMPASS)	Presently 23 Satellites (14 Operational, 9 not included in operational orbit constellation (12th July, 2017) (30)	30 MEO Satellites (21,500) 5 IGSO Satellites inclined at 55 degrees	55	Initiated by China in 1990s. Regional System declared operational in 2011. (FOC) reached in 2020.

INTRODUCTION

WHAT IS SBAS?

- Satellite-Based Augmentation System (SBAS) arose from the need to provide Continuity, Availability, Integrity and Accuracy of GNSS signals to eliminate errors and compensate for discrepancies associated with GPS and other navigation systems signals.
- The NIGCOMSAT-1R Navigation (L-Band) payload is a Space Based Augmentation System meant to provide a Navigation Overlay Service (NOS) similar to the European Geostationary Navigation Overlay Service (EGNOS).

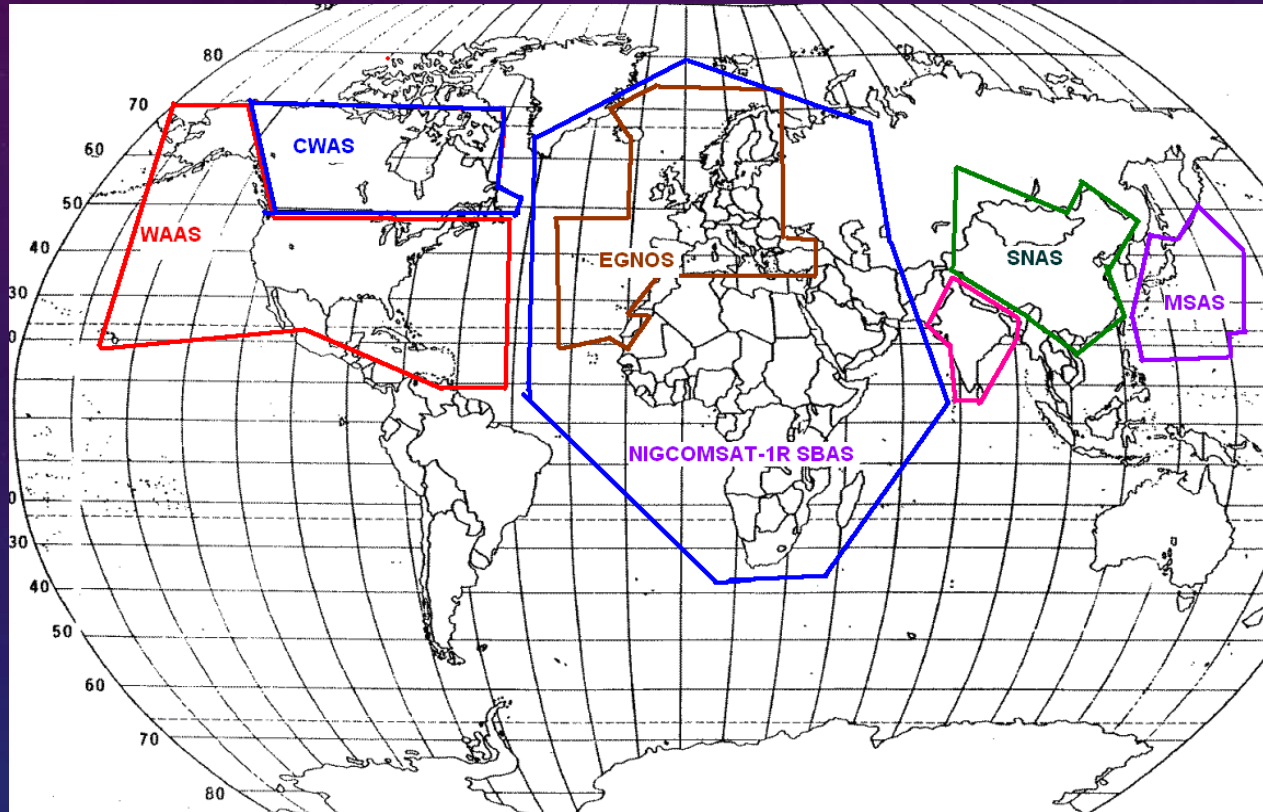
HYBRID SATELLITE

- NIGCOMSAT-1R is a hybrid satellite with a Navigation (L-Band) payload for a Space Based Augmentation System meant to provide a Navigation Overlay Service (NOS) similar to the European Geostationary Navigation Overlay Service (EGNOS).

SATELLITE BASED AUGMENTATION SYSTEM (SBAS) ACROSS THE WORLD (OPERATIONAL AND PLANNED).

- a. USA: Wide Area Augmentation System (WAAS), expanded to Canada as CWAAS and planned expansion to South America.
- b. Europe: European Geostationary Navigation Overlay System (EGNOS) with expansion over Africa.
- c. China: Chinese Satellite Navigation Augmentation System (SNAS) currently DRAGON: Differential Reference Augmentation Global Overlay Network.
- d. Japan: MTSAT Satellite Augmentation System (MSAS).
MTSAT means Multi-functional Transport SATellite.
- e. India: GPS-Aided Geo-Augmented Navigation (GAGAN).
- f. Russian Federation: System Differential Correction and Monitoring (SDCM).
- g. AFRICA: ASECNA/Nigerian Satellite Augmentation System (NSAS) Initiative

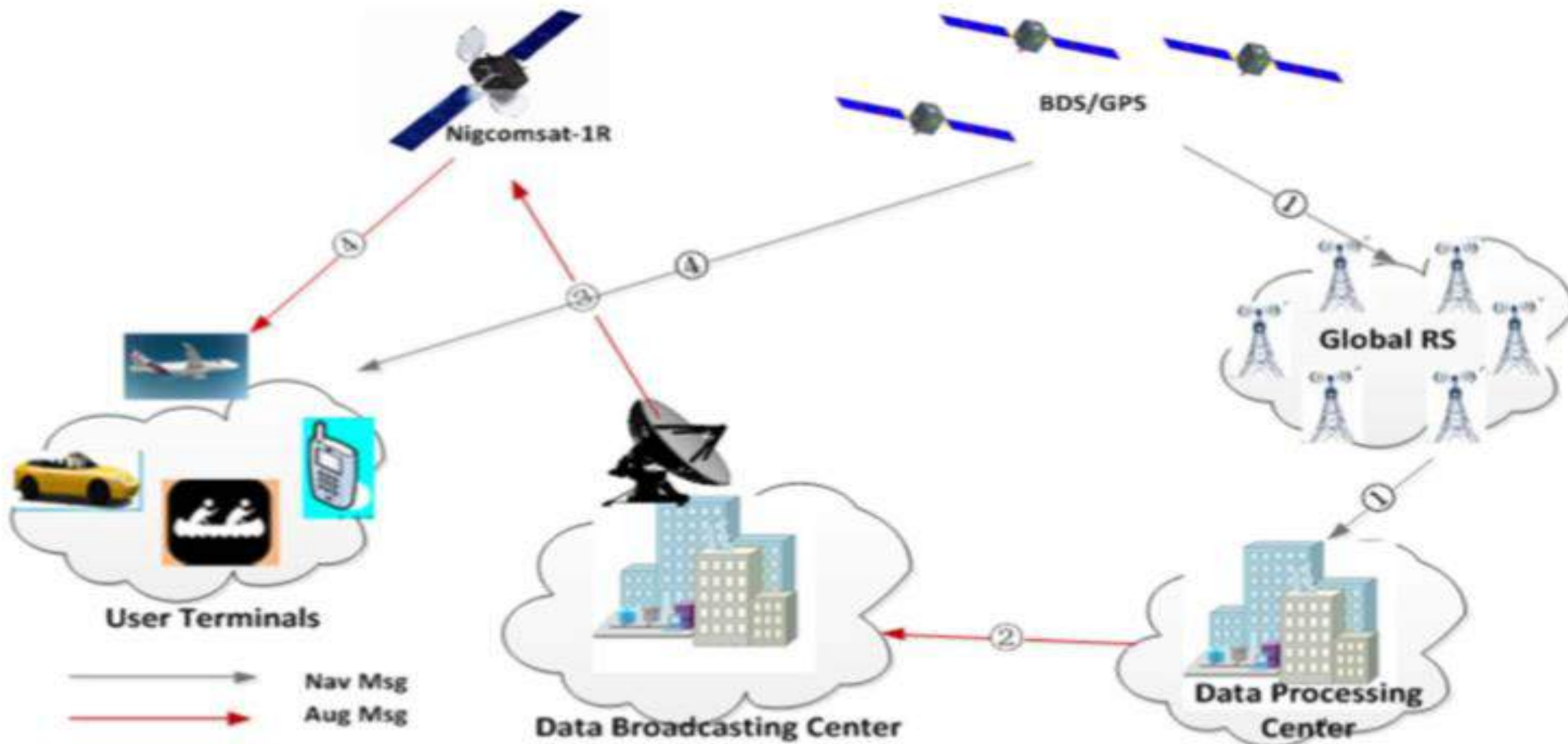
ILLUSTRATION OF REGIONAL SATELLITE BASED AUGMENTATION SYSTEM.



WAAS: US Wide Area Augmentation System EGNOS: European Geostationary Navigation Overlay Service MSAS: Japanese MTSAT Satellite Augmentation System SNAS: Chinese Satellite Navigation Augmentation System CWAAS: Canadian Wide Area Augmentation System

AFRICA'S SBAS: NIGERIA'S CONTRIBUTION TO SATELLITE-BASED AUGMENTATION SYSTEM (SBAS) WITH PRN CODE 147.

- SBAS compensates for errors of GNSS in terms of **Integrity and Accuracy**
- Provide **Continuity and Availability**
- Makes differential corrections and then broadcast the integrity messages as an augmented signal of the original GNSS Signal in Space (SiS) through Geostationary satellite (**Our NigComSat-1R**) for a wide coverage
 - ✓ Africa's SBAS in conjunction with ASECNA has **Pseudo Random Noise (PRN) code 147.**
- Conforms to **global standard** to enhance **Interoperability, Compatibility and Zero Interference.**



NSAS Architecture

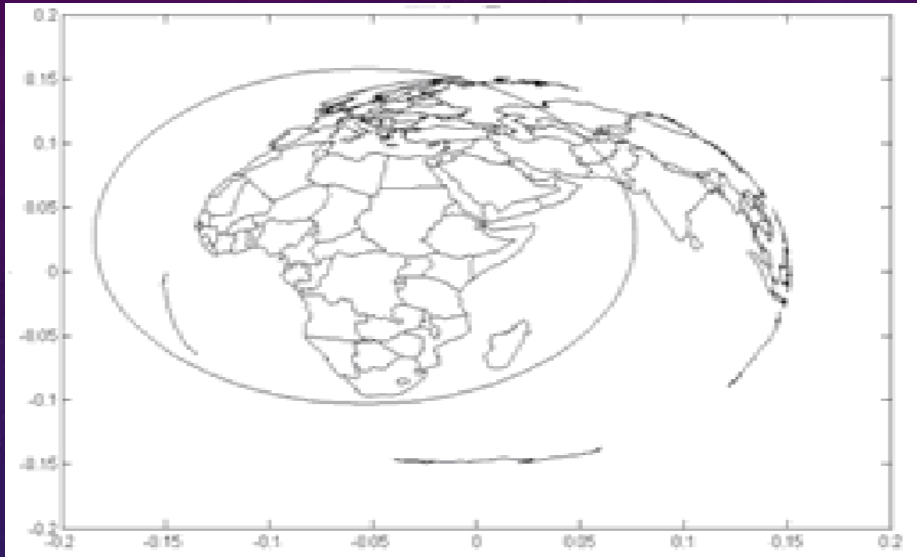
NIGCOMSAT-1R NAVIGATION PAYLOAD: AFRICA'S CONTRIBUTION TO SBAS

- *10MHz ultra stable crystal oscillator was used for the L-band payload to meet the performance requirements of frequency conversion stability and accuracy.*



10MHz Master Oscillator

NIGCOMSAT-1R NAVIGATION PAYLOAD: AFRICA'S CONTRIBUTION TO SBAS

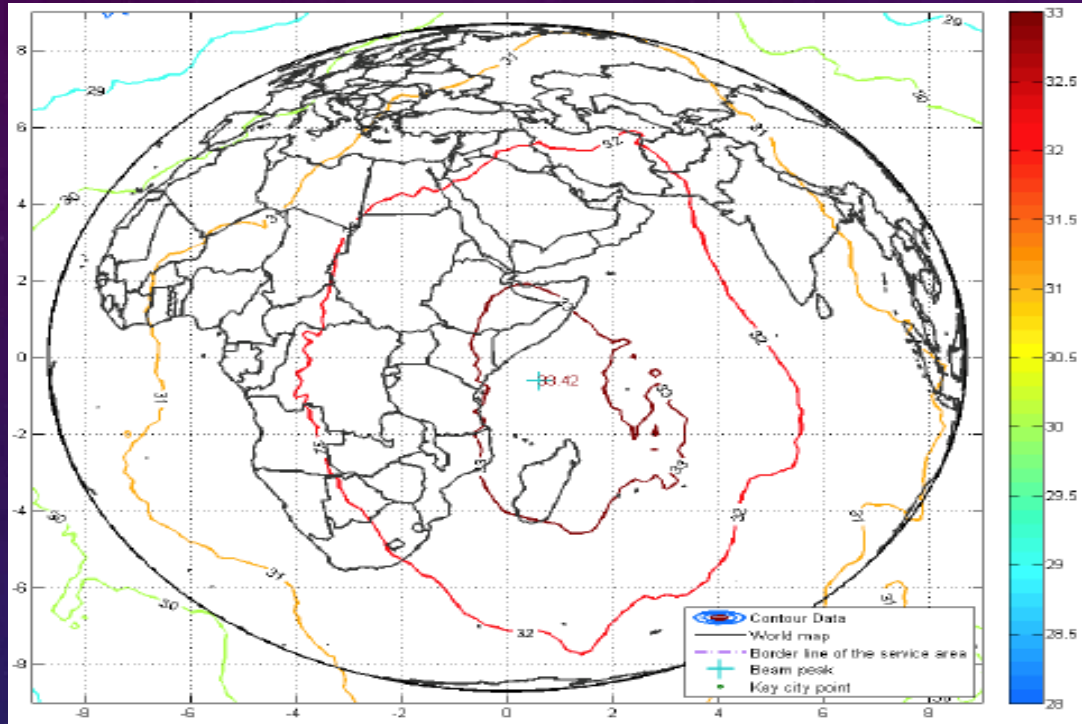


The Uplink coverage beam of NIGCOMSAT-1R Geo-Navigation Satellite using C –Band Horn Antenna.

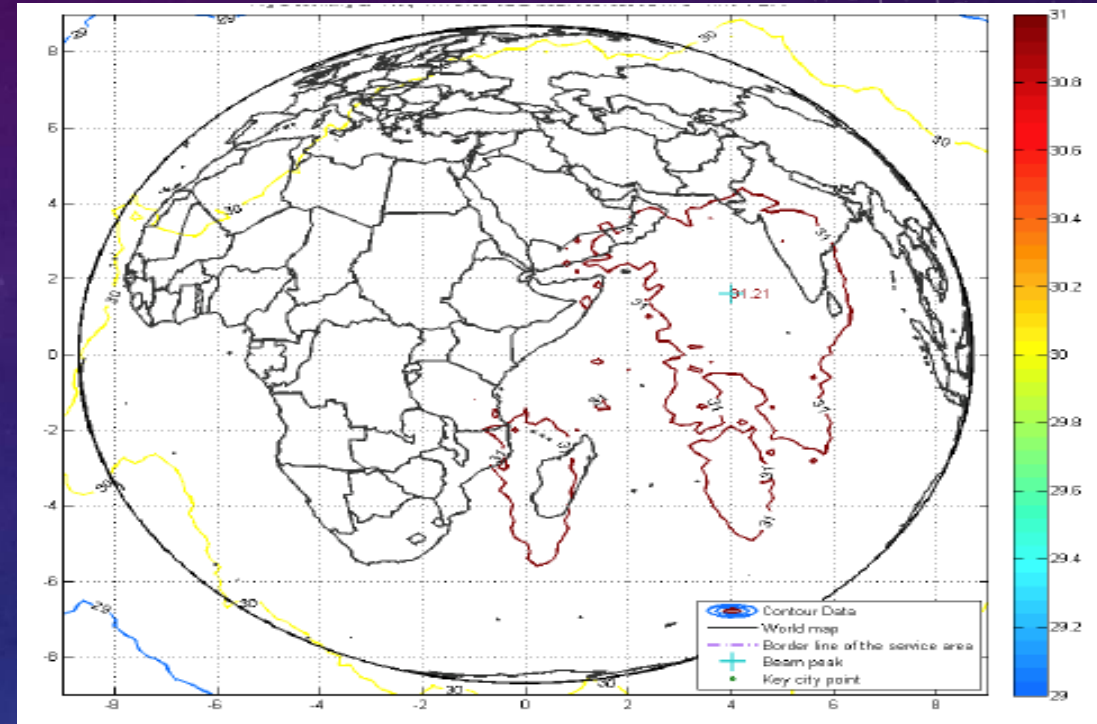


NIGCOMSAT Master Control Station with C-L Band Antenna Systems

NIGCOMSAT-1R NAVIGATION PAYLOAD: AFRICA'S CONTRIBUTION TO SBAS AND GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS).



The downlink coverage beam of NIGCOMSAT-1R
Geo-Navigation Satellite on L1 Frequency



The downlink coverage beam of NIGCOMSAT-1R
Geo-Navigation Satellite on L5 Frequency

Channel	Frequency (MHz)	Polarization	Bandwidth (MHz)
L1-Downlink	1575.42	RHCP	4
L5-Downlink	1176.45	RHCP	20

CHALLENGES AND EXPLOITATION OF NATIONAL & MULTILATERAL COOPERATION AS A MEANS OF OVERCOMING CHALLENGES AND AS WELL DRIVE ACCEPTANCE AND ADOPTION OF SBAS IN AVIATION AND NON-AVIATION SECTOR.

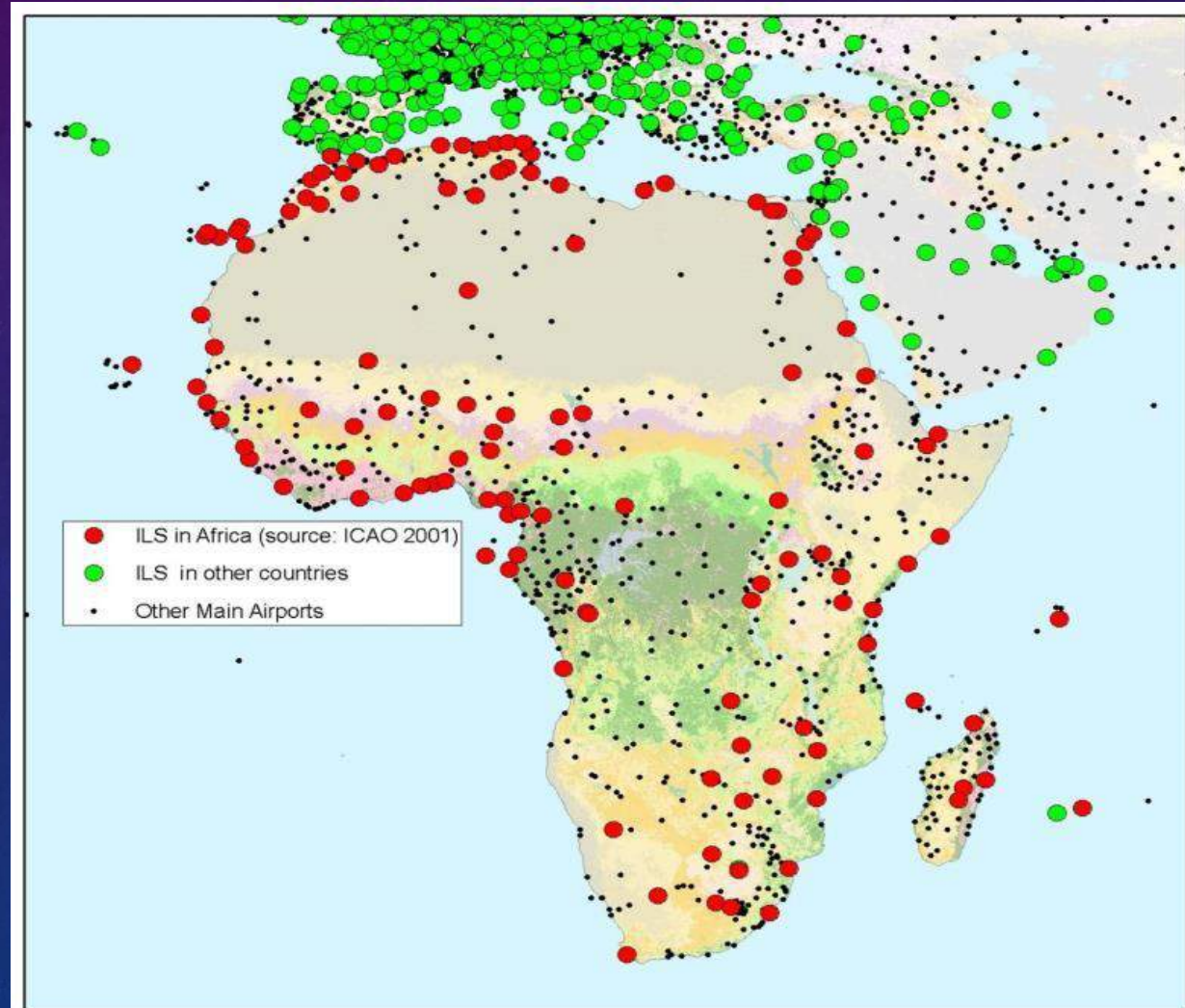
There is socio-economic and market potential in Africa as validated by viability and needs assessment of NIGCOMSAT project, validated by stakeholders as it concerns Aviation sector, non-aviation sectors such as maritime, survey, civil engineering, national security challenges, public safety needs, research and studies. However there is a huge GNSS/SBAS infrastructural gap and fund to build necessary ground infrastructure and reference stations to utilize the navigation satellite services and thus need for national and multilateral cooperation with partners to get SBAS system off the ground with sensitization exercise and demonstrations for SBAS acceptance and adoption at continental level.

MULTILATERAL COOPERATION EFFORTS

- In October, 2016 China Great Wall Industry Corporation and Spacestar Technology Company Ltd of China entered into cooperative agreement with Nigerian Communications Satellite Ltd on a Satellite-Based Augmentation System (SBAS) test bed phase trial covering performance test and assessment of the Nigerian Communications Satellite (NIGCOMSAT-1R) augmentation System exploiting NIGCOMSAT-1R L Band. The conducted tests were successful in validation of functional requirements, performance validation of sub-systems and systems of the SBAS payload.
- On the 13th of December 2018, the management of NIGCOMSAT Limited entered into cooperative agreement with Thales Alenia Space (TAS) with ASECNA as potential end-user in the aviation sector. We commenced integration with support ground equipment worth 400,000 euros followed by test and characterization of NigComSat-1R L-Band payload.

NEEDS ASSESSMENT OF SBAS IN AFRICA (AVIATION SECTOR)

In aviation, the instrument landing system (ILS) is a radio navigation system that provides short-range guidance to aircraft to allow them to approach a runway at night or in bad weather safely.



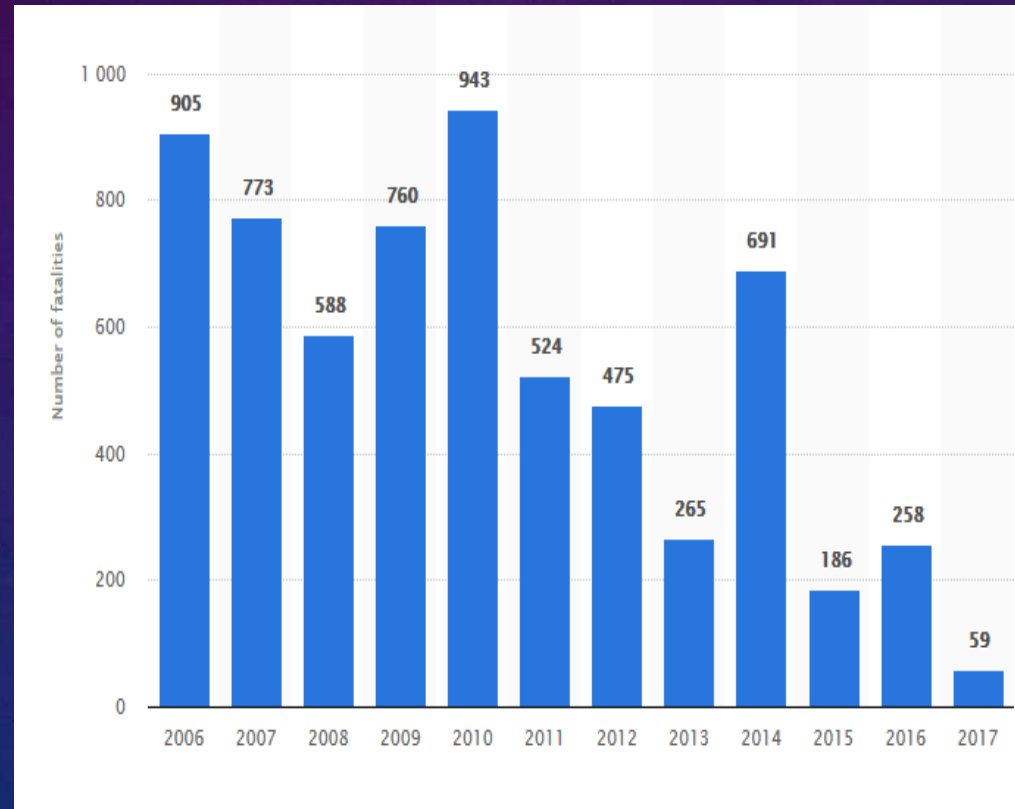
NEEDS ASSESSMENT OF SBAS IN AFRICA (AVIATION SECTOR)

- Less than 20% of Runways are equipped with Instrument Landing Systems (ILS) in Africa.
- 2011-2015 [IATA annual review 2016] Controlled Flights into Terrain (CFITs) = 20% of fatalities, most of them occurring in the approach/landing phase and being often associated with imprecise approach.
- SBAS helps overcome known safety and operational limitations of the technical constraints of lateral navigation (LNAV) and Vertical Navigation (VNAV) operations.
- Reduced maintenance Costs of Legacy Systems and calibration requirements

AIRPLANE CRASH/FATALITIES BY PHASE OF FLIGHT STATISTICS

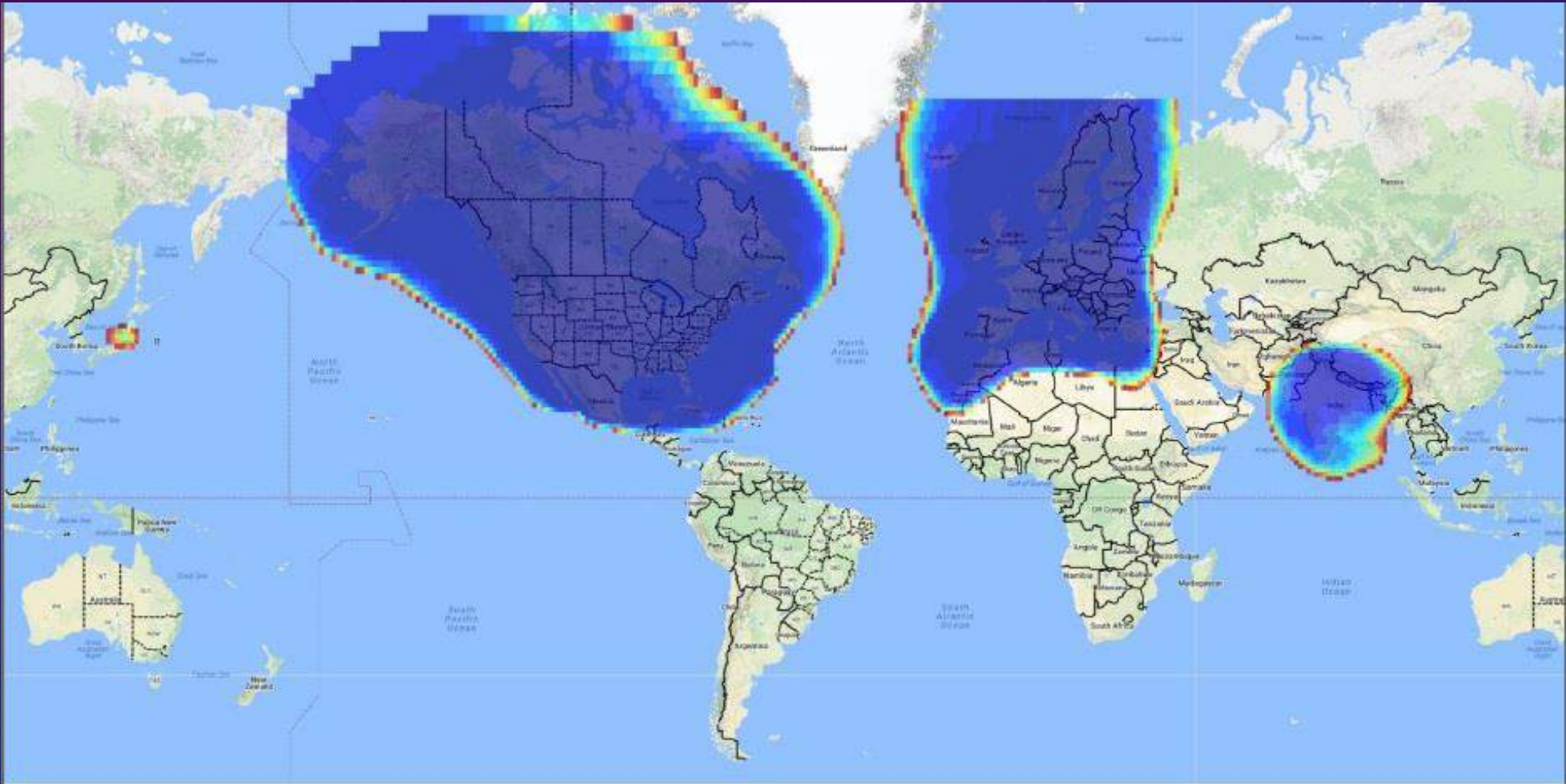
- Odds of being killed on a single airline flight 1 in 29.4 million
- Number of fatalities per million flight hours 12.25
- Survival rate of passengers on a fatal crash 24 %
- Fatalities by Phase of Flight
 - ❖ 0% during Taxi, load/unload, parked, tow
 - ❖ 16 % during Take-offs
 - ❖ 14% during Climb (flaps up)
 - ❖ 13% during Initial Climb
 - ❖ 16% during Cruise
 - ❖ 4% during Descent
 - ❖ 37 % during Initial Approach (12%), Final Approach (13%), & Landing (12%)

WORLDWIDE AIR TRAFFIC FATALITIES FROM 2006 TO DECEMBER 21, 2017



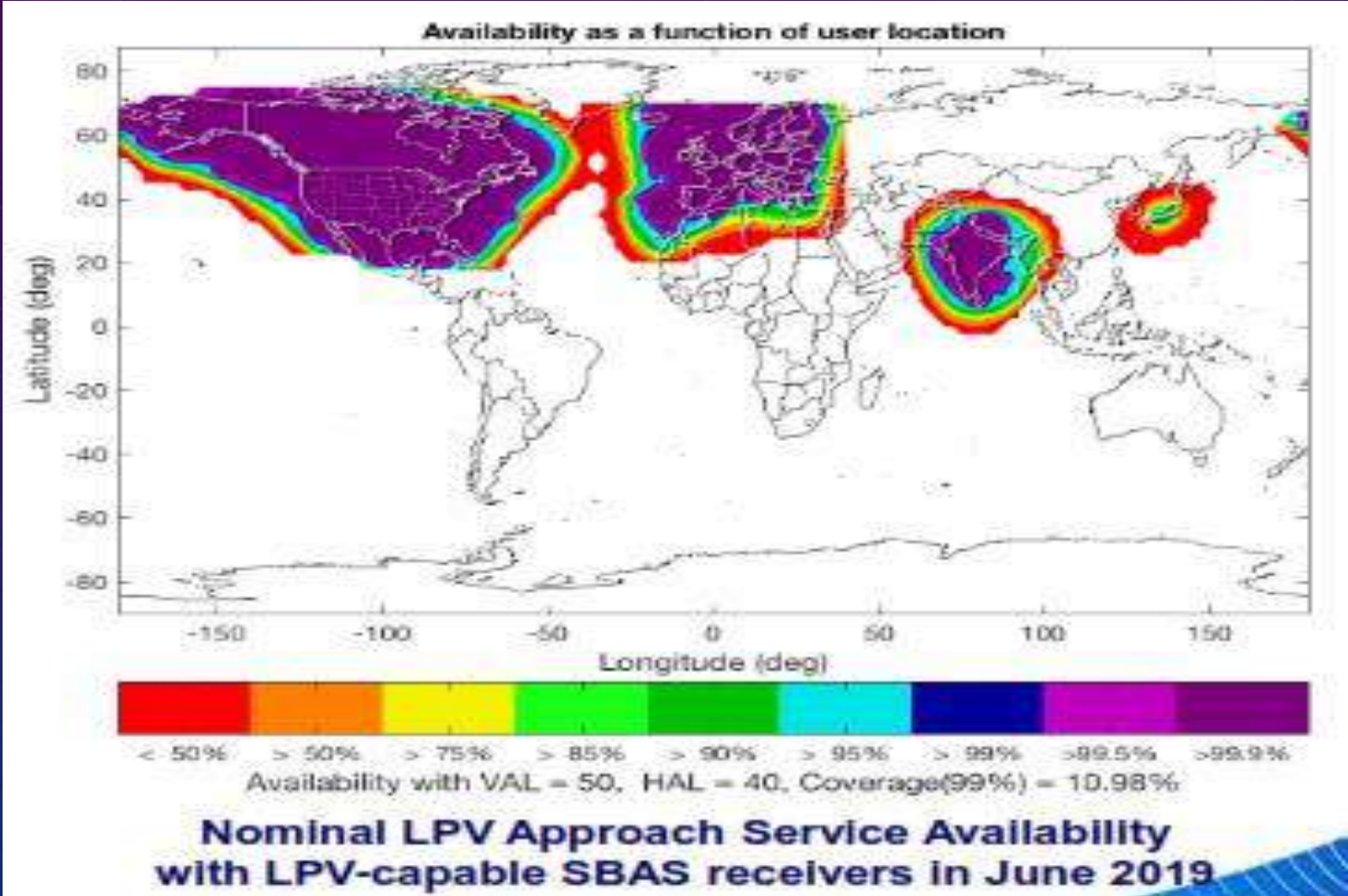
Source: <https://www.statista.com/statistics/263443/worldwide-air-traffic-fatalities/>

SBAS DEVELOPMENT: APPROACH COVERAGE MAY 1, 2016

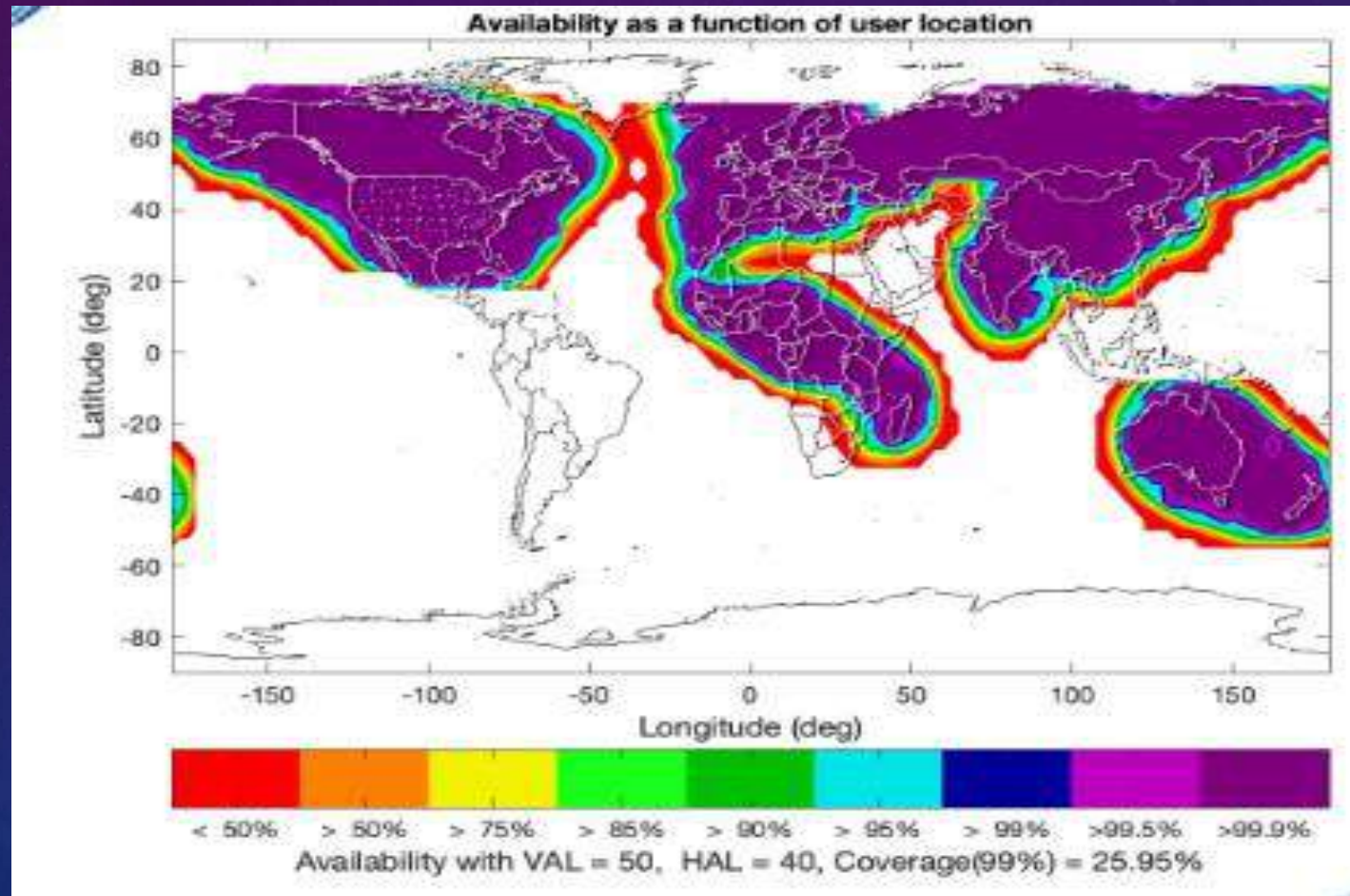


COURTESY OF FAA TECH CENTER

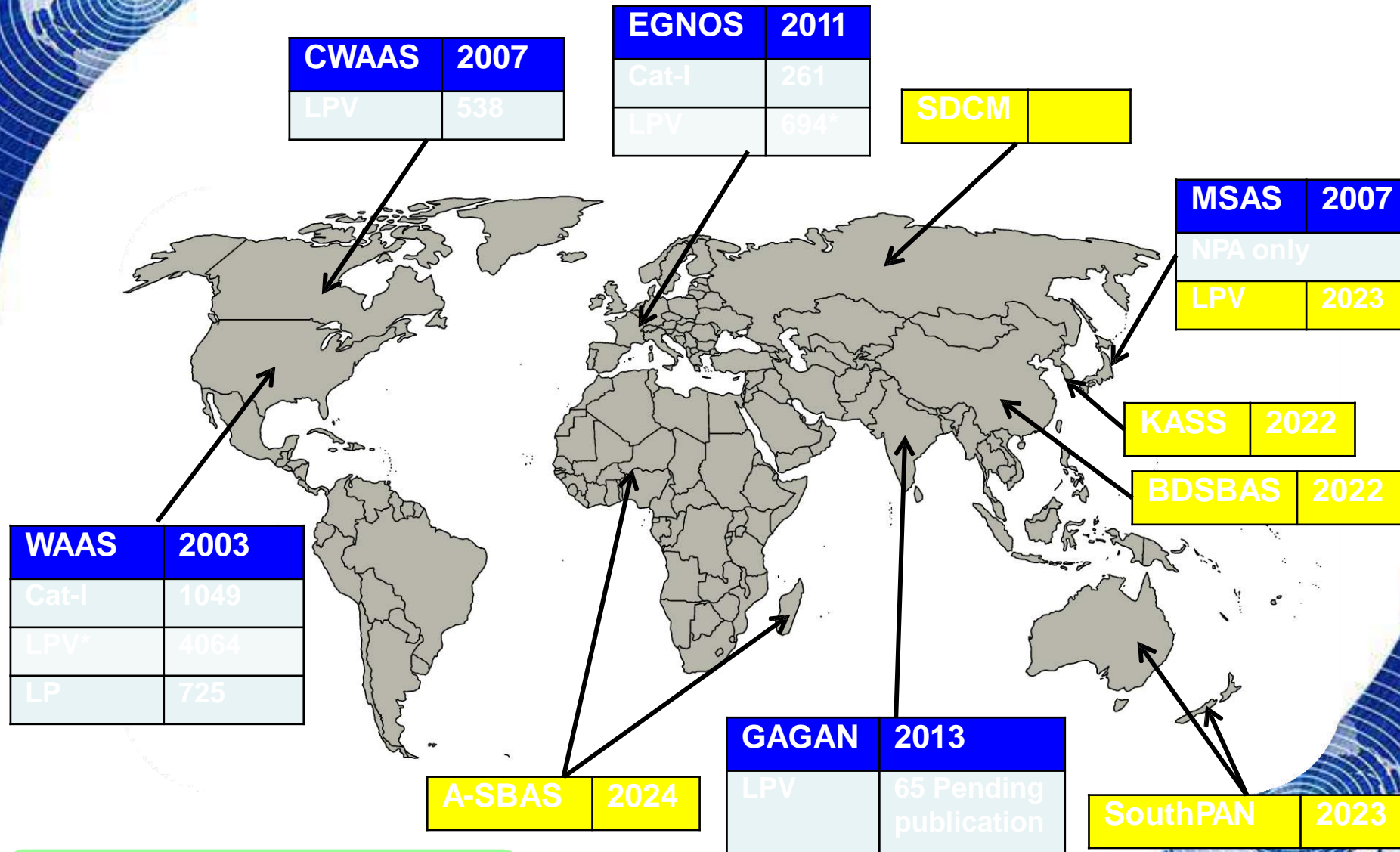
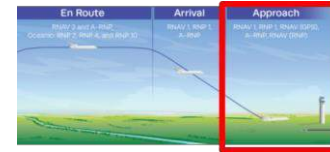
SBAS DEVELOPMENT: APPROACH/LANDING SERVICES AS AT JUNE, 2019.



SBAS DEVELOPMENT: PLANNED SBAS SERVICES WITHIN THE NEXT 4 YEARS



SBAS Services



Operational	Planned year
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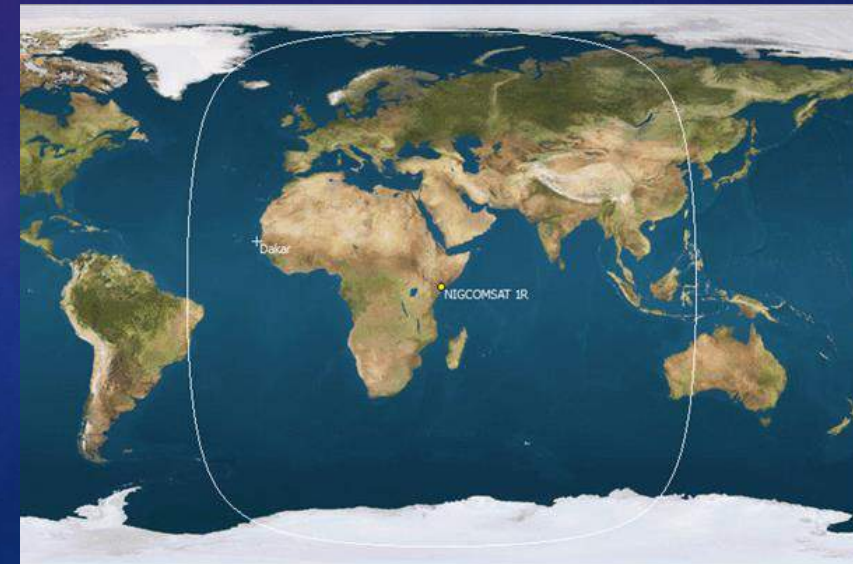
SBAS SIGNAL BROADCAST AND DEMONSTRATION EFFORTS IN AFRICA

- SBAS (Satellite-Based Augmentation System) signal broadcast over Africa & Indian Ocean (AFI) region began since September 2020, providing the first SBAS open service in this part of the world via NIGCOMSAT-1R Satellite.
- On the 27th of January 2021 a series of 5 flight demos at Lomé International Airport was conducted. The goal was to show in real configuration the efficiency of the technology developed in the frame of the early open service as part of the SBAS for Africa & Indian Ocean.
- The aim of the experiment was to demonstrate the ability of the system to allow landings on the two ends of the runway without deployment of local ground infrastructure and with a performance level close to the use of Instrument Landing Systems (ILS). It demonstrates the benefits of the future operational safety-of-life SBAS services, expected from 2024, in terms of flight safety, efficiency and of environmental protection.
- The outcomes of demonstrations and sensitization exercise, is a crucial step forward in the adoption, provision and use of satellite navigation services in the African region and surrounding waters.

FIELD DEMONSTRATION TO DRIVE ACCEPTANCE AND ADOPTION IN AFRICA.

INFRASTRUCTURE DEPLOYED FOR THE DEMO

- ✓ Extended SAGAIE GNSS stations.
- ✓ Representative system prototype deployed in Dakar.
- ✓ Uplink station in Abuja and NigComSat-1R Navigation Payload

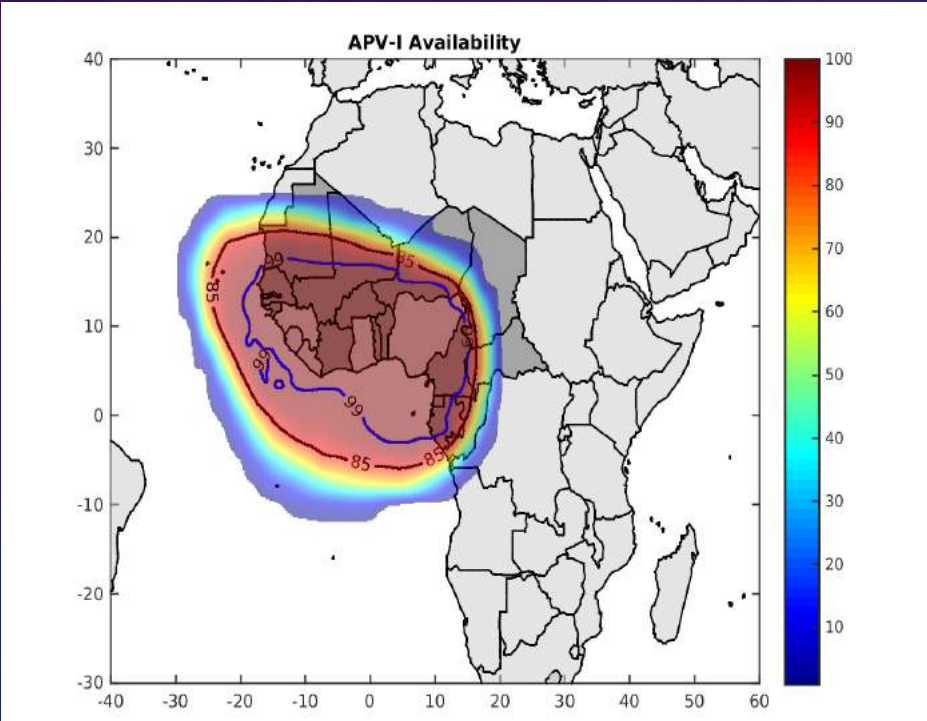


FIELD DEMONSTRATION TO DRIVE ACCEPTANCE AND ADOPTION IN AFRICA.

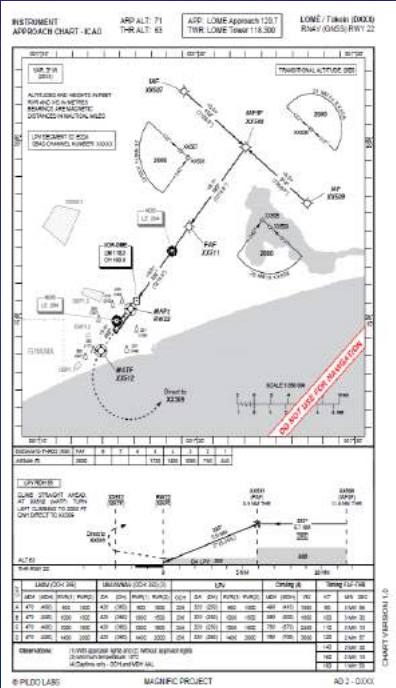
We began broadcast of a SBAS (Satellite-Based Augmentation System) signal over Africa & Indian Ocean (AFI) region since September 2020, providing the first SBAS open service in this part of the world via NIGCOMSAT-1R Satellite



RWY 22 at Lome International Airport, TOGO



APV-1 availability (05/10/2020)



OPERATIONAL BENEFITS OF SBAS

- Approach with vertical geometric guidance on non-instrumented runways
- Lower minima compared to Non-Precision Approach (NPA)
- Better stability than Instrument Landing System (ILS)
- SBAS performance is not sensitive to temperature fluctuations and has no barometric or temperature limitations.
- Performance not impacted by barometric pressure, temperature fluctuations or barometric mis-setting.
- SBAS provides benefits beyond aviation to all modes of transportation. i.e maritime, railroads, inland waterways etc.
- SBAS provides not just approach capability but en-route capability.
- SBAS does not require the installation or maintenance of ground-based navigation aids or landing systems.

OTHER BENEFITS OF SBAS AS IT CONCERNS IMPROVEMENT OF SAFETY AND REDUCTION IN OPERATIONAL COSTS AND ENVIRONMENT.

- Reduced Controlled Flight into Terrain (CFIT) risk/accident
- Reduced delays, diversions and cancellations due to weather conditions
- Reduced flight times
- Reduced fuel consumption
- Reduced CO2 and Noise emissions
- Reduced Flight crew workload by eliminating RAIM prediction requirements. RAIM=Receiver Autonomous Integrity Monitoring.
- Increases Airspace capacity.

FEEDBACK FROM PILOTS ON SBAS FLIGHT DEMONSTRATION CARRIED OUT ON 27TH JANUARY, 2021 AT LOME INTERNATIONAL AIRPORT.



‘SBAS can revolutionise navigation for the approach phase’

Capt. Patrice Moevi



‘SBAS means flight safety through approaches with minima equivalent to ILS CAT-1 everywhere at all times’

Capt. Zouel Bayli



HELICOPTER DEMONSTRATION FLIGHT BETWEEN DOUALA AND KRIBI IN CAMEROON ON 2ND JUNE, 2021



The helicopter demonstration flight was conducted along a low-level, two-way route linking two Point in Space (PinS) approaches to the Douala airport and a point near the oil platforms located on the Kribi coast, both in Cameroon. The flight was performed using a helicopter provided by Heli Union and an SBAS validation receiver from Pildo Labs. The aim of the experiment was to demonstrate the ability of the SBAS system to improve the safety of satellite navigation for helicopters through increased GNSS performance as regards flight safety, efficiency & environmental protection for enroute navigation as well as landing/approach phase.



AVIATION

- Exponential development of SBAS services in the world and widely acknowledged by airspace users.
- Most aircrafts expected to be SBAS capable from 2030. However, retrofit solutions are currently available at lower cost.
- Reduced and simplified equipment on board aircraft: SBAS airborne equipment acquisition, integration and installation costs is very minimal.
- Flight crew training costs (≈ 0).
- SBAS services expected from 2024 based on ASECNA strategy (Francophone countries in Africa).
- This is a potential for progressive coverage of the continent



The background features a dark blue gradient with faint, light blue technical diagrams. On the left side, there is a large circular scale with numerical markings from 140 to 260 in increments of 10. Several circular gauges and dashed lines with arrows are scattered across the scene, suggesting a technical or engineering context.

APPLICATIONS AND SOLUTIONS IN NON-AVIATION SECTOR

SBAS/GNSS APPLICATIONS



OTHER GNSS/SBAS APPLICATIONS:

The SBAS demonstration at Brazzaville, Republic of Congo between July 6 to 9, 2021 was in Non-Aviation sector delivering precise point positioning (PPP) to centimeter level.

The national stadium Alphonse Massamba-Debat employing a dual-frequency GNSS chipset receiving GPS and Galileo signals. The SBAS demo corrections improved positioning from 3-10metres to to centimetric level: 5 cm (East), 6.1 cm (North) and 14.4 cm (Up) with 68% confidence level. To show the improved accuracy, the demonstration device followed the marking of the football stadium as below: Football Stadium [Video Link](#).



OTHER GNSS/SBAS APPLICATIONS:

The demonstration with our partners showed system's ability to achieve positioning accuracy to within centimeters across the entire African continent. A world first, this satellite service paves the way for applications in a broad range of sectors, including precision agriculture, land and maritime transport, rail safety, drone navigation, mapping and surveying, mass-market applications etc.

We also demonstrate special urgent warning alert service via satellite showing system's ability to broadcast a warning message via SBAS signal to mobile phones, without requiring a terrestrial network. This service sends a message to the populations concerned, providing information on the type of danger and instructions to be followed. A typical example is warning alert for forest fires, landslide, terror raids etc.

OTHER GNSS/SBAS APPLICATIONS:

- Security of National Infrastructure: Pipelines, Power Lines, Gas Reservoirs, Strategic national Infrastructure.
- Improved Agricultural Practice with high yield.
- Improved Emergency Services, Recovery Services, Search & Rescue: NEMA, Fire Fighters, FRSC etc
- Utility Management: Energy and Communications Company for timing & synchronization.
- Geographic Information System Companies
- Tourism
- Telematic Services i.e Insurance Companies
- Environmental Protection, Characterization and Demography
- Paramilitary Organizations, Security Agencies etc
- Scientific Research

CONCLUSION

- *SBAS adoption in Aviation sector in Africa aligns with the Single African Air Transport Market (SAATM) agenda of African Union (AU); a flagship project of the AU agenda 2063 to advance the liberalization of civil aviation in Africa through a unified sky and acting as an impetus to the continent's economic integration agenda.*
- *Exponential development of SBAS services is ongoing worldwide and Africa as a continent should not be left out.*
- *'Commercial Aircraft are 5 times more likely to have an accident flying a non-precision approach than flying a precision approach'*
Flight Safety Foundation; March, 1996.

CONCLUSION

- *Considering the onboard navigation payload asset of NIGCOMSAT-1R, we will continue to do all that is required to demonstrate and showcase the capabilities of SBAS not only in Aviation sector but also Non-Aviation sector to drum up the required resources by stakeholders to adopt SBAS for its many benefits and applications in Africa.*
- *This is in line with policy direction of the Honorable Minister of Communications and Digital Economy of Federal Republic of Nigeria; Dr. Isa Ali Ibrahim (Pantami) FNCS, FBCS, FIIM that NIGCOMSAT-1R should be utilized for value addition and propensity not only in the Telecommunications Sector but Aviation, Maritime, Rail Transport, Precision Agriculture, Survey, Oil & Gas and Mass-Market Applications for sustainable development beyond Nigerian shores.*

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