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Government of India
Department of Space
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Antariksh Bhavan,
New BEL Road,
Bengaluru – 560 094

July 29, 2021

Subject : Indian Satellite Navigation Policy-2021 (SATNAV Policy-2021) – Hosting in public domain for comments/suggestions – reg.

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Department of Space being the administrative Ministry/Department in respect of space activities in India as per the allocation of Business Rules of Government of India, shall issue appropriate norms, guidelines and procedures including approval-mechanism from time to time for the services in satellite navigation and augmentation system along with possibility of promoting & fostering participation of Indian entities to carry out research and development activities in the field of satellite navigation.

Accordingly, the draft "Indian Satellite Navigation Policy-2021 (SATNAV Policy-2021)" is hosted in website for public consultation.

Comments on the draft policy, if any, shall be forwarded to this Department to the email id :- ***dir.projects@isro.gov.in*** at the earliest, but not later than **29.08.2021.**

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# Indian Satellite Navigation Policy – 2021

## (SATNAV Policy – 2021)

*(Draft)*

*July 2021*

**Department of Space**
**Antariksh Bhawan**
**New BEL Road**
**Bengaluru – 560 094**

# Indian Satellite Navigation Policy – 2021
# (SATNAV Policy – 2021)

## Preamble

Over the last few decades, there has been a phenomenal growth in the number of applications that rely on Position, Velocity and Time (PVT) services provided by space based navigation systems. With the advent of information and mobile phone technology, crores of users across India rely heavily on PVT based applications in virtually every walk of life.

Global Navigation Satellite Systems (GNSS) are space based navigation systems that provide navigation signals across the globe. Currently, there are four GNSS viz., GPS from USA; GLONASS from Russia; Galileo from European Union & BeiDou from China; offering PVT solution globally. In addition, there are two regional navigation satellite systems viz., NavIC from India and QZSS from Japan offering navigation signals for the defined coverage area.

The Navigation signals are offered free-to-air for a variety of applications ranging from air, space, maritime and land applications covering tracking, telematics, location based services (using cell phone and mobile devices), automotive, survey, mapping & GIS and timing.

GNSS also offer secured navigation signals exclusively for strategic applications of their respective countries as the free-to-air signals are susceptible to adversaries. There is a need for such secured services exclusively for the Indian strategic community also. The Government of India has therefore, established a resilient and independent system – Navigation with Indian Constellation (NavIC). This system is totally under the control of Government of India.

Satellite based augmentation systems (SBAS) augment navigation satellite constellations by providing integrity and correction information via geostationary satellites. WAAS of USA, EGNOS of European Union, SDCM of Russia, SNAS/BDSSBAS of China offer these services in their defined coverage area. Government of India has also established a similar SBAS system viz., GPS Aided Geo Augmented Navigation-(GAGAN) for the Indian airspace.

Space based navigation /augmentation system is essentially a public good which has to be accessible to all users. Such a national infrastructure can only be provided by the Government. Further, to strengthen Government's initiative of आत्मनिर्भर भारत (*Atmanirbhar Bharat*), it is essential to ensure continuity of NavIC and GAGAN services, upgrade the system considering the exponential technological advancements and also continue having the capability to operate in conjunction with other GNSS/SBAS.

Considering the above, it is pertinent to devise a comprehensive and substantive national policy for satellite based navigation. The Indian Satellite Navigation Policy – 2021

(SATNAV Policy – 2021) has been formulated towards effective development, operation and maintenance of satellite based navigation system and is stated hereunder.

**Policy Statement**

***"Achieve self-reliance in satellite based navigation and augmentation services with emphasis on assuring availability & quality, enhancing usage, working towards progressive evolution of the services and promoting research & development"***

The following are the objectives towards achieving the policy goal:

1. Ensure guaranteed and continuous availability of free-to-air navigation signals for civilian uses and secured navigation signals for strategic uses in the defined coverage area.
2. Ensure guaranteed and continuous availability of Satellite Based Augmentation System (SBAS) for aviation safety in the defined coverage area.
3. Ensure judicious dissemination of Signal-In-Space (SIS) interface definition and system performance reports for the intended use.
4. Work towards progressive evolution of navigation signals and expansion of coverage for enhanced use.
5. Focus on technology development for enhancing the navigation satellite systems.
6. Work towards compatibility and interoperability of Indian satellite navigation and augmentation signals with other GNSS/SBAS signals.
7. Promote Indian Industry and academia to carry out research and development activities in the field of satellite navigation based applications with emphasis on societal benefits.
8. Work towards facilitating global usage of Indian satellite navigation and augmentation systems.

Department of Space, being the administrative Ministry for space activities under Government of India, shall issue appropriate norms and guidelines from time to time for the services rendered using Indian satellite navigation system.

Further, Department of Space shall put in place mechanisms to promote the participation of NGPEs, state government bodies, non-government bodies and academia towards creating ecosystem built using Indian satellite navigation system which are socially and economically beneficial.

Accordingly, Indian Satellite Navigation Policy – 2021 and its objectives are issued that shall come into effect, upon approval of the Cabinet.

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# Indian Satellite Navigation Policy – 2021

# [SATNAV Policy – 2021]

# (Draft)

# Indian Satellite Navigation Policy – 2021

# [SATNAV Policy – 2021]

# (Draft)

**July 2021**

**Department of Space**
**Antariksh Bhawan**
**New BEL Road**
**Bengaluru – 560 094**

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## Important Terms

"**Accuracy**" refers to the degree of conformance of a position/velocity/time estimated or measured with the true position, velocity and/or time.

"**Augmentation**" refers to space and/or ground-based systems that provide users of space-based positioning, velocity and timing signals with additional information that enables users to obtain enhanced performance when compared to the un-augmented space-based signals alone. These improvements include better accuracy, availability, integrity, and reliability; with independent integrity monitoring and alerting capabilities for critical applications.

**"Availability"** refers to the percentage of time that the services of the system are usable by the navigator.

"**Compatibility**" refers to the ability of global and regional navigation and augmentation system to be used separately or together without causing unacceptable interference and/or other harm to an individual system and/or service;

"**Continuity**" refers to the ability of the total system to perform its function without interruption during the intended operation. More specifically, continuity is the probability that the specified system performance will be maintained for the duration of a phase of operation, presuming that the system was available at the beginning of that phase of operation.

"**Coverage**" refers to the surface area or space volume in which the signals are adequate for the user to determine position to specified level of accuracy.

"**GAGAN**" stands for 'GPS Aided GEO Augmented Navigation' which is the space based augmentation system developed to provide GPS augmentation services in the Indian region.

**"GNSS"** stands for 'Global Navigation Satellite System' referring to space-based positioning and navigation systems designed to provide worldwide, all weather, passive, three-dimensional position, velocity and timing data.

**"Geostationary orbit"** is a circular orbit 35,785 km above Earth's Equator in which a satellite's orbital period is equal to Earth's rotation period. A spacecraft in this orbit appears to an observer on Earth to be stationary in the sky.

"**Geosynchronous orbit**" refers to an Earth-centered orbit with an orbital period that matches Earth's rotation period (one sidereal day). The synchronization of rotation and orbital period means that, for an observer on Earth's surface, an object in geosynchronous orbit returns to exactly the same position in the sky after a period of one sidereal day.

"**Interoperability**" refers to the ability of global, regional navigation and augmentation systems and the services they provide to be used together to provide better capabilities at the user level than would be achieved by relying solely on the open signals of one system.

**"Integrity"** is the measure of trust that can be placed in the correctness of the information supplied by a navigation system. Integrity includes the ability of the system to provide timely warnings to users when the system or some of its elements should not be used for navigation.

"**NavIC**" stands for 'Navigation with Indian Constellation' which is the navigation satellite system independently developed by India to provide positioning, velocity and timing services;

"**Navigation satellite system**" refers to a system consisting of a constellation of navigation satellites with global or regional coverage and its supporting infrastructure designed to provide all weather, passive, three-dimensional position, velocity and timing data.

**"PVT"** stands for 'Position, Velocity and Time' which is a solution derived by the user receiver using the navigation signals received from at least four satellites of one GNSS/Regional Navigation Satellite System.

**"Regional Navigation Satellite System"** means space-based positioning and navigation systems designed to provide all weather, passive, three-dimensional position, velocity and timing data within a defined regional coverage.

"**SBAS**" stands for 'Satellite Based Augmentation System' which refers to a space based system that augments navigation satellite constellations by providing integrity and correction information via geostationary satellites.

**"SIS"** stands for 'Signal in Space' which refers to the navigation signals broadcasted by GNSS satellites that are in turn used by the ground receiver to derive the PVT solutions.

**"Space Service Volume"** refers to the baseline performance of navigation signals in the region from low earth orbit to geosynchronous orbit altitude and beyond.

## 1 Introduction

1.1 Over the last few decades, there has been a phenomenal growth in the number of applications that rely on Position, Velocity and Time (PVT) services provided by space based navigation systems. With the advent of information and mobile phone technology, crores of users across India rely heavily on PVT based applications in virtually every walk of life.

1.2 Global Navigation Satellite Systems (GNSS) are space based navigation systems that provide navigation signals across the globe. Currently, there are four GNSS viz., GPS from USA; GLONASS from Russia; Galileo from European Union & BeiDou from China; offering PVT solution globally. In addition, there are two regional navigation satellite systems viz., NavIC from India and QZSS from Japan offering navigation signals for the defined coverage area.

1.3 The navigation signals are offered free-to-air for a variety of applications ranging from air, space, maritime and land applications covering tracking, telematics, location based services (using cell phone and mobile devices), automotive, survey, mapping & GIS and timing.

1.4 GNSS also offer secured navigation signals exclusively for strategic applications of their respective countries as the free-to-air signals are susceptible to adversaries. There is a need for such secured services exclusively for the Indian strategic community also. The Government of India has therefore, established a resilient and independent system –Navigation with Indian Constellation (NavIC). This system is totally under the control of Government of India.

1.5 Satellite based augmentation systems (SBAS) augment navigation satellite constellations by providing integrity and correction information via geostationary satellites. WAAS of USA, EGNOS of European Union, SDCM of Russia, SNAS/BDSSBAS of China offer these services in their defined coverage area. Government of India has also established a similar SBAS system viz., GPS Aided Geo Augmented Navigation-(GAGAN) for the Indian airspace.

1.6 Space based navigation /augmentation system is essentially a public good which has to be accessible to all users. Such a national infrastructure can only be provided by the Government. Further, to strengthen Government's initiative of आत्मनिर्भर भारत (Atmanirbhar Bharat), it is essential to ensure continuity of NavIC and GAGAN services, upgrade the system considering the exponential technological

advancements and also continue having the capability to operate in conjunction with other GNSS/SBAS.

1.7 The Indian Satellite Navigation Policy-2021 (SATNAV Policy – 2021) has been formulated with an aim to address and meet the growing demands of space based navigation and timing applications and advancements in the relevant technologies for self-sustenance in areas of commercial, strategic and societal applications to maximise the socio-economic benefits.

## 2 Policy Statement

***"Achieve self-reliance in satellite based navigation and augmentation services with emphasis on assuring availability & quality, enhancing usage, working towards progressive evolution of the services and promoting research & development"***

## 3 Objectives

3.1 Ensure guaranteed and continuous availability of free-to-air navigation signals for civilian uses and secured navigation signals for strategic uses in the defined coverage area.

3.2 Ensure guaranteed and continuous availability of Satellite Based Augmentation System (SBAS) for aviation safety in the defined coverage area.

3.3 Ensure judicious dissemination of Signal-In-Space (SIS) interface definition and system performance reports for the intended use.

3.4 Work towards progressive evolution of navigation signals and expansion of coverage for enhanced use.

3.5 Focus on technology development for enhancing the navigation satellite systems.

3.6 Work towards compatibility and interoperability of Indian satellite navigation and augmentation signals with other GNSS/SBAS signals.

3.7 Promote Indian Industry and academia to carry out research and development activities in the field of satellite navigation based applications with emphasis on societal benefits.

*3.8* Work towards facilitating global usage of Indian satellite navigation and augmentation systems.

Department of Space, being the administrative Ministry for space activities under Government of India, shall issue appropriate norms and guidelines from time to time for the services rendered using Satellite Navigation.

The objectives are elaborated in the following sections.

## 4 Satellite based Navigation System

*"Ensure guaranteed and continuous availability of free-to-air navigation signals for civilian uses and secured navigation signals for strategic uses in the defined coverage area"*

4.1 ISRO/DOS shall ensure nominal operation and maintenance of existing NavIC space segment and also ensure adequate measure in place to realise sufficient spare satellites to meet the nominal end-of-life replacement and/or any exigency arising due to unforeseen failure in the in-orbit satellites. (ISRO/DOS has established a regional navigation satellite system viz., NavIC which is described in §1 of Annexure.)

4.2 ISRO/DOS shall ensure flexibility of incorporating new navigation signals/services in the space segment in addition to the broadcast of legacy navigation signals and to cater to national needs as deemed necessary.

4.3 ISRO/DOS shall diligently plan towards upgradation / replacement / augmentation of ground segment without affecting the services being rendered.

4.4 ISRO/DOS shall ensure protection for the frequency allocated towards operation of space and ground segment, including the broadcasted navigation signals.

4.5 ISRO/DOS shall restrict access to space and ground infrastructure only to authorized personnel. A risk mitigation plan shall be devised and implemented to protect the infrastructure from any security threats.

4.6 ISRO/DOS shall devise a mechanism to assist strategic users in development of specific techniques to ensure protection against and to mitigate the possible threats on usage of secured navigation signals of NavIC.

## 5 Satellite Based Augmentation System (SBAS)

*"Ensure guaranteed and continuous availability of Satellite based Augmentation System (SBAS) for aviation safety in the defined coverage area "*

5.1 ISRO/DOS shall ensure nominal operation and maintenance of existing GAGAN space segment. In order to ensure seamless continuity of GAGAN service, ISRO/DOS shall have adequate measures in place to realise a GAGAN payload on a suitable satellite to meet the nominal end-of-life replacement and/or any exigency arising due to unforeseen failure in the in-orbit GAGAN payload/satellite. (ISRO/DOS and Airport Authority of India have jointly established a Satellite Based Augmentation System (SBAS) viz., GAGAN which is described in §2 of Annexure.)

5.2 GAGAN services are currently being rendered from three GEO satellites. Considering possible scope of enhancement in terms of wide area (continental level) coverage, ISRO/DOS shall assess the number of GAGAN payloads that are required to be operational simultaneously either from different GEO satellites or from non-GEO satellites as deemed necessary.

5.3 ISRO/DOS shall develop a mechanism of along with the GAGAN augmentation signals shall evolve to support dual-frequency signals from multiple GNSS.

5.4 ISRO/DOS shall develop a mechanism involving the concerned stakeholders for extending the utility of GAGAN for non-aviation related applications.

5.5 ISRO/DOS and the concerned stakeholder(s) shall evolve a mechanism for strict control of the critical information regarding the operation of the space and ground segment to protect the augmentation system.

5.6 ISRO/DOS and the concerned stakeholder(s) shall restrict the access to space and ground infrastructure only to authorized personnel. A risk mitigation plan shall be devised and implemented to protect the infrastructure from any security threats.

## 6 Dissemination of Signal-In-Space (SIS) interface definition

*"Ensure judicious dissemination of Signal-In-Space (SIS) interface definition and system performance reports for the intended use."*

6.1 ISRO/DOS shall continue to ensure that SIS interface definition of free-to-air navigation signals and information related to performance of free-to-air signal transmission is available in public domain to enable development of civil application. (ISRO/DOS currently provides the above information in public domain, which is described in §3 of Annexure.)

6.2 ISRO/DOS shall release in public domain the performance parameters of free-to-air navigation signals periodically and the navigation satellite system operational advisories, if any, as and when it occurs.

6.3 ISRO/DOS along with the identified agency/agencies shall devise a mechanism for dissemination of secured signals' SIS interface definition to protect the confidentiality during development, production and operational phase of the receivers.

## 7 Progressive Evolution of Navigation Signals and Expansion of Coverage

*"Work towards progressive evolution of navigation signals and expansion of coverage for enhanced use."*

7.1 ISRO/DOS shall devise a mechanism to adopt advanced techniques in the realisation of navigation signals considering the technological trends and ensure compatible with legacy systems.

7.2 ISRO/DOS, in addition to the PVT services, shall plan for having signals to support allied services, such as, search & rescue, emergency warning system, high accuracy services, etc...

7.3 The current navigation signals primarily cater to the users within the defined coverage area on Earth. ISRO/DOS shall also work towards making the navigation signals capable for supporting space service volume.

7.4 ISRO/DOS shall work towards expanding the coverage from regional to global to ensure availability of NavIC standalone signal in any part of the world without relying on other GNSS and aid in wide utilisation of Indian navigation system across the globe.

## 8 Technology Development in the space based navigation system of India

*"Focus on technology development for enhancing the navigation satellite systems"*

8.1 While many of the space and ground based systems used for navigation and augmentation system are indigenously developed, ISRO/DOS shall put best efforts towards reduction of dependence on foreign imports.

8.2 ISRO/DOS share ensure that the ground systems are periodically augmented with state-of-the-art systems.

8.3 ISRO/DOS shall work towards harnessing the emerging technological advancements such as, highly stable clocks, artificial intelligence, machine learning, inter-satellite links, on-orbit re-programming of navigation signals, quantum communication, etc. in space segment

## 9 Compatibility and Interoperability

*"Work towards compatibility and interoperability of Indian satellite navigation and augmentation signals with other GNSS/SBAS signals."*

9.1 ISRO/DOS shall continue to work towards necessary coordination with ITU for frequency allocation for broadcasting navigation and augmentation signals. (The current practices of frequency coordination are described in §6 of Annexure.)

9.2 ISRO/DOS shall put continuous efforts towards ensuring the Indian navigation and augmentation signals compatible with other free-to-air navigation and augmentation signals. (The current practices of ensuring compatibility are described in §6 of Annexure.)

9.3 ISRO/DOS shall put continuous efforts towards ensuring the Indian navigation and augmentation signals are interoperable with other free-to-air navigation and augmentation signals. (The current practices of ensuring interoperability are described in §6 of Annexure.)

9.4 ISRO/DOS shall engage in interactions with multilateral forums such as ITU, ICG, UNCOPUOS, ICAO, IMO, etc. and in bilateral forums to safeguard and to further the interests of Indian navigation and augmentation signals. (Some of the major bi-lateral/multi-lateral forums are described in §6 of Annexure.)

## 10 Role of Indian Industry and Academia in Satellite Navigation Services and Applications

*"Promote Indian Industry and academia to carry out research and development activities in the field of satellite navigation based applications with emphasis on societal benefits."*

10.1 ISRO/DOS shall put in place mechanisms to promote the participation of NGPEs, state government bodies, non-government bodies and academia towards creating ecosystem built using Indian satellite navigation system which are socially and economically beneficial.

10.2 ISRO/DOS, in consultation with the Central /State ministries, shall identify applications for societal benefits using Indian satellite navigation system, shall execute proof of concept demonstration/pilot projects and shall eventually enable Indian industry for productionisation.

10.3 ISRO/DOS shall provide technical support for academic institutions in the field of GNSS research and applications.

10.4 ISRO/DOS shall constantly endeavour to encourage all the concerned Central/State Ministries towards utilisation of NavIC applications with a view to promote the Indian industry engaged in developing indigenous NavIC based solutions.

10.5 ISRO/DOS shall organise regular interactions among users, industry and academia to synergise their research & development activities and end use deployment.

10.6 ISRO/DOS shall organise / aid in organising outreach events such as, exhibitions, webinars, trainings etc. create awareness of Indian satellite navigation systems and capabilities. ISRO/DOS shall organise hackathons towards innovative problem solving and new applications using satellite navigation.

10.7 ISRO/DOS shall work with concerned ministries/departments to introduce specialisation courses on satellite navigation in academic institutions so as to develop indigenous expertise in the field of satellite navigation.

10.8 ISRO/DOS shall explore possibilities of international collaboration to evolve satellite navigation based applications for societal benefits and aide in promoting Indian Industry /academia to support these endeavours.

## 11 Facilitating Global Usage of NavIC & GAGAN

*"Work towards facilitating global usage of Indian satellite navigation and augmentation systems"*

11.1 ISRO/DOS shall continue to work with Indian Standard Development Organisations (SDO) such as, Bureau of Indian Standards (BIS) and relevant international SDOs such as ISO, ICAO, IMO, IEC, 3GPP, RTCM, RTCA, NMEA, etc. to develop Indian and Global standards to enable Indian satellite navigation and augmentation based applications.

11.2 ISRO/DOS shall ensure representation of Indian satellite navigation and augmentation system in the relevant National and International Standard Development Organisation/ committees to safeguard the interests of Indian navigation and augmentation systems.

11.3 ISRO/DOS shall jointly work with concerned stakeholders from India towards the recognition of Indian satellite navigation and certification of augmentation system from International organisations like IMO, ICAO etc. where ever necessary.

** ** **

# Annexure

# to

# Indian Satellite Navigation Policy – 2021

# (Draft)

# 1 Satellite based Navigation System

Government of India has developed a Regional Navigation Satellite System, viz., NavIC (**Nav**igation with **I**ndian **C**onstellation), an all-weather space based navigation system operating within the specified coverage area. NavIC provides signals which can be used to accurately determine position, velocity, and time in a common reference frame on a 24x7 basis.

The NavIC system consists of Space Segment and Ground Segment

The space segment operates in conjunction with ground segment to enable the navigation services for the end user. ISRO/DOS is responsible for establishment and maintenance of both the space segment and ground segment;

The end use for satellite based navigation system is broadly classified as civilian and strategic.

## 1.1 Space Segment

NavIC space segment has been established by ISRO/DOS.

It comprises of a constellation of seven satellites located in various geo-synchronous orbits and is scalable to meet enhanced coverage requirements.

The use of orbital slots for the specific satellite mission is governed by International Telecommunication Union (ITU) Radio Regulation (RR). The orbital slots for NavIC satellites are informed, coordinated, notified and registered at ITU. Indian orbital resources are under the exclusive control of Government of India.

The Radio Frequencies currently being used by NavIC for broadcasting the navigation signals are filed a priori in the ITU and necessary approvals are in place.

## 1.2 Ground Segment

NavIC system comprises of the following ground systems established by ISRO.

1. Range and Integrity Monitoring Stations
2. Two-way Ranging Stations
3. Network Time Facility
4. Navigation Control Centre
5. Data Communication Network
6. Spacecraft Control Centre

These ground systems, established across India as well as beyond the Indian Mainland, are interconnected through terrestrial/satellite link to generate the navigation parameters and uplink them to NavIC space segment. The user receiver acquires these parameters from NavIC space segment for computing its own position.

The ground segment is operated on a 24x7 basis with sufficient redundancies supporting the satellite constellation.

## 2 Satellite Based Augmentation System (SBAS)

Government of India has developed a Satellite Based Augmentation System, viz., GAGAN (GPS Aided Geo Augmented Navigation) - an all-weather space based augmentation system operating within the specified coverage area.

The objective of GAGAN is to establish and deploy a certified satellite based augmentation system primarily for safety-of-life civil aviation applications catering to the Indian airspace.

GAGAN has been declared operational for safety-of-life application in civil aviation and a seamless operation of GAGAN system is being ensured. Efforts towards utilisation of GAGAN for non-aviation sector related applications are also being carried out.

The GAGAN system consists of space and ground segment. The space segment works in conjunction with ground segment to enable the augmentation services for the end use.

### 2.1 Space Segment

ISRO/DOS has established the space segment for GAGAN and is responsible for its operations and maintenance.

The space segment comprises of GAGAN payload accommodated on three satellites located in geo-stationary orbit.

The Radio Frequencies currently being used by GAGAN for space as well as ground segment for providing the augmentation services are filed in the ITU and necessary approvals are in place.

### 2.2 Ground Segment

Airports Authority of India (AAI) has established ground segment of GAGAN and is responsible for its operation and maintenance. Directorate General of Civil Aviation (DGCA) is the certifying authority for aviation use of the GAGAN system.

GAGAN system comprises of following ground systems established by Airport Authority of India.

1. Reference Stations
2. Master Control Station
3. Data communication network
4. Uplink Station

These stations collect and process navigation data from GPS to generate the correction messages and integrity information which are subsequently uplinked to the GAGAN satellites and transmitted by the satellites in L1 and L5-bands.

Currently, GAGAN is augmenting the navigation signals received from single frequency of GPS.

The GAGAN signal-in-space format complies with ICAO standards and recommended practices for satellite-based augmentation systems.

## 3 Dissemination of Signal-In-Space (SIS) interface definition

The satellite navigation and augmentation systems publish the detailed Signal-in-Space characteristics on their respective websites in the form of Interface Control Document (ICD) to enable industry in developing products and academia in pursuing Research & Development.

The performance parameters of free-to-air navigation signals are periodically shared in public domain to provide confidence in the satellite navigation system.

The Signal-in-Space Interface Control Document and performance report of NavIC are made available on ISRO website.

## 4 Progressive Evolution of Navigation Signals and Expansion of Coverage

In the past few decades, satellite navigation has been revolutionised in terms of coverage and accuracy. The emergence of multiple global constellations has significantly penetrated into various sectors working on PVT solutions.

In order to meet the demand for enhanced positioning performance arising due to continuous expansion of satellite navigation applications, GNSS systems worldwide are adopting latest techniques to improve the navigation signals.

The Indian satellite navigation system, NavIC is also continuously evolving by introducing new signals, capabilities and expansion of coverage area.

## 5 Technology Development in the space based navigation system of India

The technologies being used for space and ground segments of navigation and augmentation systems are developing continuously in terms of improved performance, reliability, efficiency etc...

The technology development in Indian satellite navigation and augmentation system is focussed on indigenisation, miniaturisation and improvement in performance of space and ground segments.

## 6 Compatibility and Interoperability

Navigation and augmentation satellite systems share the same radio frequency bands for broadcasting the navigation signals. The International Telecommunication Union (ITU) regulates the radio frequency allocation.

The navigation and augmentation satellite systems are being used separately or together without causing unacceptable interference and/or other harm to each other.

The interoperability of the signals broadcast from multiple GNSS constellations will result in improved signal availability, end-user accuracy in the environments where visibility satellites from a single constellation may be partly or wholly obscured. Therefore, the user receiver systems are now being designed for a multi-constellation system.

International Committee on GNSS (ICG) under United Nations Office for Outer Space Affairs (UNOOSA) provides a framework towards coordination among providers of satellite navigation and augmentation systems for ensuring compatibility and interoperability. In addition, International Civil Aviation Organization (ICAO) provides the forum to assure common understanding among the augmentation systems' service providers for implementation in aviation services

NavIC and GAGAN systems comply with the standards, practices, guidelines and regulations of ITU, ICG and ICAO.

## 7 Role of Indian Industry and Academia in Satellite Navigation Services and Applications

Over the years, ISRO/DOS has fostered a network with industry and academia to meet the needs of various fields of space technology/applications through inclusive and supportive efforts.

ISRO/DOS is also interacting with other user departments within Government for ensuring optimal utilisation of Indian space assets.

Government's initiatives like digital India, smart city, Make in India and other key flagship programmes has created opportunities for Indian Industry, start-ups and academia to work towards innovation in the field of satellite based navigation services.

## 8 Facilitating Global Usage of NavIC & GAGAN

Standards provide systematic guidelines so as to ensure uniformity in the products thereby facilitating better adoption, interchangeability, efficiency and cost effectiveness.

NavIC is now a part of some key international standards such as RINEX, NMEA, RTCM and 3GPP and national standards such as AIS-140. NavIC has also been accorded recognition by the International Maritime Organisation (IMO).

GAGAN system has been recognised by International Civil Aviation Organisation (ICAO) and certified by the Directorate General of Civil Aviation (DGCA).

** ** **