Measurements are an integral part of living; we measure time, measure steps walked to know the calories burnt, measure the materials added for cooking, and measure the size of clothes to know whether it fits perfectly. Sometimes we fail to know the exact measurement, and the values vary, leading to errors. In this article, let us learn about measurement, errors in measurement, types of errors and how to avoid the errors.

Measurement

Measurement is the foundation for all experimental science. All the great technological development could not have been possible without ever-increasing levels of accuracy of measurements. The measurement of an amount is based on some international standards, which are completely accurate compared with others. Just like your vegetable vendors, measurements are taken by comparing an unknown amount with a known weight. Every measurement carries a level of uncertainty which is known as an error. This error may arise in the process or due to a mistake in the experiment. So 100% accurate measurement is not possible with any method.

An error may be defined as the difference between the measured and actual values. For example, if the two operators use the same device or instrument for measurement. It is not necessary that both operators get similar results. The difference between the measurements is referred to as an ERROR.

To understand the concept of measurement errors, you should know the two terms that define the error. They are true value and measured value. The true value is impossible to find by experimental means. It may be defined as the average value of an infinite number of measured values. The measured value is a single measure of the object to be as accurate as possible.

Types of Errors

There are three types of errors that are classified based on the source they arise from; They are:

- Gross Errors
- Random Errors
- Systematic Errors

Gross Errors

This category basically takes into account human oversight and other mistakes while reading, recording, and readings. The most common human error in measurement falls under this category of measurement errors. For example, the person taking the reading from the meter of the instrument may read 23 as 28. Gross errors can be avoided by using two suitable measures, and they are written below:

- Proper care should be taken in reading, recording the data. Also, the calculation of error should be done accurately.
- By increasing the number of experimenters, we can reduce the gross errors. If each experimenter takes different readings at different points, then by taking the average of more readings, we can reduce the gross errors

Random Errors

The random errors are those errors, which occur irregularly and hence are random. These can arise due to random and unpredictable fluctuations in experimental conditions (Example: unpredictable fluctuations in temperature, voltage supply, mechanical vibrations of experimental set-ups, etc, errors by the observer taking readings, etc. For example, when the same person repeats the same observation, he may likely get different readings every time.

Systematic Errors:

Systematic errors can be better understood if we divide them into subgroups; They are:

- Environmental Errors
- Observational Errors
- Instrumental Errors

Environmental Errors: This type of error arises in the measurement due to the effect of the external conditions on the measurement. The external condition includes temperature, pressure, and humidity and can also include an external magnetic field. If you measure your temperature under the armpits and during the measurement, if the electricity goes out and the room gets hot, it will affect your body temperature, affecting the reading.

Observational Errors: These are the errors that arise due to an individual's bias, lack of proper setting of the apparatus, or an individual's carelessness in taking observations. The measurement errors also include wrong readings due to Parallax errors.

Instrumental Errors: These errors arise due to faulty construction and calibration of the measuring instruments. Such errors arise due to the hysteresis of the equipment or due to friction. Lots of the time, the equipment being used is faulty due to misuse or neglect, which changes the reading of the equipment. The zero error is a very common type of error. This error is common in devices like Vernier callipers and screw gauges. The zero error can be either positive or negative. Sometimes the scale readings are worn off, which can also lead to a bad reading.

Instrumental error takes place due to :

- An inherent constraint of devices

- Misuse of Apparatus
- Effect of Loading

Errors Calculation

Different measures of errors include:

Absolute Error

The difference between the measured value of a quantity and its actual value gives the absolute error. It is the variation between the actual values and measured values. It is given by

Absolute error = |VA-VE|

Percent Error

It is another way of expressing the error in measurement. This calculation allows us to gauge how accurate a measured value is with respect to the true value. Per cent error is given by the formula

Percentage error (%) = (VA-VE) / VE) x 100

Relative Error

The ratio of the absolute error to the accepted measurement gives the relative error. The relative error is given by the formula:

Relative Error = Absolute error / Actual value

How To Reduce Errors In Measurement

Keeping an eye on the procedure and following the below listed points can help to reduce the error.

- Make sure the formulas used for measurement are correct.
- Cross check the measured value of a quantity for improved accuracy.
- Use the instrument that has the highest precision.
- It is suggested to pilot test measuring instruments for better accuracy.
- Use multiple measures for the same construct.
- Note the measurements under controlled conditions.

The Global Positioning System (GPS) is a U.S.-owned utility that provides users with positioning, navigation, and timing (PNT) services. This system consists of three segments: **the space segment, the control segment, and the user segment**.

GPS is made of three components namely, **satellites, ground stations, and receivers**

Turn on high accuracy mode

1. On your Android phone or tablet, open the Settings app .
2. Tap Location.
3. At the top, switch location on.
4. Tap Mode. High accuracy.

There are three major types of error correction.

- Automatic repeat request. ...
- Forward error correction. ...
- Hybrid schemes.

There are three types of errors that are classified based on the source they arise from; They are: **Gross Errors**. **Random Errors**. **Systematic Errors**.

GPS satellites broadcast their signals in space with a certain accuracy, but what you receive depends on additional factors, including **satellite geometry, signal blockage, atmospheric conditions, and receiver design features/quality**. For example, GPS-enabled smartphones are typically accurate to within a 4.9 m (16 ft.)

Which of the following will affect the accuracy of the GPS positioning? Explanation: The GPS accuracy depends upon **the receiver station and the atmospheric conditions**. In case of dull atmosphere, the information transmitted cannot reach the receiver end at a full length.

The major sources of GPS positional error are: **Atmospheric Interference**. Calculation and rounding errors. Ephemeris (orbital path) data errors.

Turn on high accuracy mode

To help Google Maps find your location with the most accurate blue dot, use high accuracy mode. Tap Location. At the top, switch location on. High accuracy.

Sources of Errors in GPS and Error Correction - Satellite Error, Multi Path Error & Receiver Error

The errors originating at the receiver include **receiver clock errors, multipath error, receiver noise, and antenna phase center variations**. The signal propagation errors include the delay of the GPS signal as it passes through the ionospheric and tropospheric layers of the atmosphere.

What are GPS differential corrections?

Every time a GPS receiver calculates its position, there is some amount of error inherent in the calculated position. Errors can be introduced from a number of sources (e.g., GPS clock errors, atmospheric conditions, the distribution of GPS satellites) over which the GPS user has little control.

Differential correction is a commonly used technique to reduce the systematic errors that decrease the accuracy of GPS positions. All differential correction techniques use correction data from a GPS base station to improve GPS locations calculated by a GPS receiver in the field (often called the “rover” because it moves with the person carrying it). The GPS base station is permanently fixed to the same location, and, as a result, its location is known with a high degree of certainty.

As part of the differential system, the base station acts as a reference location of known coordinates to determine how much error is present in the GPS system at any time. Each time the base station GPS calculates its position based on the GPS signal, the deviation from its actual location can be calculated (i.e., the error at that time can be determined). Error corrections can then be calculated almost continually and applied to data being collected in the field by a rover GPS unit in the vicinity of that base station. Differential corrections can be performed after field work (post-processing) and/or real time through a correction signal broadcast via a radio beacon or geostationary communication satellites.

The most common satellite-based differential correction of this type is a signal most GPS receivers have the capacity to receive: the Wide Area Augmentation System (WAAS), provided through the Federal Aviation Administration. Real-time differential corrections also are broadcast by the U.S. Coast Guard via radio signals and can be received and used by GPS receivers outfitted with special radio receivers.

Differential correction techniques are **used to enhance the quality of location data gathered using global positioning system (GPS) receivers**. Differential correction can be applied in real-time directly in the field or when postprocessing data in the office.The major sources of GPS positional error are: **Atmospheric Interference**. Calculation and rounding errors. Ephemeris (orbital path) data errors.

Differential correction is **a method of removing the errors, both man-made and natural, that affect GPS measurements**. Corrections of GPS coordinates can be accomplished at a later time (postprocessing) or while the 'roving' GPS receiver is in use (real time DGPS).

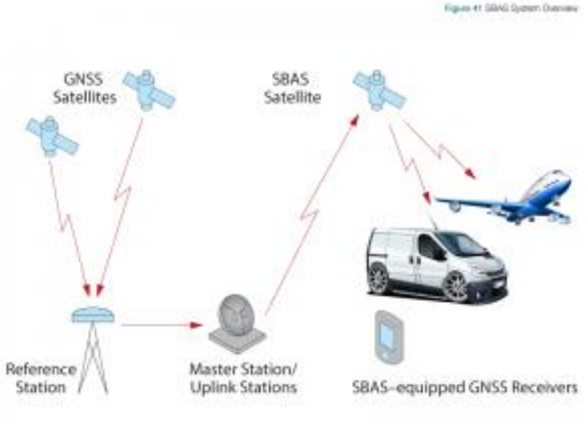
A Satellite Based Augmentation System (SBAS) is a wide area differential Global Navigation Satellite System signal augmentation system which uses a number of geostationary satellites, able to cover vast areas, to broadcast primary GNSS data which has been provided with ranging, integrity and correction information. From all the SBAS systems in the world, three are already operational (WAAS, MSAS and

EGNOS), three are under implementation (GAGAN, SDCM, BDSBAS (formerly SNAS)) while others are under feasibility studies; SACCSA, Malay, African and South Korean SBAS.SBAS systems include **reference stations, master stations, uplink stations and geosynchronous satellites**, Space Based Augmentation System (SBAS) is a highly accurate and reliable Navigation Satellite System that allows to augment GNSS system like GPS. Current GNSS (like GPS) systems give users an accuracy of **between 5 and 15 metres**

Satellite Based Augmentation Systems

For applications where the cost of a differential GNSS system is not justified, or if the rover stations are spread over too large an area, a Satellite Based Augmentation System (SBAS) may be more appropriate for enhancing position accuracy. SBAS systems are geosynchronous satellite systems that provide services for improving the accuracy, integrity and availability of basic GNSS signals.

- Accuracy is enhanced through the transmission of wide-area corrections for GNSS range errors.
- Integrity is enhanced by the SBAS network quickly detecting satellite signal errors and sending alerts to receivers that they should not track the failed satellite.
- Signal availability can be improved if the SBAS transmits ranging signals from its satellites. SBAS systems include reference stations, master stations, uplink stations and geosynchronous satellites, Reference stations, which are geographically distributed throughout the SBAS service area, receive GNSS signals and forward them to the master station. Since the locations of the reference stations are accurately known, the master station can accurately calculate wide-area corrections.



Corrections are uplinked to the SBAS satellite then broadcast to GNSS receivers throughout the SBAS coverage area. User equipment receives the corrections and applies them to range calculations. The following sections provide an overview of some of the SBAS services that have been implemented around the world or that are planned.

Wide Area Augmentation System (WAAS): The US Federal Aviation Administration (FAA) has developed the Wide Area Augmentation System (WAAS) to provide GPS corrections and a certified level of integrity to the aviation industry, to enable aircraft to conduct precision approaches to airports. The corrections are also available free of charge to civilian users in North America. A Wide Area Master Station (WMS) receives GPS data from Wide Area Reference Stations (WRS) located throughout the United States. The WMS calculates differential corrections then uplinks these to two WAAS geostationary satellites for broadcast across the United States. Separate corrections are calculated for ionospheric delay, satellite timing, and satellite orbits, which allows error corrections to be processed separately, if appropriate, by the user application. WAAS broadcasts correction data on the same frequency as GPS, which allows for the use of the same receiver and antenna equipment as that used for GPS. To receive correction data, user equipment must have line of sight to one of the WAAS satellites.

European Geostationary Navigation Overlay Service (EGNOS): The European Space Agency, in cooperation with the European Commission (EC) and EUROCONTROL (European Organization for the Safety of Air Navigation) has developed the European Geostationary Navigation Overlay Service (EGNOS), an augmentation system that improves the accuracy of positions derived from GPS signals and alerts users about the reliability of the GPS signals. Three EGNOS satellites cover European Union member nations and several other countries in Europe. EGNOS transmits differential correction data for public use and has been certified for safety-of-life applications. EGNOS satellites have also been placed over the eastern Atlantic Ocean, the Indian Ocean, and the African mid-continent.

MTSAT Satellite Based Augmentation Navigation System (MSAS): MSAS is an SBAS that provides augmentation services to Japan. It uses two Multi-functional Transport Satellites (MTSAT) and a network of ground stations to augment GPS signals in Japan.

GPS-Aided GEO Augmented Navigation System (GAGAN): GAGAN is an SBAS that supports flight navigation over Indian airspace. The system is based on three geostationary satellites, 15 reference stations installed throughout India, three uplink stations and two control centers. GAGAN is compatible with other SBAS systems, such as WAAS, EGNOS and MSAS.

System for Differential Corrections and Monitoring (SDCM): The Russian Federation is developing SDCM to provide Russia with accuracy improvements and integrity monitoring for both the GLONASS and GPS navigation systems. By 2016, the Russian Federation plans to provide L1 SBAS coverage for all Russian territory and by 2018 L1/L5 coverage. SDCM will also provide Precise Point Positioning (PPP) services for L1/L3 GLONASS by 2018.

Other SBAS Systems: China is planning SNAS (Satellite Navigation Augmentation System), to provide WAAS-like service for the China region.

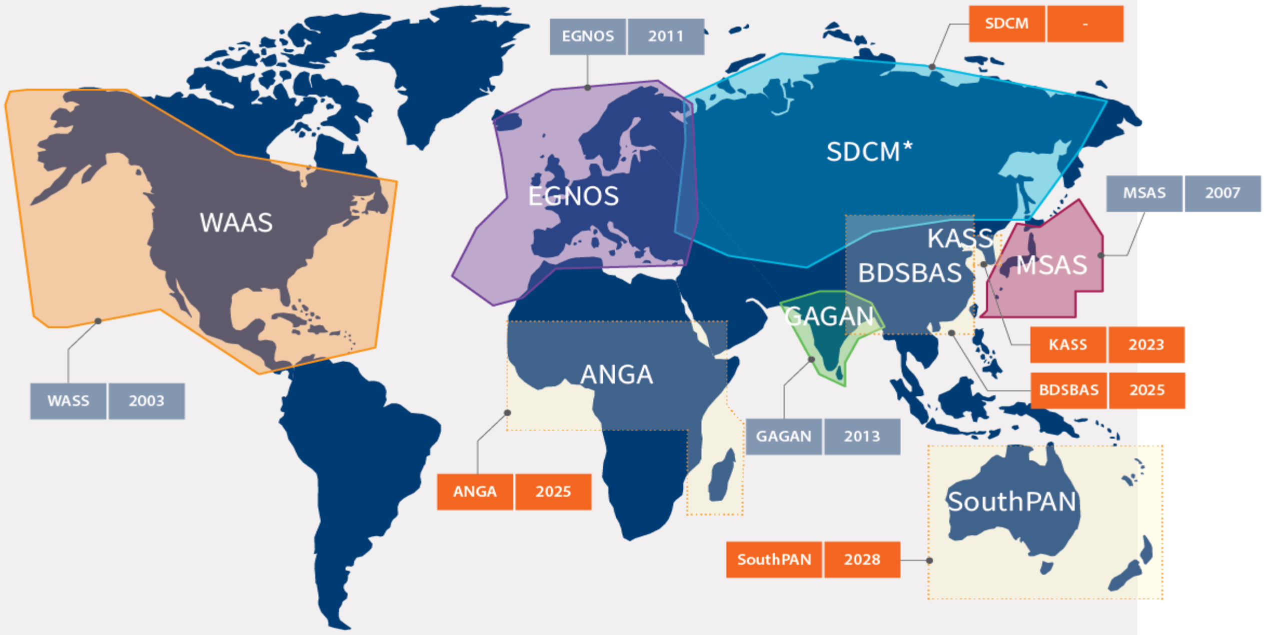
Ground Based Augmentation System:A Ground Based Augmentation System (GBAS) provides differential corrections and satellite integrity monitoring to receivers using a VHF radio link. Also known as a Local Area Augmentation System (LAAS), a GBAS consists of several GNSS antennas placed at known locations, a central control system and a VHF radio transmitter. GBAS covers a relatively small area (by GNSS standards) and is used for applications that require high levels of accuracy, availability and integrity. Airports are an example of a GBAS application.

Existing SBAS

Several countries have implemented their own Satellite-based Augmentation System. For example, in Europe EGNOS covers the majority of the European Union (EU), along with some neighbouring countries and regions. Other national SBASs include:

- **USA:** Wide Area Augmentation System (WAAS)
- **Japan:** Michibiki Satellite Augmentation System (MSAS)
- **India:** GPS-aided GEO-Augmented Navigation (GAGAN)
- **China:** BeiDou SBAS (BDSBAS) (in development)
- **South Korea:** Korea Augmentation Satellite System (KASS) (in development)
- **Russia:** System for Differential Corrections and Monitoring (SDCM) (in development)
- **ASECNA:** Augmented NaviGation for Africa (ANGA) (in development)
- **Australia and New Zealand:** Southern Positioning Augmentation Network (SouthPAN) (in development)

SBAS Indicative Service areas



Operational/certified for civil aviation

Planning

Under development/definition
*System not yet certified for civil aviation

The picture depict available information as of September 2022 and may be subject to changes.