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Overview of Satrack Systems

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Abstract--The guided missile came into existence when Werner Von Siemens suggested a concept for guiding submarines in the late 19th century. This paper deals with the measurement concepts that tests the accuracy of the system. Satrack is basically an acronym for satellite tracking system which uses a GPS i.e Global Positioning System for sending the signals to the missile launched in the space. Satrack has fulfilled all the guidance subsystem requirements and has provided a weapon system error model which is possible only due to its ability to detect and allocate major error contributors that are responsible to miss the predetermined path of the guided missile. During the missile flight , signals sent by the GPS are received at the missile , then they are translated to s band frequencies and relayed to the ground station. In this way satrack is able to track the missile to keep it in proper trajectory. This guidance system evaluation concept is the best in the current test and evaluation technology for guided weapons systems. This paper also gives the comparison of the satrack systems.

Keywords—satrack, GPS, weapon system error model, missile flight, trajectory, guidance system

I. INTRODUCTION

The dictionary meaning of guidance is the process of guiding the path of an object towards a given point. This point may be moving. If the target is moving relative to the guided object then the process of guidance is dependent upon the position and velocity of the moving target. Nowadays all the ballistic missiles are guided with the help of GPS satellites *[1]*. Satrack has been a significant contributor to the development and operational success of present day ballistic missiles. It is basically used to provide a unique monitoring function for evaluating the error model of any weapon system. Satrack basically validates and monitors the missile guidance error model in the flight test program. The reason behind using the satrack for evaluating and validating the error model is its ability to receive record, rebroadcast and track the satellite signal. It identifies the major error contributors that are responsible to miss the track of the missile from its predetermined path *[2]*.

A. *What is a Guidance System?*

The guidance system in a missile is similar to the human pilot of an airplane. Guidance system of any missile mainly contains two systems *[3]*.

1) *Attitude control system:* This system maintains the missile in the ordered flight path by controlling the missile in roll, pitch and yaw. This system also works as an autopilot which damps out the fluctuations causing the missile to deflect from its trajectory.

2) *Flight path control system:* The function of the flight path control system is to determine the flight path which is best suited for the target interception and generate the orders for the attitude control system to maintain that path.

B. *Inertial Guidance System*

The principle of inertia is basically used in the guidance system of missiles. This system provides the intermediate push to the missile to bring it back on the proper path. The inertially guided missile receives the programmed information before its launch. Even if there is no electromagnetic contact between the missile and the launching station, the missile is able to make corrective adjustment in the flight path itself.

Inertial guidance measures all in flight accelerations and attitude control system generates corresponding correction signals to maintain the proper fight path. The use of inertial guidance takes much of the guesswork out of long range missile delivery. The unpredictable outside forces acting on the missile are sensed by the accelerometers and thesolutions generated by them helps the missile to correct its path. This system is reliable than any other long range guidance missile *[3]*.

Figure 1 works as follows:

For a number of days surrounding the missile, the GPS ground stations receives, tracks and records the GPS signals. . During the missile launch, signals of GPS are received by missile, changed in frequency, and are given to the surface station. the missile signals are received and separated by the tracking antenna. The post-flight process uses the recorded data to give satellite ephemerides & clock estimates tracked signal-data from the post-flight receiver, and missile guidance sensor data. After the signal tracking data are corrected, all the analyzed data and the system elements are used by the missile processor to produce the data products.

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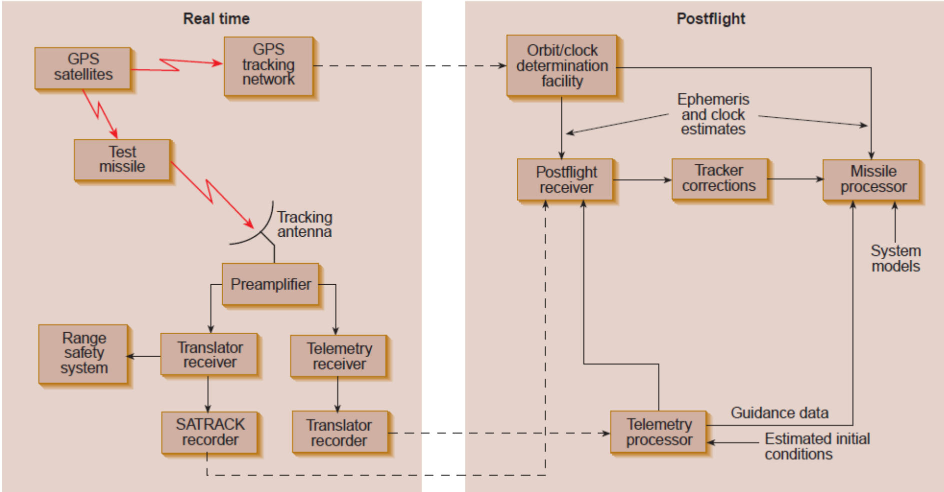

Fig. 1 Satrack configuration

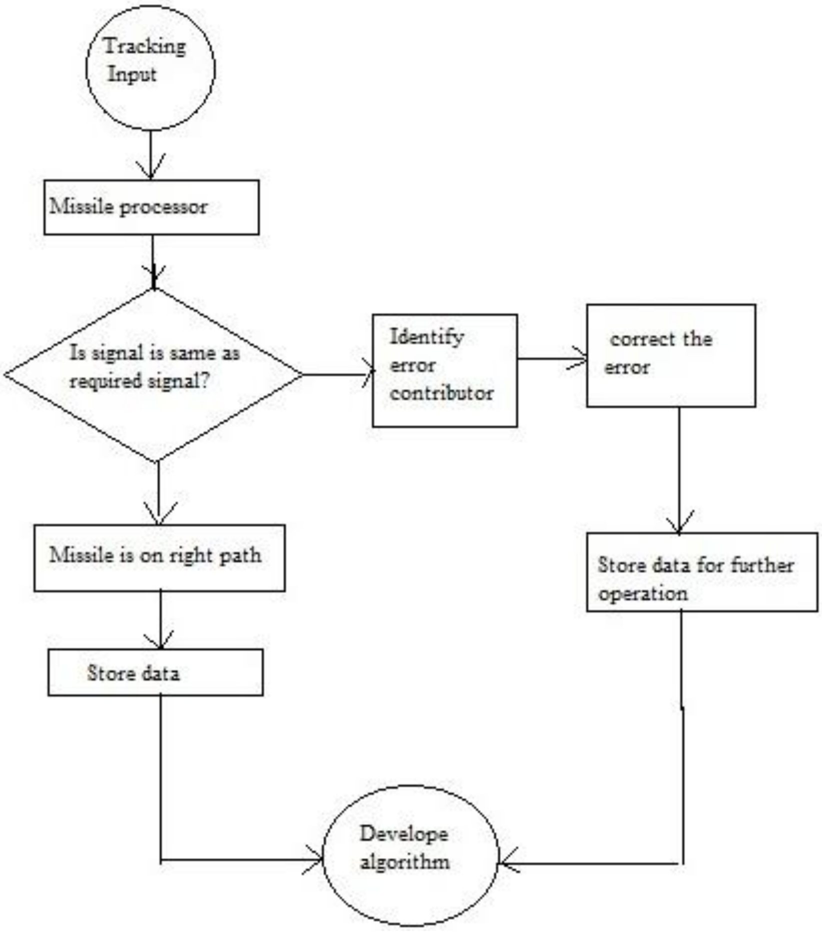

Fig. 2 Flowchart

Fig .2 gives the flowchart of the operation of the satrack. It shows how the tracking of the signal takes place.

II. LITERATURE REVIEW

A. Satrack Evolution

The satrack technology started to evolve when the Global positioning System had been developed in the year 1973. It would have been a great advantage if the use of GPS is considered in the satellite test program. Only the changes in the missile and ground station design were required. The satrack development is initiated to bring into existence the missile with the GPS facilities included.

The evolution of the satrack is as follows:

- Satrack 1- A technology project to develop the processing system using Trident 1 missile (1973-1983) *[4]*
- Satrack 2- The operational system designed to meet system requirements of Trident 2 missile (1983-present) *[4]*
- Satrack 3- Current system upgrade and future applications *[4]*

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1) Satrack 1: Satrack 1 was also called C4 missile. The development of satrack 1 for Trident 1 missile began in 1974. It was aimed at Analysing the insights needed to achieve improved accuracy in existing Trident 1 missile and developing the evaluation system with improved accuracy taking into account the major error contributors. Satrack 1 was the development over the tracking methods and large kalman filter design required in the early test flight programs. It used 4 GPS antennas over the s band antennas which were placed in missile circumference. As the spacing between the antenna elements was much wider, the signal sums caused the strong interferometer null patterns. The translator was time multiplexed with two interferometers and multiplexing rate was set high enough so as to track both the inputs simultaneously when the signal were strong *[4]*.The signal is significantly refracted at GPS prime frequency (L1=1575.42 MHz) and it needs to be corrected for precision positioning. For this purpose the GPS provides additional frequency L2=1227.60MHz) which is used with the prime frequency to compute the needed correction for signal refraction *[4]*. L1 frequency could be modulated using two range code modulations, one with 2 MHz bandwidth and other with 20 MHz bandwidth. L2 could be modulated using only 20 MHz bandwidth. Narrow bandwidth code is called as clear/acquisition (C/A) code and wide bandwidth code is called as precision (P) code *[4]*. The main problem associated with the satrack 1 was regarding the antenna design which was providing very poor gain over a large region. (i.e less than 14 dB over 15% coverage region.) This poor gain was coupled with the GPS satellite signal levels hence creating a challenging condition for signal tracking *[5]*.

2) Satrack 2 : Satrack 2 was related to the accuracy evaluation requirements of the D5(Trident 2) missile. It began in 1981. It was aimed at using a dual frequency GPS signal capability to permit ionospheric corrections and tracking 12 dual frequencies from left to right (i.e 48 range codes). As we know the L2 signal could only be modulated using P code. The satrack 2 technology aims to modulate the L2 signal using C/A code as well as P code. To achieve this the switching between the two codes would be impractical as it could cause the effect on other users. The alternative to this is to use another GPS frequency called L3 frequency which needed to be derived from the same frequency source as the positioning signals. The frequency should be selected such that it could support the C/A code modulation. This was considered as the baseline for satrack 2 *[4]*. The satrack 2 technology provides overlaying of the two GPS signals on the same translator channel. The separation of the signals could be done during the signal tracking operation by virtue of the code differences but at the expense of increased noise n each signal *[6]*. The another advancement was in the antenna used. Depending upon the analysis of phase noise characteristics of the different configurations wraparound antenna was chosen. This antenna was chosen because it minimised the phase variations in the missile roll plane. These were all the upgrades in the satrack 1 systems *[4]*.

3*) Satrack 3:* Satrack 3 can be viewed as the advanced satrack technology which taking the full advantages of the technological growth in the processing hardware and software. This technology is used to guide all the present day ballistic missiles. This technology is designed to be compatible with the satrack 1 and satrack 2 technologies so that C4 and D5 missiles can also be guided using this technology. This is big advantage of satrack 3. This technology is intended to serve both range safety and post flight evaluation objectives for variety of range applications. *[4]*

The comparison of the above discussed satrack systems are given below.

Table I Comparision of satrack systems

System	Established in	Designed for	Antenna Used	Frequency Used
Satrack 1	1973-1983	Trident 1 (C4)	S-band & GPS	L1-1575.42 MHz L2- 1227.60 MHz
Satrack 2	1983-present	Trident 2 (D5)	Wraparound array	L1-1575.42 MHz L2- 1227.60 MHz L3- same as positioning signals
Satrack 3	Present	Both C4 & D5	GPS	-------------------------

III. APPLICATION

- The best flight path for the aircrafts during post flight processing.
- vehicle tracking
- The spot Satellite GPS Messenger

IV. CONCLUSION

The satrack has the significant contribution to the successful development and operational success of the Trident weapon system. It plays an important role in providing a unique monitoring function in maintaining the missile trajectory. The development and research in the technology responsible for bringing the latest GPS receiver, translator, data recorders, and missile processors in the missile flight program to monitor and evaluate the error model. This model helps to identify the major error contributors responsible for the misalignment of the missile path. The development of satrack looks forward to the implementation of the Low Cost Missile Test Kit. This technology also developed sophisticated tools for optimal target perception, analyzing methods, and the use of expensive flight tests assets were also born out of the satrack research. All the research about satrack is done in APL (Applied physics Laboratory).

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V. FUTURE SCOPE

A. Evaluation Capability for Cumulative Flight Test Accuracy

The limitations of the test geometry prohibit observations of all the errors in any flight test program. As every test flight observes underlying system missile guidance errors, combines the data from many flight programs. The finally analysed flight test data are cumulatively combined to produce a guidance error model for the navigation system. The observations from ach test flight are combined to derive a missile guidance model that is both tactically representative and based completely on the flight test data.

B. Full Digital Implementation

The full digital implementation is of the Portable ground equipment and processing facility. This is a very big improvement over the analogue circuitry such as the analogue PLLs used for carrier- phase tracking. Moreover the use of digital technology removes the need for periodic hardware calibration that accompanies the analogue circuits.

C. Batch Mode Processing

This type of processing allows hardware to operate with software easily. The hardware that is fully configurable under software control implemented the most crucial portions of the process such as signal autocorrelation, generation of code and strength of carrier signal mixing.

D. Flexible Architecture Receiver

The stand alone real time capable receiver called FAR operates with the help of batch mode processing. FAR is a single channel L1 C/A only receiver with a front-end data storage memory which can track the real time data up to 16 satellite without loss of multiplexing.

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