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Multi Sensor Track Data Generator Design using Procedural Approach

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Abstruct

Multi sensor track data generator (MSTDG) computes the tracking information of a flight vehicle that would be sent by the tracking sensors like EOTS, Radar and Telemetry, then sends it to the Data Processing Server. The tracking information sent by the MSTDG is calculated using various parameters like the nominal data of trajectory, chamber pressure and body rates, the tracking instrument coordinates and the launch point coordinates. It is as per the format of the tracking information sent by the tracking sensors and at the rate at which tracking sensors send data. The MSTDG has an extensive GUI allowing configuration of necessary parameters and displaying nominal data as it is sent. This paper also demonstrates the realization of the architectural design in the form of data flow diagram based on the requirements specified for the MSTDG system.

Keywords: *EOTS, Generator, Radar, Sensor, Telemetry*

1. Introduction

A tracking range of flight vehicles is equipped with a number of tracking instruments to cover the total flight path of test vehicles. These include the: Electro-Optical Tracking System (mobile and fixed), S-band Tracking Radar (mobile), C-band Tracking Radar (fixed) and Telemetry (fixed and mobile) [1]. These instruments track the flight vehicle and send data to the Data Processing Server (DPS) where the data is processed and meaningful information is extracted. Also, using this information, the necessary Computer Designated Mode (CDM) bearings are sent to tracking instruments for locating the flight vehicle if they lose track of it. DPS sends data to multicast display server for real time visualization of the flight vehicle. Block diagram of the existing system is given in the figure1. A reliable communication network is essential to connect all the active participating stations (where tracking instruments are located) for tracking. In this paper, multi sensor track data generator is designed based on the information available in Internet [2].

The paper is organized as follows. Section 2 explains about Electro-optical tracking systems then section 3 and section 4 elaborates the concept of radar and telemetry systems respectively. Different coordinate systems are explained in Section 5. Section 6 shows the context and dataflow diagram of the system. Finally conclusion is drawn.

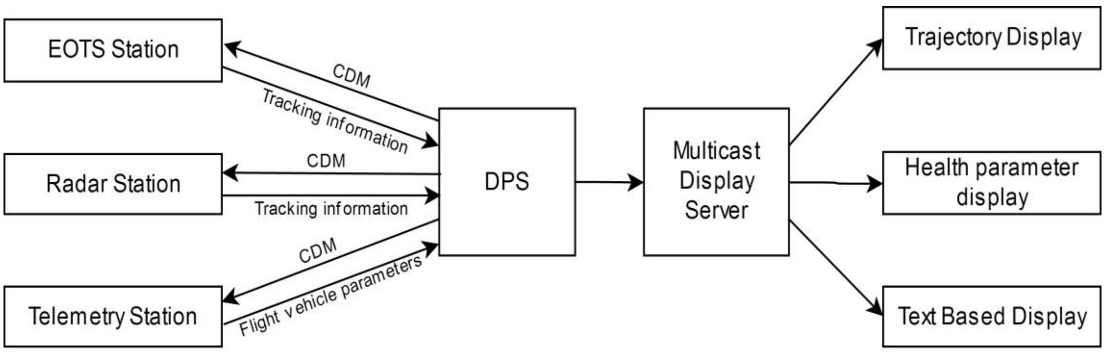

Fig 1: Block diagram of existing system along with data flow direction

2. Electro-Optical Tracking System

EOTS utilizes a combination of electronics and optics to generate, detect, and/or measure radiation from airborne vehicles in the optical spectrum. The portion of the electromagnetic spectrum used by EOTS includes infrared radiation, visible light and ultra-violet radiation. The operational requirements for EOTS are target detection, target auto track and data collection. Various tracking algorithms like Edge Tracking, Centroid Tracking and Correlation Tracking can be used to track airborne vehicles [3].

EOTS can operate in Manual, Designate or Auto position system. In the Manual system, the operator positions the gimbal through a positional control following the target's motion. In a Designate system, the target's trajectory is determined from a prior knowledge of the target trajectory (nominal trajectory). This data is used to drive the gimbal's position encoders to known positions. In an Auto position system, initial acquisition is accomplished by operator identification and selection of the target. The operator then initiates the auto positioning or auto track mode and the tracking processor positions the gimbal based on the calculated target position [3].

The tracking data for EOTS sent by the MSTDG to the DPS includes various parameters like GPS time, Range, Azimuth and Elevation.

3. Radar Systems

Radar is an object-detection system that uses radio waves to determine the range, angle, or velocity of objects. A radar system consists of a transmitter producing electromagnetic waves in the radio or microwave domain, a transmitting antenna, a receiving antenna (often the same antenna is used for transmitting and receiving) and a receiver and processor to determine properties of the object(s). Radio waves (pulsed or continuous) from the transmitter reflect or scatter from the object and return to the receiver, giving information about the object's location and speed [4]. The types of tracking radar are STT Radar (Single Target Tracking Radar), ADT Radar (Automatic Detection and Tracking Radar), TWS Radar (Track While Scan Radar), and Angle Tracking Radar, Phased Array Tracking Radar and Mono pulse Tracking Radar [5].

The tracking data for Radar sent by the MSTDG to the DPS includes various parameters like GPS time, Range, Azimuth and Elevation.

4. Telemetry Systems

Telemetry is an automated communications process by which measurements and other data are collected at remote or inaccessible points and transmitted to receiving equipment for monitoring. The word is derived from Greek roots: tele meaning remote, and metron meaning measure. Telemetry is used in testing of airborne vehicles since it allows the automatic monitoring, alerting, and record-keeping necessary for efficient and safe operation. Telemetry is vital in the development of missiles, satellites and aircraft because the system might be destroyed during or after the test. Engineers need critical system parameters to analyze (and improve) the performance of the system. In the absence of telemetry, this data would often be unavailable [6].

The tracking data for Telemetry sent by the MSTS to the DPS includes various parameters like GPS time, down range, cross range, altitude, quaternion angles, roll, pitch, yaw and chamber pressures.

4.1 Angular Body Rates

There are many ways of representing the rotation of a flight vehicle in three dimensions, including roll, pitch, yaw and quaternion angles.

4.1.1 Roll, pitch and yaw:

The three critical flight dynamics parameters are the angles of rotation in three dimensions about the vehicle's center of mass, known as roll, pitch and yaw (Fig 2). Rotation around the front-to-back axis is called roll. Rotation around the side-to-side axis is called pitch. Rotation around the vertical axis is called yaw. These axes move with the vehicle and rotate relative to the Earth along with the craft [7].

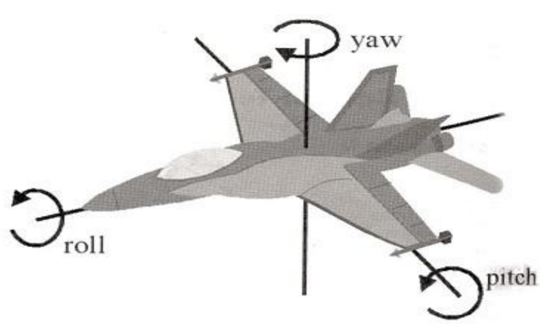

Fig 2: Roll, pitch and yaw

4.1.2 Quaternion angles:

Quaternion angles provide a convenient mathematical notation for representing orientations and rotations of objects in three dimensions using four numbers. Quaternions have applications in computer graphics, computer vision, robotics, navigation, flight dynamics and orbital mechanics of satellites [8].

5. Coordinate Systems

5.1 ENU Coordinate System:

The East-North-Up (ENU) coordinate system is defined with respect to a location on the earth's surface, i.e. it is a local coordinate system (Fig 3). In this system, the origin is arbitrarily fixed to a point on the earth's surface, the +X axis points to the east, the +Y axis points to the north and the +Z axis points to the vertically upward direction. The Z axis passes through the center of the earth when using a spherical earth simplification, or is along the ellipsoid normal when using a geodetic ellipsoidal model of the earth [9].

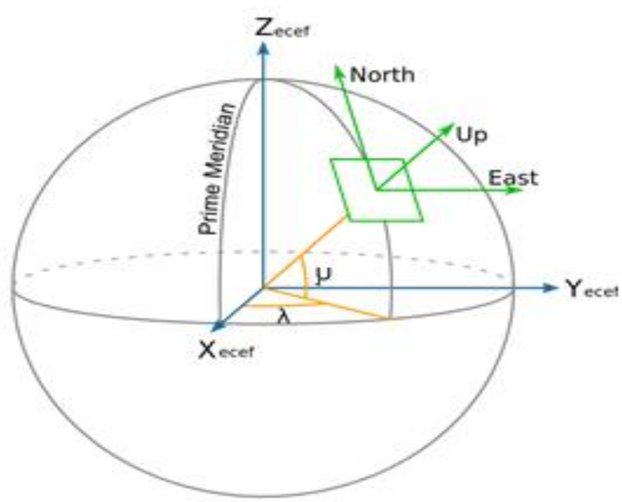

Fig 3: ENU and ECEF coordinate systems

5.2 ECEF Coordinate System:

In the Earth-Centered, Earth-Fixed (ECEF) coordinate system, the origin is at the center of the earth, the X-axis intersects the sphere of the earth at 0° latitude (the equator) and 0° longitude (prime meridian in Greenwich), the Z-axis extends through true north and the Y-axis is orthogonal to both the X and Z axes following the right-hand rule (Fig 3). The ECEF axes rotate with the earth, and therefore coordinates of a point fixed on the surface of the earth do not change [10].

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5.3 Cartesian and spherical coordinates:

The Cartesian coordinate system specifies each point uniquely in space by three numerical coordinates, which are the signed distances to the point from three fixed perpendicular directed lines (Fig 4). Each reference line is called a coordinate axis or just axis of the system, and the point where they meet is its origin, usually at ordered pair (0, 0, 0) [11].

The spherical coordinate system is a coordinate system where the position of a point is specified by three numbers: the radial distance of that point from a fixed origin, its polar angle measured from a fixed zenith direction, and the azimuth angle of its orthogonal projection on a reference plane that passes through the origin and is orthogonal to the zenith, measured from a fixed reference direction on that plane [12].

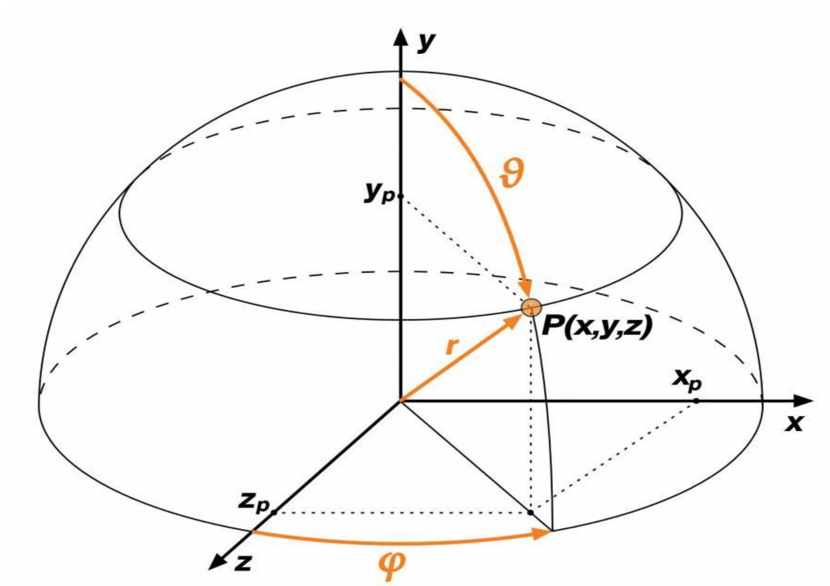

Fig 4: Cartesian and spherical coordinates

6. Context and Data Flow Diagram

Inputs required to create the tracking information sent by the MSTDG and the output packets which contain the simulated tracking information are shown in the context diagram (Fig 5).

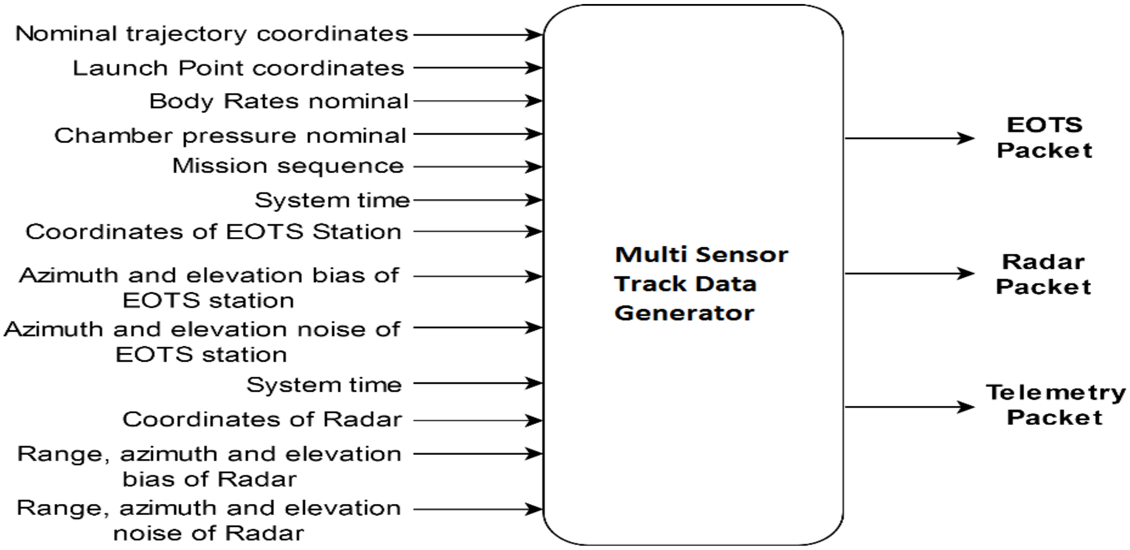

Fig 5: Context diagram

In the level 1 diagram, the conversions required for creating the packets from the nominal data available are shown. The trajectory coordinates, which are available in ENU format with respect to launch point, are first converted to ECEF format. Then using various input data like location of the tracking station, range, azimuth and elevation noise and bias, the packet sent by the tracking instrument is created (Fig 5).

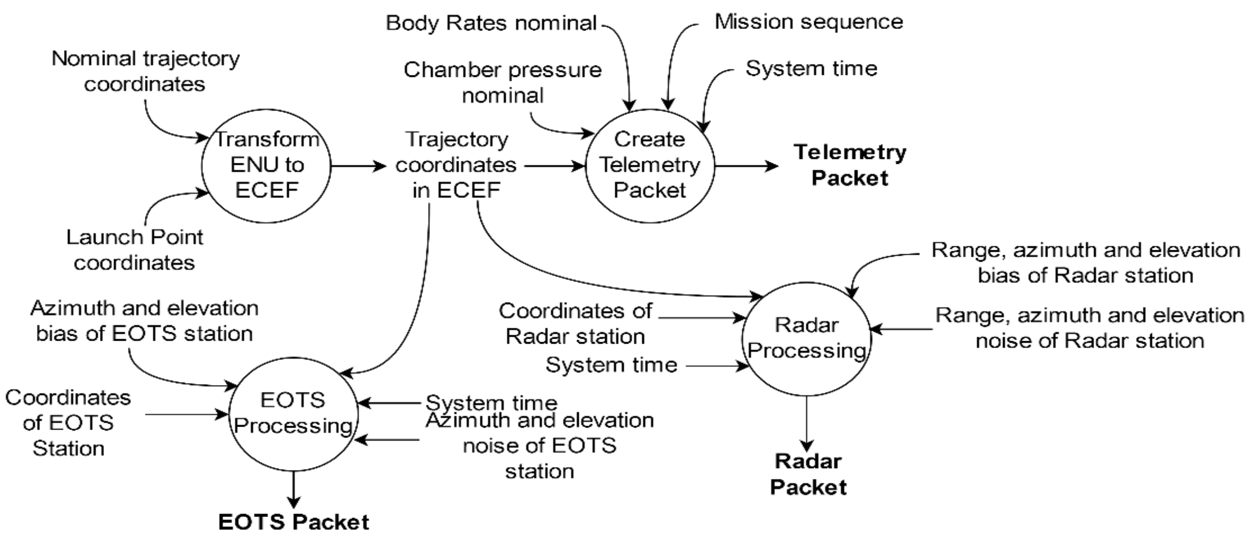

Fig 5: Level 1 Data Flow Diagram

In the level 2 diagram, the conversions required are shown in more detail. The trajectory coordinates converted to ECEF format are converted to ENU format for the EOTS and Radar stations on the basis of the position coordinates of stations. These trajectory coordinates are used to calculate various input data like range, azimuth and elevation as applicable by conversion to the spherical coordinate system, also taking into consideration the range, azimuth and elevation noise and bias of each station. The packet created for telemetry stations contains various health parameters and positional information.

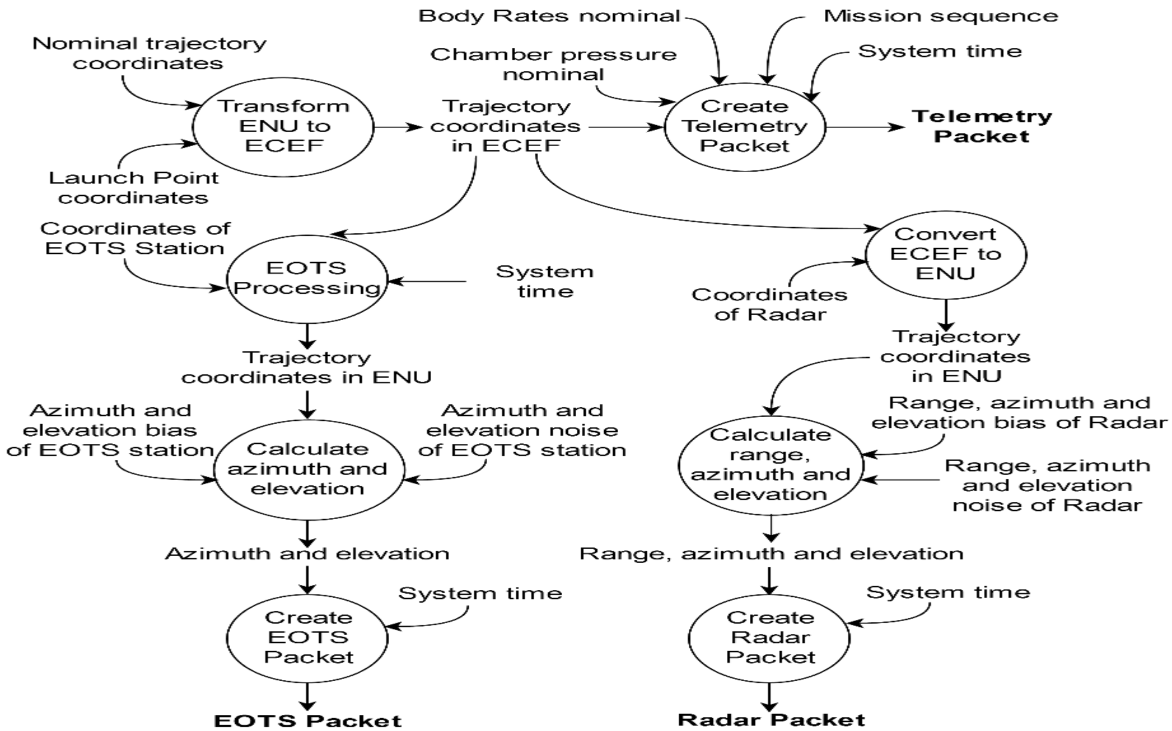

Fig 6: Level 2 data flow diagram

7. Conclusion

The MSTDG developed in this paper creates and sends packets that would be sent by each of the tracking instruments to the Data Processing Server at the rate at which the tracking instruments send data. It thus validates the modules of the Data Processing Server without the physical presence of any tracking instrument. The real life problem of simulating data transmission from tracking instruments has been modeled using data flow diagrams. Further details of the terms used can be found in the Internet.

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