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REMOTE FLIGHT RECORDER AND TIMELY AIRCRAFT ADVISORY SAFETY SYSTEM, ~~RAFTS~~RAFTSS

ABSTRACT

Apparatus for a remote located flight crash recorder and a real time aircraft pilot crash avoidance safety advisory system is achieved by continuously monitoring aircraft sensors such as aircraft position, altitude, speed, control surfaces, engine revolutions per minute, temperatures, stress, and fuel. Then by radio frequency world wide transmission, such as via satellite communication links, sends these parameters along with any cockpit audio data, video data, aircraft identification and configuration to a central ground monitoring station where they can be continually and safely recorded and analyzed. The transmission of the aircraft data via the communication link permits the aircraft performance and cockpit communication data to be memorized in a ground based recorder for after crash analysis without the necessity of crash shock rugged and waterproof monitoring apparatus aboard the aircraft. Furthermore, in the advent of a pilot initiated pre-crash alert or a ground station initiated alert, based on the real time automated analysis of the aircraft's flight worthiness, a pilot crash avoidance safety advisory can be radioed back to the aircraft that provides the pilot with expert advise as to the safest approach for the operation of the aircraft. For rescue and aid in the event of a crash, the remote monitoring system would provide an accurate estimate of the downed aircraft's location based on the real time telemetry of the aircraft's navigation and an analysis of the recorded vehicle dynamics data.

The central ground based monitoring system can utilize the real time aircraft sensor data, aircraft configuration data and experts familiar with the aircraft in arriving at the best safety advisory. The computational analysis processors used to perform the safety analysis on the ground are not limited by the space and power restrictions that exist aboard the aircraft and thus can provide high fidelity simulation and analysis of the aircraft's problem. In this mode of operation, the central ground based monitoring site would maintain a communication, utilizing fiber optic ground or satellite links, with government flight controller facilities and with the aircraft manufacturers. It would distribute the aircraft sensor data to them in real time so as to solicit their expert analysis and help in the crash avoidance advisories. Real time analysis of the prior to take off, pre-flight, aircraft data along with other data such as weather, airport and its local area map, three dimensional ~~digitized~~ topographical map ~~data~~information from data bases such as Digital Terrain Elevation Data (DTED), aircraft flight controller data, wind shear and aircraft configuration would also be used to provide a safe to take off advisory.

If an aircraft exhibits a mechanical equipment failure prior to take off this data would also be communicated back to the aircraft manufacturer in real time via the distribution of the aircraft's sensor monitoring telemetry. The aircraft manufacturer then could provide an expert system for fault isolation that could save both time and money in getting a safe to fly aircraft back in service.

For aircraft that are equipped to receive the satellite constellation Global Positioning System (GPS) precision navigation signals, this real-time sensor data of aircraft location would also be sent to the Remote Flight Recorder Transmitter and then via telemetry to the Ground Based Processing Station. This very accurate aircraft position data would be utilized to augment the air

traffic controllers in flight and airport taxi collision avoidance systems as well as to enhance the all weather landing systems. It would provide the air traffic controllers ground based radar systems with a level of redundancy as well as enhance the radar systems by providing high fidelity three dimensional world wide aircraft separation distances. An added economic benefit of utilizing this position data blended with other aircraft sensor information and world wide weather and destination airport traffic data available at the Ground Based Processing Station would be to provide the aircraft with a real time fuel conservation and economy of flight advisory. The world wide communication up link advisory to the aircraft during flight for fuel conservation and economy of flight operation would be based on the blending of the data sources in a ground based digital processor. Thus, for this additional function, there would be no need for added equipment to be carried aboard the aircraft.

This invention relates to the automatic, real time, collection of aircraft data for safety of flight and then transmitting this sensor data to a world wide communication system for subsequent reception at a Central Ground Based Processing Station. The ground station's computers would analyze the sensor data and archival store it in it's memory system. The analyzed data can be transmitted back to the aircraft in order to provide an advisory for optimum safe performance. The Central Ground Based Processing Station could also distribute the aircraft information to the aircraft manufacture's facilities for expert timely advise as to how best to operate an aircraft that exhibits an in air equipment failure and how to best service an aircraft when it has ground problems. These advisories would be transmitted back to the aircraft. In addition to the above, the Central Ground Based Processing Station, would utilize the aircraft sensor data and world wide weather data, ground based traffic control radar and airport destination data to provide the aircraft with the safest and most economical way to operate the aircraft. In the advent of a crash the aircraft sensor data stored at the Central Ground Based Processing Station, which has a record of the operating condition of the aircraft at the time of the crash, would provide the best estimate of the downed aircraft's location for timely recovery and potential rescue operations as well as the parameters that may have caused the crash. Further-more, for operational aircraft experiencing an equipment failure or in a potentially over congested area of operation, the real time expert advisories communicated to the aircraft may well prevent the loss of life by giving the pilot the best crash avoidance information. In addition the post flight analysis of aircraft data may provide the clues to the cause of a problem so as to prevent its reoccurrence in the future. Even for operational aircraft experiencing no current faults the Central Ground Based Processing Station would keep a record of flight hours accumulated on the air frame and critical parts to assure that routine maintenance is adhered to and that the vehicle doesn't accumulate excessive stress build up on flight critical assemblies. The CGBS would send out alerts for maintenance actions.

The system integrates the voice, video and instrument data into a single aircraft telemetry system that provides two way, world wide communication with the aircraft and ground based archival recording of the data. It could also communicate, via a local computer terminal or visor display to the aircraft ground maintenance personnel, the problem specific vehicle aircraft manual data that would show how best to service the vehicle. By so doing, it could eliminate, much of the paper manuals and assure that the latest aircraft maintenance information is being utilized for the repair.

In order to promote a clear understanding of the invention, a preferred embodiment thereof will be described by way of example with reference to the accompanying drawings, in which:

FIGURE 1 is a block schematic of an aircraft's multiplexed flight sensors, sensor transmitter and advisory receiver according to the invention.

FIGURE 2 is a block schematic of the Central Ground Based Processing Station according to the invention.

FIGURE 3 is a block schematic of the Ground Based Distribution System according to the invention.

Referring to Figure 1, the aircraft is fitted with a device, named Sensor Multiplexer Receiver & Transmitter (SMRT) module, that accepts sensor signals that depict the performance of many of the flight safety critical assemblies. It converts any of the analog sensor data into a digital format. These signals are the same as those that are presently sent to the existing flight crash recorders aboard aircraft which records vital flight information such as air speed, height, attitude, landing gear status as well as the position of the aircraft controls. Unlike the existing crash recorder that must be recovered from a crash site to obtain an understanding of the cause of the aircraft, the system depicted in Figure 1 has a telemetry system to radio these signals to a world wide communication system and to a final destination known as the Central Ground Based Processing Station (CGBS). It is at the CGBS where the archival storage of these signals take place as well as the distribution of some of the aircraft data and signals to other ground based facilities that require this data. In addition to the standard flight sensors presently used in existing flight recorders, position and velocity signal from the GPS receivers, acoustical sensors that record cockpit communication, and video camera data that records the passengers entering the vehicle, the states of the cargo hull and the cockpit during flight, aircraft identification and latest configuration are also sent to SMART for telemetry to the CGBS. The SMART module accepts these signals and then transmits these signal over the radio frequency link. The preferred embodiment of this patent utilizes a global satellite communication system. The SMART module's radio frequency output is sent to a satellite antennae where the signal is radioed to a satellite that is in a direct line of sight with the aircraft. The signal is then relayed, either by low earth orbit or a synchronous orbit world wide communication satellite chain, until it is transmitted to the CGBS by the communication satellite that is in a direct line of sight with the CGBS antennae. The aircraft satellite antennae also accepts advisory signals sent from the CGBS to the aircraft. The SMART module receives these signals and sends the audio signals to the pilot and the digital signals to a pilot warning panel so as to alert the pilot. Thus SMART concentrates the audio, video, digital discrete and sensor signals to minimize the weight, power expended, cost of equipment and radio frequency antennas carried aboard the aircraft.
Figure 1A illustrates the invention by showing an aircraft 1 that is equipped with the SMRT line replaceable unit 2. SMRT accepts the flight critical aircraft performance monitoring sensors labeled M1 to MN. acoustic sensors MA, and video sensors MV. SMRT periodically samples the sensor signals, converts all non digital sensor signals into a digital format, adds a sensor identification label to each signal, an aircraft identification and configuration label, ultra high frequency radio electronically modulates the data and then sends the data to the aircraft satellite telemetry antennae 3. The ultra high frequency signal is radiated 4 by the aircraft antennae to an earth orbiting communication satellite 5 that is located in a direct line of sight with the aircraft.

The aircraft data is then relayed by the communication satellite link to the CGBS for analysis and recording.

Figure 1B illustrates the communication satellite link between the aircraft and the CGBS. It has a SMRT equipped aircraft 6 transmitting its sensor data over an ultra high frequency radio, line of sight, transmission with satellite S1 7. The satellite world wide communication link then relays the data by line of sight transmission with other satellites S1 to S2 8, S2 to S3 9, and then S3 to the CGBS 10. The transmission of aircraft advisories from the CGBS to the aircraft is accomplished by communicating along the same path but in the reverse direction. Figure 1B also illustrates another aircraft labeled aircraft 2 13 with SMRT. This aircraft also communicates with the CGBS via satellite SN+1 12 to satellite SN 11, SN to S1, S1 to S2, S2 to S3, and then S3 down to the CGBS. Figure 1B depicts a continuous, around the clock, world wide communication link that provides two way communication with all of the aircraft equipped with SMRT in the RAFT system. Satellites S4, SN+2 and SN+3 are also shown in Figure 1B to indicate that there can be other satellites in the world wide communication link. The number of satellites in the communication link depends on whether a geosynchronous or low earth orbit satellite, LEO, constellation is utilized. The system will work with either of the satellite constellations. The LEO constellation requires smaller, lighter and lower power equipment but a larger number of satellites.

Referring to FIGURE 2, that is a block diagram of the CGBS, it shows the satellite antennae system, the radio frequency interface that converts the radiated satellite signal into an electrical signal that is representative of the aircraft sensors, audio and video signals. These signals are then sent to the CGBS processing station for data analysis, problem simulation, expert system crash avoidance simulations, archive storage, aircraft advisories, distribution to aircraft manufacturer's ground based facilities for expert crash avoidance and maintenance advisories, and distribution to airport and area government flight traffic control facilities. Since the CGBS is on the ground it's temperature environment, humidity and air can be controlled so that the archive storage of the aircraft's sensor data is very reliable. In addition, the real time analysis of the data can alert the operational aircraft of problems, in some cases, that may occur prior to the pilot's recognition of a problem. Thus in addition to reducing the equipment aboard the aircraft it can lighten the pilot's work load.

The ground communication can be made over wide band width fiber optic cables, satellites or other radio frequency communication links. In the continental United States the wide band width fiber optic communication link is the preferred ground communication embodiment of RAFTS. The CGBS acts as communication concentrator and it is through this facility where the world wide communication with the aircraft occurs. At this facility weather data is collected from the government weather bureau facilities, over the wide band width fiber optic communication link. The weather data is combined with other aircraft operational data to provide fuel efficiency and safety of flight aircraft advisories.

Referring to Figure 2, a satellite 14 receives the monitored data of flight critical equipment from aircraft equipped with SMRT modules. The satellite is in line of sight communication with the CGBS. The satellite transmits and receives data radiated from the CGBS antennae 15. The antenna is controlled by antenna control and radio frequency (RF) interface module 16. The RF aircraft signals are also demodulated and sorted, by aircraft, in module 16. The data is then sent to the ground processor 17, for analysis. One function of the ground processor is to send the data to the archival data storage system 20 where it is safely stored in an air conditioned environment, for future retrieval, on magnetic disc or tape. Another function of the processor is to coordinate its data with the aircraft simulation processor 19 for safety of flight advisories aircraft based on the monitored aircraft data telemetered to the CGBS. It also performs an expert system analysis based on past performance data, aircraft specific stress accumulation statistics and world wide weather and wind shear information. Aircraft real time emergency advisories 18 would be generated for aircraft experiencing problems. These real time emergency advisories would also be based on aircraft manufacture's simulations conducted at their facilities and communicated to the CGBS via the wide band width fiber optic link 24. The data can be viewed by the CGBS operators on the display system 25. The position, altitude and aircraft velocity data is sent to the government traffic controller communication module 21 for real time transmission to the government airport and area flight controllers over the wide band width fiber optic communication link 22. Also over this link is communication with government supported weather services. This data when mixed with the aircraft sensor data at the aircraft simulation can provide world wide safety of flight trajectories, safe to take off and land, and fuel efficiency economy of flight advisories. These advisories would be sent to the aircraft over the world wide communication link illustrated in Figure 1B. In addition, world wide advisories could also be sent to the aircraft by the traffic controllers based on their information of aircraft separation. In a similar manner, the monitored aircraft data is sent to aircraft manufacturer personnel by the communication module 23 over the wide band width fiber optic link 24. Advisories can be sent by the manufacturers providing the best way to handle a problems based on their expert knowledge of the aircraft. These could aid in safely flying the aircraft or efficiently servicing an aircraft that is experiencing equipment malfunctions on the ground. The in air safety of flight advisories would go to the real time emergency advisory 12 center to be integrated with CGBS and air traffic controller generated emergency information so as to provide a single emergency advisory, based on all of the data. This advisory would be sent to the aircraft. For aircraft experiencing problems on the ground, an aircraft manufacturer would remotely sample the telemetry of the aircraft's flight critical performance monitors and then send advisories directly to the aircraft's ground maintenance personnel that represent the latest diagnostic procedures and problem specific maintenance information. These would be sent to an aircraft maintenance terminal display that would interface with the SMRT communication system on board the aircraft. The maintenance advisory would provide efficient, safe and effective repair of the aircraft that used the preferred procedures.

Referring to FIGURE 3, is a block diagram of the CGBS ground based communication and distribution system of the aircraft signals. It shows the aircraft data being distributed to the aircraft manufacturers where they maintain aircraft configuration logs that provide the information that is needed to optimally diagnose equipment failures and to make expert system evaluations of the safest way of dealing with a failure in an operational aircraft as well as the safest and most efficient way of eliminating a ground based failure in order to get an aircraft operational. It also shows the distribution of the aircraft communication signals to the government's ground facilities for the air traffic controllers that exist at the exit and destination airports, and continental coverage. Another communication input to the CGBS is a world wide weather data. This is used to direct the aircraft to the safest and economy of flight fuel efficient route. FIGURE 3 illustrates the CGBS communication with the ground based government and manufacturing facilities. The CGBS ground processor 17 communicates with the government air traffic controller communication module 21. Digital data is communicated serially over a wide band width fiber optic link to the air traffic controller facilities 27. There are a large number of civil and military air traffic in present use. These are indicated as 1 to y for the airport air traffic

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