

# **In-flight continuous vital signs telemetry via the Internet**

**by**

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**Abstract:**

Introduction: Currently, there is no method available to assess a passenger condition by means of telemetry of vital signs from a commercial aircraft during an in-flight medical emergency.

Critical communication channels between the airplane and ground rely only on voice communication via a two-way radio. The purpose of this study was to test the efficacy of cellular telephone technology via the Internet as a cost-effective way to obtain the “linking” pathway from an aircraft to a ground medical facility conducting a simulated on line triage.

Methods: On July 31, 1997 we transmitted vital signs from a Boeing 757, flying from Chicago to Los Angeles, simultaneously to The Saddle Back Memorial, in Laguna Hills, CA, Hospital Santojanni in Buenos Aires, Argentina and the Medical Department of American Airlines in Dallas/Fort Worth. Three lead EKG, heart rate, blood pressure, arterial oxygen saturation, end tidal CO<sub>2</sub>, respiratory rate body temperature and real time video were collected from a passenger and transmitted to each facility from the aircraft via the Internet. Access to the Internet was gained via the cellular phone aboard the aircraft. Results: Twenty simulated scenarios were successfully transmitted simultaneously to all health care facilities. All data was received without any corruption with an average delay time of 1 sec. Conclusions: Close monitoring of the patient can lead to a better understanding and assessment of a medical condition, improving in-flight patient care, accelerating the decision making process by making an early diagnosis, and correcting a life-threatening condition before the patient arrives at the destination.

**Introduction:**

In-flight medical emergencies remain a concern for airlines. According to the Federal Aviation Administration, 65% of US airline carriers reported a total of 14,334 in-flight medical emergencies from 1990 to 1993, averaging approximately 10 cases per day. This resulted in 190 unscheduled landings due to the inability to assess or treat the ailing passenger on-board (1). Cardiac, neurological and respiratory events accounted for most of the unscheduled landings. Unofficial sources estimate that any diversion represents an average cost from \$30,000 to \$50,000. According to Cummins, most of in flight medical emergencies which made an unscheduled landing were unnecessary as the morbidity probably would not have changed had the treatment been delayed for one or two hours (2).

The implications for any unscheduled landing could be efficiently prevented if an adequate assessment was made in the air. As of today, there is no method available to estimate a patient's condition by means of telemetry of vital signs from a commercial aircraft.

Interestingly, at only two years away from the 21st. century, critical communication channels between the airplane and ground rely only on voice communication via a two-way radio. As of today there is no method to broadcast patient's vital signs in real time from a commercial aircraft, as critical communication channel between the aircraft and ground is limited by voice communication via a two-way radio. The objective of this study was to test the feasibility of combining already existing technologies to find a cost-effective way to obtain the "linking" pathway from an aircraft to a ground medical facility to transmit vital signs and real time video of a sick passenger, conducting a simulated on line triage.

**Material and Methods:**

The system consisted of a medical monitoring system, a lap top computer, cellular telephone technology (aircraft seat-back telephone) and the Internet. Only customized software was written specifically to integrate and coordinate the hardware employed.

The vital signs monitoring setup consisted of a portable device, Propaq 106 provided by Protocol Systems (Beaverton, Oregon). This apparatus was the perfect monitor for this application due to its light weight (<13 lbs. fully configured), and its communication port.

Also, it is the only monitor approved by the USAF for large body carriers.

Using the device serial data port (RS-422 or RS-423 protocol), all data collected from the sick passenger by the monitor was transmitted to a 200 MHz Pentium chip based laptop computer, running on a Windows'95 architecture at 19,200 bps.

We developed a powerful software in order to obtain the data, streaming from the Propaq serial port, and to send it as compressed "packets" to the Internet. At the same time a graphical representation of the patient's vital signs were displayed in the LCD window of the computer.

These software algorithms were written in C++ for the Windows95 operating system and utilized the OpenGL graphics library for display. It consists of four separate components: a SerialDevice class, a PacketProcessor class, a ProtocolEngine class, and a Graphical User Interface (GUI) class. The Serial Device class handles raw, byte-level communication with the Propaq device. The PacketProcessor class composes or decomposes messages into packets. The ProtocolEngine encodes or decodes messages into the protocol that the Propaq can understand. Finally, the GUI class handles information display and user interaction.

All packets of "vital signs data" gained access to the Internet via the seat-back telephone aboard the aircraft. This technology sends data from the phone handset to a transmitter in the

plane's belly and then down to one of 130 radio base stations. From there it is sent to one of the ground switch nodes, and then over to the public telephone network to the Internet provider server modem. Audio between the aircraft and recipients was maintained through a second analog phone line. Although the computer modem speed can go as high as 33,600 bps the actual connection achieved was 4,800 bps, which is the standard data transmission speed for cellular technology. Despite this narrow bandwidth, the software compression also allowed the broadcast of real time color video from a digital camera (Pixera, Mountain View, California) connected to the computer allowing the ground stations to act as a remote triage. In addition to the video format, still images were captured from a 640 X 480 pixels window at 24 bit color resolution and imported into a white-boarding application for transmission prior to JPEG compression.

**Results:**

After two consecutive successful ground tests and prior to the flight test, American Airlines technical staff and the Federal Aviation Administration assessed the electromagnetic emission profile of the devices to ensure on board safety. Only aircraft equipped with an cellular phone (AIRONE -AT&T) were eligible for the experiment. All measurements were taken by the authors.

On July 31, 1997, we transmitted vital signs and real time video from a Boeing 757, flying from Chicago to Los Angeles, simultaneously to The Saddle Back Memorial, in Laguna Hills, CA, Hospital Santojanni in Buenos Aires, Argentina and the Medical Department of American Airlines in Dallas/Fort Worth. The primary ground station in California linked to the other health care facilities to the system, mimicking a distributed medical network for remote consultation and diagnosis.

Three lead EKG, heart rate, blood pressure (systolic/diastolic/mean), arterial oxygen saturation, end tidal CO<sub>2</sub>, respiratory rate, body temperature and real time video were collected from a passenger in a non-invasive fashion and transmitted to each facility from the aircraft via the Internet.

In addition, during the broadcast, a computerized vital signs simulator, connected to the portable monitor was used to generate different pathological hemodynamic situations for the ground stations to diagnose. A total of twenty simulated scenarios were successfully transmitted simultaneously to all health care facilities. All data was received without any corruption with a maximum delay time of 1 sec.

**Conclusions:**

To the best of our knowledge, this event was the first of its kind in the field of aerospace communication and/or Telemedicine applications. During the eventuality of an in-flight medical emergency crew members can broadcast passenger's vital signs not only to an assigned medical facility but also to the patient's physician or specialist's desktop computer at the office, anywhere in the world, disregard the geographical location of the aircraft at that time. It only requires an Internet connection. Furthermore, with today's technology vital signs can also be transmitted to any hand-held portable device with Internet capabilities built-in. This system can enable medical staff 30,000 feet below to tell whether a passenger is suffering from heart attack or just having an "upset" stomach, giving the millions of people who fly each day the same emergency medical resources available on the ground.

According to FAA studies, not only more people are flying but also more "elder" people are choosing the aircraft as the ideal transportation (1). However, individuals with already known underlying medical conditions such as heart or lung problems (asthma, coronary disease, emphysema etc) are not aware of the danger and risks involved in flying and being exposed to an artificial environment such as an airplane cockpit. As of today pre-flight screening of this "high risk" civil airline passengers group is not yet available, as legal and human right issues are needed to be solved (3). Acceleration during take-off, dehydration, immobilization for long periods in seated positions, vaso-vagal reaction are some of the most common factors that contribute to stress while flying and can evolve into an in-flight medical emergency (4). In addition, oxygen saturation of the blood is lower on an aircraft flying at 30,000 feet than it is on the ground (5).

Furthermore, the number of this "high risk traveler" group seemed to be in increase, as reported by the FAA, after 1990 passage of the Americans with Disabilities Act, which forbids airlines to screen travelers for physical disabilities. As of today there is no way to decide whether a passenger is suffering from a heart attack or an upset stomach, and upon this situation the plane will land mainly because the information passed by the pilot is generally insufficient. On the 1997 report (1), the FAA noted an increased incidence of in-flight illness aboard the U.S airlines, from less than two cases per million passengers in 1990 to almost four per million in 1993. Our system has the potential to identify this group of "medically at risk passengers", and monitor them all along the flight, trying to prevent any medical condition before it happens. The FAA also reports that a physician is found on board on 85% during an in-flight medical emergency. Despite these figures air-safety is still compromised as airlines, especially US carriers, are equipped with very basic medical supplies, so even a well-trained doctor can provide with very limited help.

In 1986 the Federal Aviation Administration regulated the use of the "medical kit" on board (6). This set of useful medications which includes epinephrine, nitroglycerin, diphenidramine, and 50% Dextrose solution are available to be used on an ailing passenger without any monitoring of vital signs during an in-flight emergency crisis. In order to achieve better patient care, administration of such drugs should be closely administered and its effects monitored as it's been done in an Intensive Care Unit setting. An in-flight telemetry unit with built in video can help crew members to safely administer such drugs and the effects closely monitored by the ground medical staff.

Flight attendants can easily be trained to set up the monitoring device which only requires attaching three wired "sticky pads" to the passenger's chest and turn a computer on. This

system can make the pilot work with physicians on the ground to choose to continue or to make an emergency landing which by itself it is a very costly decision if not necessary.

Because we were looking for a very versatile system, the Internet was chosen, as the electronic bond to deliver the information to any computer or hospital network in the world as Internet language (TCP/IP) can be understood by any computer disregard its operative system (DOS/Windows/UNIX/Mac/OS). Security is not a problem as today's encryption codes allow data delivery in a very safe fashion. As the data transmitted is sent in digital format and traveling over a wireless network, its quality is significantly superior to that one transmitted from ambulances over radio frequencies for short distances. This technology is not exclusive from the aerospace industry, therefore this application can be useful in other public places located in remote areas such as ski centers, seaside resorts, ships, police vehicles, etc.

Currently, ambulances and other rescue vehicles use analog radio signals as the only wireless alternative to transmit medical data such as electrocardiogram and other vital signs to medical facilities only. However, the range of this transmission is very limited depending on factors like the signal power, geography of the region and hospital location. Evidently this type of resources are not applicable if transmission of vital signs from a flying jet is sought. With the help of computers we were able to convert the same data into a digital format delivering it to the desired location without any corruption and with no limitations.

The concept of telediagnosis is not new. Information technology has been used "on the ground" for many years to examine patients located in distant areas, to review pathology tissue samples or to examine X-rays. The bandwidth used for this purpose ranges from 28,8 Kbps to 10 Mbs, which contrast significantly with the almost 5 Kbps available in a commercial aircraft

through the cellular phone. Our main contribution was to adapt this "ground wire-based" technology to work on an airplane in a "wireless fashion".

The use of satellites will definitively increase the speed of communications from 4,800 bps to 64,000 bps, but this technology is very costly. An alternative would be to increase the amount of data per transmitted packet as opposed to increasing the packet transmission rate. Undoubtedly, software developers will be playing a crucial role in this field. We believe that a portable monitor can merged with a computer into a single portable unit able to gain access to the Internet via modem or satellite.

The general public is perhaps facing new challenges in how health care will be handled in the next century. Telemedicine is a new growing discipline, which relies on information technology to diagnose diseases and treat patients in remote locations without the need for the acting physician to be physically at the site

In summery, we proved that vitals signs and real time video from ailing passengers aboard commercial aircraft can be transmitted to doctors anywhere on the ground during an in-flight emergencies in a very cost-effective fashion using cellular telephone technology. Close monitoring of the airborne patient will lead to a better understanding and assessment of a medical condition, improving in-flight patient care, accelerating the decision making process by making an early diagnosis, and correcting a life-threatening condition before the patient arrives at the destination.

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