CONSERVING TELEMETRY BANDWIDTH IN FLIGHT TEST INSTRUMENTATION

Carl E. Hoefener
Director, Business Development
Interstate Electronics Corporation
Anaheim, California 92803

ABSTRACT

The more sophisticated weapons systems become, the more information is required for thorough system test and evaluation. With the increasing capability in instrumentation technology, more data is being generated, and this in turn is stressing the amount of telemetry bandwidth available. In the training community this is even more serious because of the extremely large training areas and number of players involved. Total data bandwidth required becomes an insurmountable problem.

When examining the telemetry data requirements for each application, we must constantly remember that information transfer is the key, not necessarily the transfer of large amounts of data. This problem can be solved by applying instrumentation techniques that enable significant information transfer without requiring excessive data bandwidth of the telemetry system.

The general approach to the solution of this problem has been applied to the U.S. Government's SDI Program. Here the total system is modeled in a computer, and a complete test exercise can be simulated. Only significant information from the vehicle under test is telemetered periodically to verify the simulation. Another approach has been postulated by the U.S. Defense Advanced Research Projects Agency (DARPA) in their SIMNET studies. Here an exercise is simulated both on the ground and in the test vehicle, and information is transmitted from the test vehicle only when the actual vehicle performance differs from the simulation. By using techniques of this type, savings of a factor of 10 or more can be experienced in the required telemetry bandwidth. This paper examines various techniques that can be used to minimize required telemetry bandwidth.

THE PROBLEM

Information transfer in test and evaluation and training exercises is a growing requirement because of the ever more complex platforms, weapons systems, and test and training scenarios. Advancements in electronics and instrumentation system technology enable us to acquire vast amounts of data very rapidly. Therefore those conducting test and training exercises expect vast amounts of data from these exercises. Severe problems then occur because of the total telemetry bandwidth required to transfer these large amounts of data. Since the available radio frequency spectrum is extremely limited, we must carefully select the data to be transmitted, eliminating all redundant or meaningless data. What we actually require, however, is not data but information. We must stand back and take a higher level view of the purpose of the exercise we are trying to instrument. By data, we are referring to "symbols," usually binary symbols, or bits, which are sent down on the telemetry link. By information, however, we mean that the redundancies have been removed, and each bit represents a true bit in the information theory sense. This requires carefully planning our tests from the top down, constantly questioning what information is required, not what data can be made available.

Striving to minimize the required telemetry bandwidth, therefore, we must reduce our system data requirements to represent true information. The training community has continued to ask for more and more data as instrumentation capability improves, but we must now reexamine our real data requirements to provide only information we really require. Fortunately much work has been accomplished in this area of bandwidth reduction both by DARPA (Defense Advanced Research Project Agency) and the SDIO (Strategic Defense Initiative Organization). To illustrate, some real examples are in order.

EXAMPLES

In the SDI Program the test and evaluation program is centered at the National Test Facility in Colorado Springs, Colorado. This is a large computer installation where the performance of various vehicles can be simulated. Let's take a launch vehicle, for example, where we want to verify its performance. We can simulate it and obtain only actual test data to verify the simulation. If we know the state vector of the launch vehicle, we can easily simulate or compute skin temperatures and pressures, using the known aerodynamic characteristics of the vehicle. It is not necessary then to transmit loads of temperature and pressure data if we have an accurate state vector of the vehicle in flight. Most of the required data can be derived from the simulation, and only key information needs to be transmitted from the test vehicle. Through simulation and verifying key parameters by actual flight test, the transmission of much redundant data can be eliminated. This, of course, assumes a good model of the vehicle.

TECHNIQUES

Another fallacy promulgated in our test and training community is the continuing increased requirement for the decreasing allowable amount of data latency for a measurement. It is recognized that we must know precisely when an event took place, but forcing an increase in data sample rate to reduce data latency is not the solution. With modern capability available, such as GPS, we can know time on the test vehicle to 100 nanoseconds. Data samples can be easily time-tagged, enabling precise exercise reconstruction at the data reduction facility. Only in the case of safety of operation can the real requirement for minimum data latency be justified regardless of the test or training scenario. By the full application of precision time tagging, the required data sample rate of many of our test and training data requirements can be greatly reduced.

In many instances we are interested in when an event happens, such as the firing of a weapon. In the past we would have sampled trigger position continuously at a relatively high rate to detect the precise time of trigger pull. By properly implementing this measurement, we would send only trigger pull information the moment it occurred or simply transmit a precise trigger pull time after the fact. Techniques such as this can greatly reduce telemetry data bandwidth requirements.

One of the most useful methods used to reduce required telemetry bandwidth is the application of dead reckoning models. It has been stated that “dead reckoning is used to reduce the amount of network data traffic to a manageable level without the need for high-cost, usually proprietary, transmission medium.”(1) This technique is commonly used in DARPA SIMNET applications. A dead reckoning model of player position is carried both in the player and at the ground control site. By using a precise positioning source, such as GPS, the player can determine its exact state vector and transmit it to the ground. If the player maintains course and speed, he easily updates his position by the dead reckoning models both on the vehicle and on the ground, making continuous transmission of position data unnecessary. Limits are established on the vehicle dead reckoning model so that whenever the actual position of the vehicle, as determined by GPS, differs from that computed by the model by more than 1 meter, for example, the model is corrected, and the new position data is also transmitted to the ground. Position data is therefore transmitted from the vehicle only when required, not continuously at an artificially high rate. For example, during low activity such as level flight, position data might be transmitted at a low rate such as one sample per second, but when the aircraft begins violent maneuvers, the sample rate would increase to perhaps 30 times a second or more. Then when the aircraft returns to level flight, the data sample rate would be reduced.

RESULTS

This concept has been studied using actual data taken from violently maneuvering aircraft. Updating the position and orientation of remote vehicles at extremely high sample rates to achieve remote vehicle position and orientation accuracies has been proven unnecessary to achieve fully effective training and engineering applications. An experiment was conducted using simulator flight test data derived from the F-16 Paris Air Show routine flown in the late 1970s. The maneuvers performed during this flight routine can be described as approaching the extremes for human-controlled flight performance. The flightpath was analyzed by a program that implements a first-order dead reckoning algorithm and counts how many position updates would have been “sent” over the 5-minute course of the air show routine. The results of this experiment indicated that 1-meter position accuracy could be maintained with a sample rate of only 2.5 samples per second during the entire routine. This of course means that for normal test and training scenarios having lower dynamics, very low sample rates are permissible, and these rates would have to be increased to only 2.5 samples per second or above in very rare circumstances.

This paper calls attention to our current tendency to increase the quantity of data and the data sample rates requested simply because the instrumentation capability exists. The real choke point, whether in test and evaluation or training, is that the available telemetry bandwidth is always limited, and we increase the available bandwidth at tremendous expense.

In the past we have simply tended to increase the number of data channels and sample rates because of vehicle dynamics and data latency requirements without actually examining the information required in our test and training operations.

REFERENCE

1. Harvey E, Schaffer R, and Waters R: “Is distributed interactive simulation technology adequate for aviation tactical team training?,” BBN Systems and Technologies, Cambridge, Massachusetts.