PCM BACKFILL: PROVIDING PCM TO THE CONTROL ROOM WITHOUT DROPOUTS

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ABSTRACT

One of the initial control room capabilities to be demonstrated by iNET program is the ability to provide data displays in the control room that do not contain data dropouts. This concept is called PCM Backfill where PCM data is both transmitted via traditional SST and recorded onboard via an iNET compatible recorder. When data dropouts occur, data requests are made over the telemetry network to the recorder for the missing portions of the PCM data stream. The retrieved data is sent over the telemetry network to the backfill application and ultimately delivered to a pristine data display. The integration of traditional SST and the PCM Backfill capability provides both real-time safety of flight data side-by-side with pristine data suitable for advanced analysis.

KEY WORDS

Pulse Code Modulation (PCM), network, wireless, telemetry, data processing, Telemetry Network System (TmNS), integrated Network Enhanced Telemetry (iNET), Transmission Control Protocol (TCP), recorder, Enhanced Query Data Recorder (EQDR).

INTRODUCTION

Telemetry via PCM is inherently prone to data dropouts. The concept of being able to fill in these dropouts, a process called PCM Backfill, was introduced in [1]. In that paper, PCM Backfill, an application in the Mission Control System (MCS) telemetry processor, was introduced as a demonstration application of the network telemetry link being implemented by the iNET program. This application requires the capability to send a command from the ground to the test vehicle and receive data via the network telemetry link (in contrast to the serial streaming telemetry (SST) PCM link.) Another key dependency is the existence of an intelligent recorder that can service data requests in flight for the dropped data and return the data in a timely manner. The Test & Evaluation Science & Technology (T&E S&T) Spectrum Efficient Technology (SET) portfolio has been funding the development of such a recorder, the Enhanced Query Data Recorder (EQDR). These two capabilities provided by MCS and the EQDR implement the basic infrastructure needed to backfill PCM and display a pristine data stream (i.e., a data stream with few or no dropouts).

A test flight is a series of test points. Test points are not always flown correctly first time they are tried. Further, test points are sometimes sequentially dependent with increasing risk. Each test point is thus validated before moving on to the next test point. The purpose of data monitoring in the control room is to insure the integrity of the data recorded and to make sure the test was conducted in a way that maximizes the usefulness of the data collected. By providing error free data in the control room, engineers are able to engage in more extensive data analysis in real-time, thus allowing for critical decisions to be made rapidly. This can allow implementing more test points during a test and avoiding costly and time consuming re-testing.

In a typical test scenario, engineers monitor data in a control room for several purposes, chief among them are safety of flight and test efficiency. PCM Backfill may play a role in both of these purposes but should be the most beneficial for test efficiency. The data retrieval process takes some finite amount of time so PCM Backfill may or may not provide additional information in the split-second timing needed to make safety of flight decisions. However for test efficiency, PCM Backfill might recover data so that a test point with dropouts does not need to be repeated. This allows the project to move on to the next test point quickly thus saving money for the project.

SYSTEM ARCHITECTURE

The PCM Backfill effort was added to an existing project called Onboard Smart Sensor (OSS). OSS is an effort to integrate networks of smart sensors with an onboard data acquisition system. The test configuration for PCM Backfill consists of both test article hardware and a ground data processing system as shown in figure 1.

TEST ARTICLE HARDWARE

The OSS test instrumentation configuration was augmented with an L3 Communications Telemetry East Compact Data Manager (CDM) (1) and a Kauai Software Solutions EQDR (2) for PCM backfill. The CDM bridges standard Serial Streaming Telemetry (SST) Pulse Code Modulation (PCM) to a network. The CDM outputs standard iNET TmNS Data Messages. In-flight, the EQDR (2) records the TmNS data messages received from the CDM. The EQDR also services data requests received from the ground data processing system. TTC nXCVR-2000 (3, 4) network radios are used to construct a wireless telemetry network between the test article and a ground station.

GROUND DATA PROCESSING SYSTEM

The ground processing system is based on the JT3 LLC Mission Control System (MCS) telemetry processor used by the 412th Test Wing at Edwards AFB. The MCS consists of a Computer Sciences Corporation (CSC) DX Decommutator (PCM Decommutator) tied to commodity hardware with a CSC ION data bus. Rack mounted Dell 1950 computers are used to perform engineering units (EU) and application processing in the MCS (6) as well as for the PCM Backfill module. The MCS was also augmented with an EQDR (5) that is used to record TmNS Data Messages generated by the PCM Backfill module.

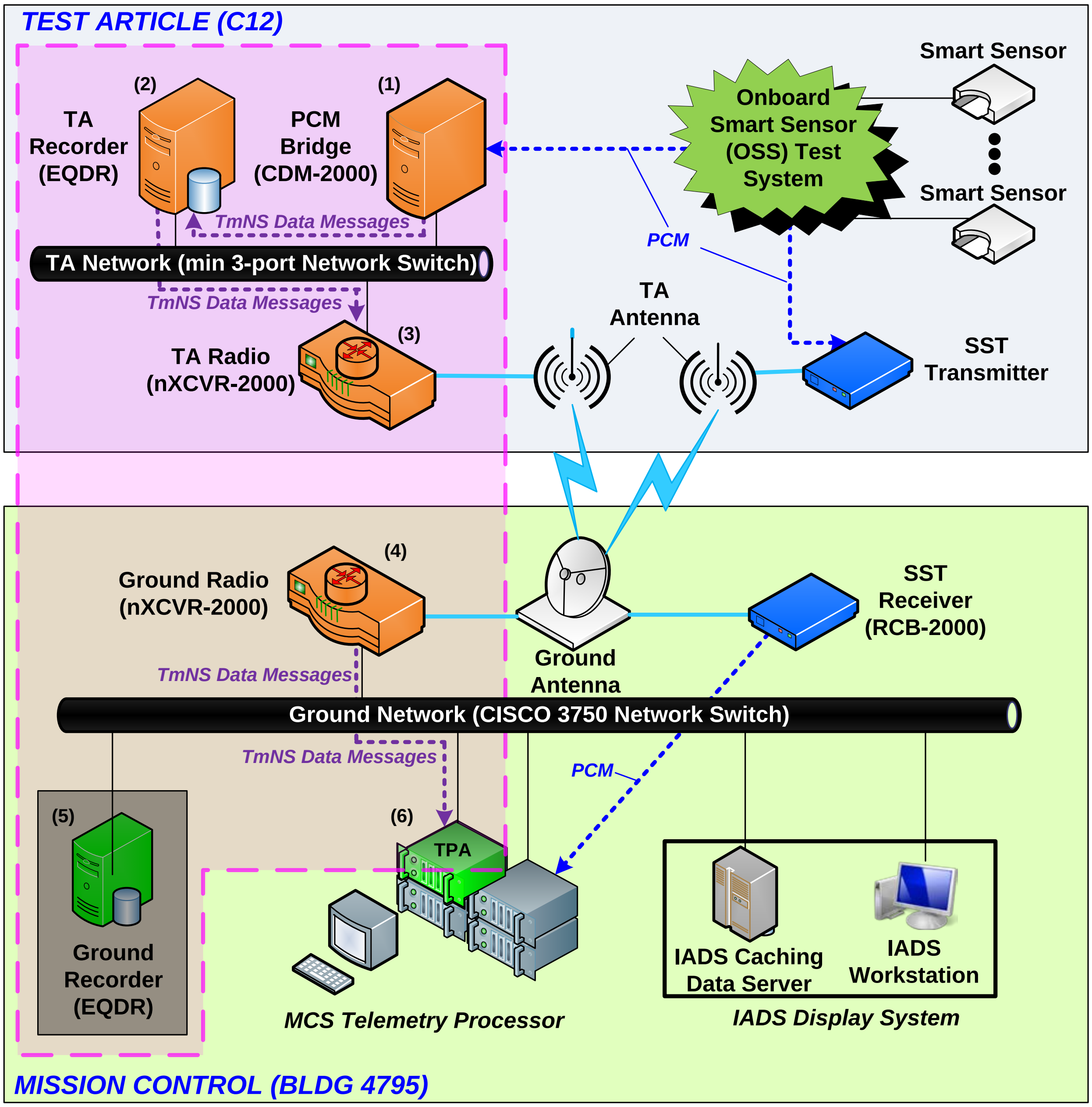

Figure 1 Ground Data Processing System and Test Article

SOFTWARE ARCHITECTURE

The DX Decommutator deserializes IRIG 106 standards PCM and transfers this data to the other MCS components using the ION Bus. The PCM Backfill module receives the PCM data from the ION Bus and performs software frame synchronization on the PCM stream. This creates a virtual flow of PCM data frames. When the PCM Backfill module detects a PCM dropout, any subsequently received PCM frames are stored in a first-in-first-out (FIFO) queue for later processing. Once the dropout ends PCM data frames in the form of TmNS data messages are requested from the test article EQDR. Theses PCM frames are inserted into the virtual flow of PCM data frames to replace the PCM frames lost in the dropout. The completed flow of PCM data frames is output as iNET TmNS data messages as well as processed with the standard MCS modules for software decommutation and EU conversion used for standard SST PCM data streams. This pristine data as well as the standard, noisy SST PCM stream are then sent from the MCS to the Symvionics Interactive Analysis and Display System (IADS) to be time aligned and displayed. A detailed decomposition of the PCM Backfill module is provided in figure 2.

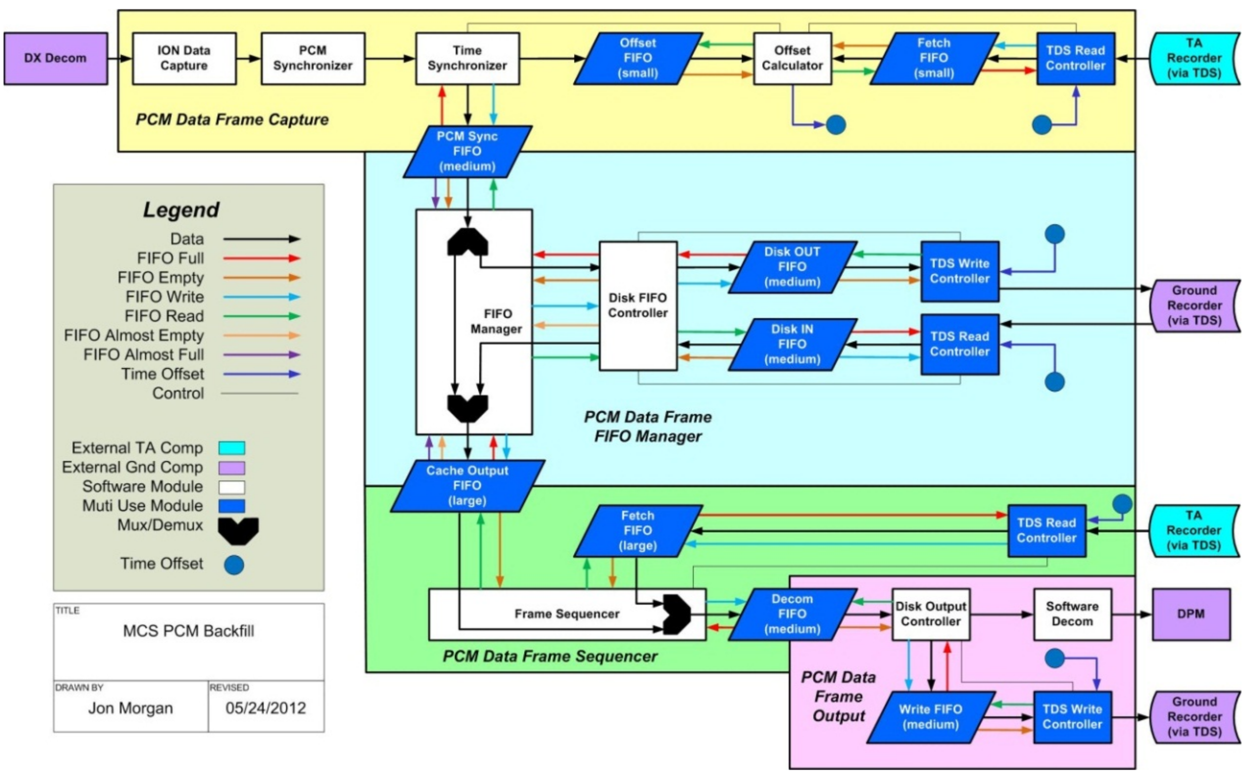

Figure 2 Detail of the Decomposition of the PCM Backfill Module

REAL-TIME DISPLAY

An example of a dropout recovery operation is shown in this PCM Backfill test display in figure 3.

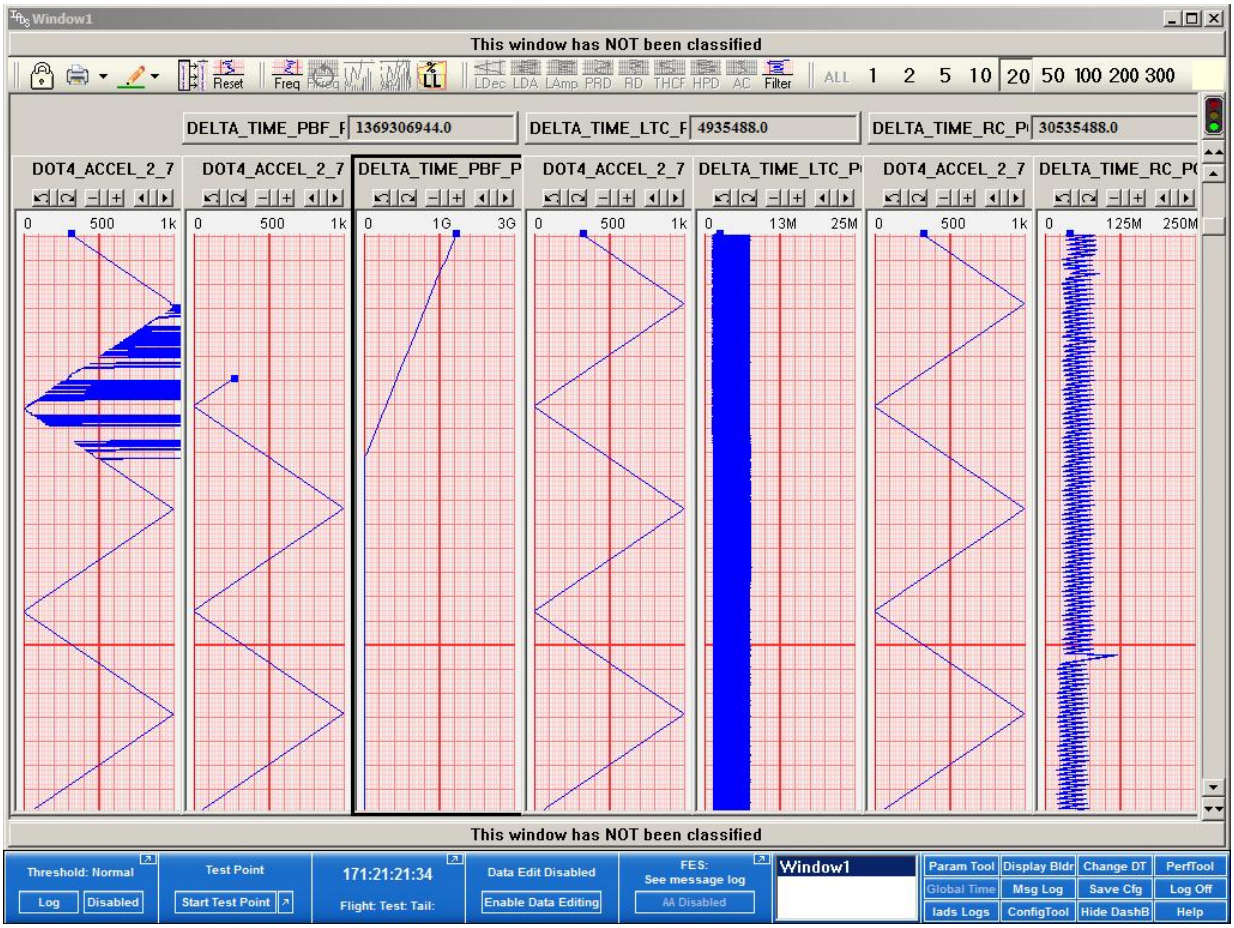

Figure 3 IADS Display of a Dropout Recovery Operation

There are 7 traces on the IADS Display shown above in figure 3, referenced left to right:

1. The normal SST PCM measurement DOT4_ACCEL_2_7.
2. The PCM Backfill version of measurement DOT4_ACCEL_2_7. Notice that the pen for trace #2 is approx. 25% of the way down the chart. This is because of the dropouts shown on trace #1 are being actively retrieved from the test article EQDR.
3. The time in nanoseconds that trace #2 is behind trace #1. In the above example, '1G' represents 1 second. UDP Streaming version of DOT4_ACCEL_2_7.
4. The UDP streamed version of measurement DOT4_ACCEL_2_7.
5. The time in nanoseconds that trace #4 is behind trace #1. In the above example, it bounces between approximately 2 and 7 milliseconds.
6. DOT4_ACCEL_2_7 retransmitted via TCP from the test article EQDR.
7. The time in nanoseconds that trace #6 is behind trace #1. In the above example, it bounces between approx. 30 and 75 milliseconds.

When data is not dropping out, all traces look much the same as in figure 4 below. Notice that the trace #2 is only 3 to 5 milliseconds behind trace #1.

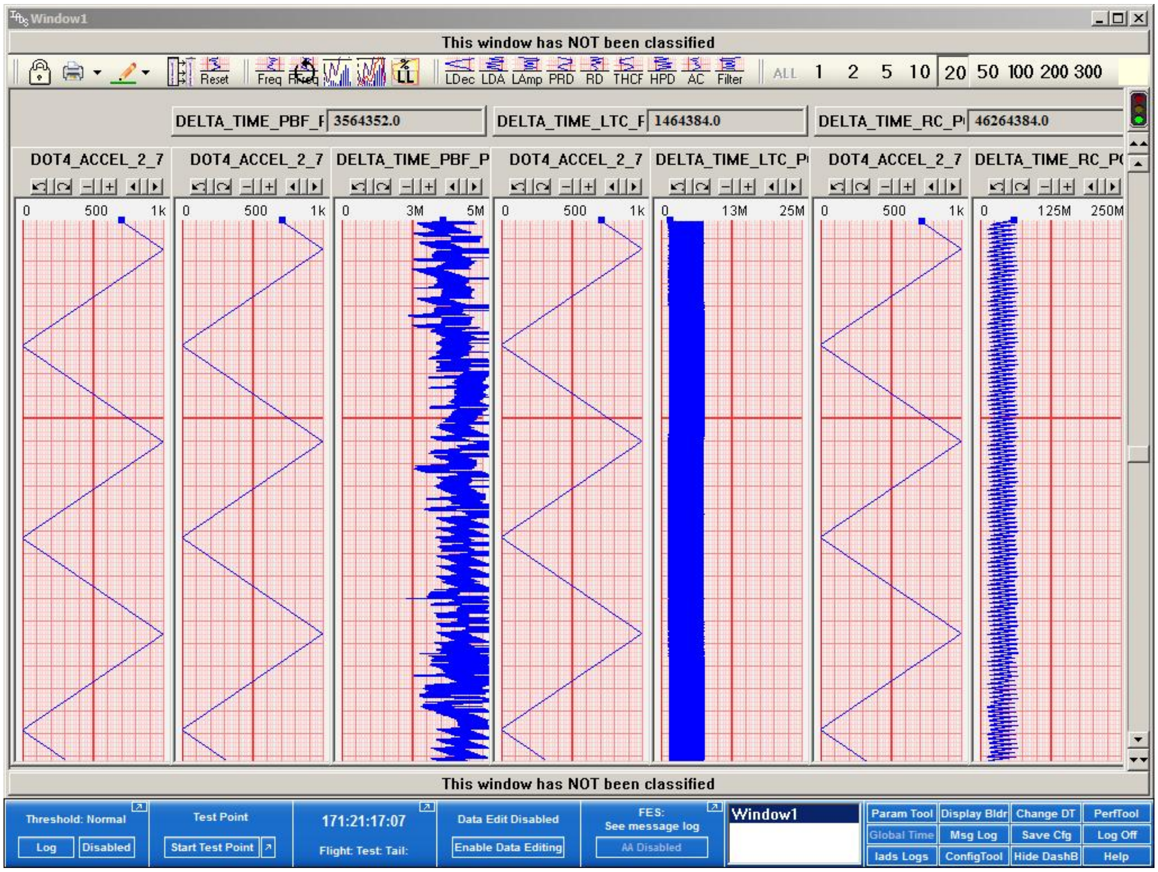

Figure 4 IADS All Traces Look the Same When Data is not Dropping Out

TIMING AND SYNCHRONIZATION

Proper synchronization of time between the iNET TmNS Data Messages recorded on the test article EQDR and the ground PCM processing system is crucial. If the system is unable to select the proper PCM frames off the EQDR recorder for insertion into the PCM Backfill stream, then a lossless PCM data flow cannot be established.

The PCM Backfill module establishes proper time synchronization by periodically selecting a successfully acquired SST PCM frame and then querying the test article EQDR for a time range that should include that frame. Each frame retrieved from the test article EQDR is then compared to the successfully acquired SST PCM frame. Once a match is found, a time offset between the recorded data on the test article EQDR and the ground PCM data is established. Future queries can use this offset to determine proper selection and insertion of retrieved frames into the PCM Backfill data flow. It is important to note that the PCM data must be unique. That is, each of the frames selected in the window of comparison must be uniquely differentiable; otherwise, a false synchronization may occur.

DATA ANALYSIS

To determine the effectiveness of PCM Backfill, two methods of verification were used, measurement based comparison and iNET TmNS Data Message based comparison.

Measurement base comparison was performed during lab testing. Real-time data verification tools were used to verify the data output of the backfill module before, during, and after backfill operations. These tools operate by using simulated PCM data with a long sequence of known values for each measurement and then examining the value of each measurement in real-time to determine the values are in the proper sequence. These tools can operate on all measurements simultaneously. The only downside of these tools is that they only work with known, simulated data.

The INET TmNS data message comparison tool was developed to compare iNET TmNS Data Messages. This tool took the contents of both the test article EQDR and the ground recorder and compared the PCM frame data to ensure that no frames were lost, inserted or duplicated.

CONCLUSION

PCM Backfill has been implemented using an iNET based telemetry network and an intelligent airborne recorder (the EQDR). Required changes to 412th Test Wing's control room hardware were minimal. Some software was developed, but this was interface software that did not drastically affect the existing MCS/IADS system. The two main difficulties were designing a software architecture to implement the backfill and establishing methods for synchronization and timing that minimize delays in displaying the pristine PCM stream.

The ability of PCM Backfill to provide near-real time error free data allows test engineers to be more aware of what is happening on the test vehicle. This error free data also allows for more complete data analysis in the control room during the test. The importance of this error free data is that more test points can be safely flown during a single test operation (or, conversely, to more easily and quickly identify problems that require test termination). This, in turn, decreases costs and schedule by potentially eliminating retests and reducing the number of test operations needed in the first place.

REFERENCES

[1] Laird, Daniel T., Edwards AFB, and Morgan, Jon, Data Flow and Remote Control in the Telemetry Network System, Proc. International Telemetering Conf., Vol. XLV (2009) Paper 09-24-02.

ACKNOWLEDGEMENTS

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ERRATA

Dr. Jones would like to correct an egregious omission in the ITC 2000 paper "*Juggling and Telemetry*". In that paper, Dr. Jones omitted an acknowledgement that Jon Morgan originally identified the basic relationship between juggling patterns and PCM formats.