# ENCRYPTED BIT ERROR RATE TESTING

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## Abstract

End-to-End testing is a tool for verifying that Range Telemetry (TM) System Equipment will deliver satisfactory performance throughout a planned flight test. A thorough test verifies system thresholds while gauging projected mission loading all in the presence of expected interference.

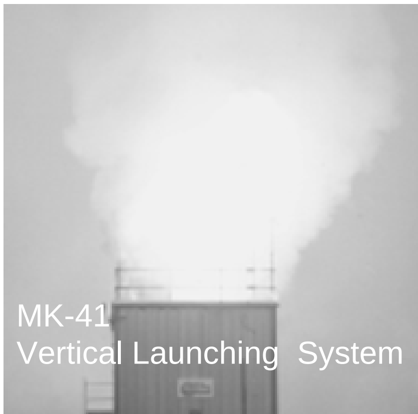
At the White Sands Missile Range (WSMR) in New Mexico, system tests are routinely conducted by Range telemetry Engineers and technicians in the interest of ensuring highly reliable telemetry acquisition. Even so, flight or integration tests are occasionally halted, unable to complete these telemetry checks. The Navy Standard Missile Program Office and the White Sands Missile Range, have proactively conducted investigations to identify and eliminate problems. A background discussion is provided on the serious problems with the launcher acquisition, which were resolved along the way laying the ground work for effective system testing. Since there were no provisions to test with the decryption equipment an assumption must be made. *Encryption is operationally transparent and reliable.*

Encryption has wide application, and for that reason the above assumption must be made with confidence. A comprehensive mission day encrypted systems test is proposed. Those involved with encrypted telemetry systems, and those experiencing seemingly unexplainable data degradations and other problems with or without encryption should review this information.

*Keywords: Encryption, Bit Error Rate Test and Systems Test.*

## Background

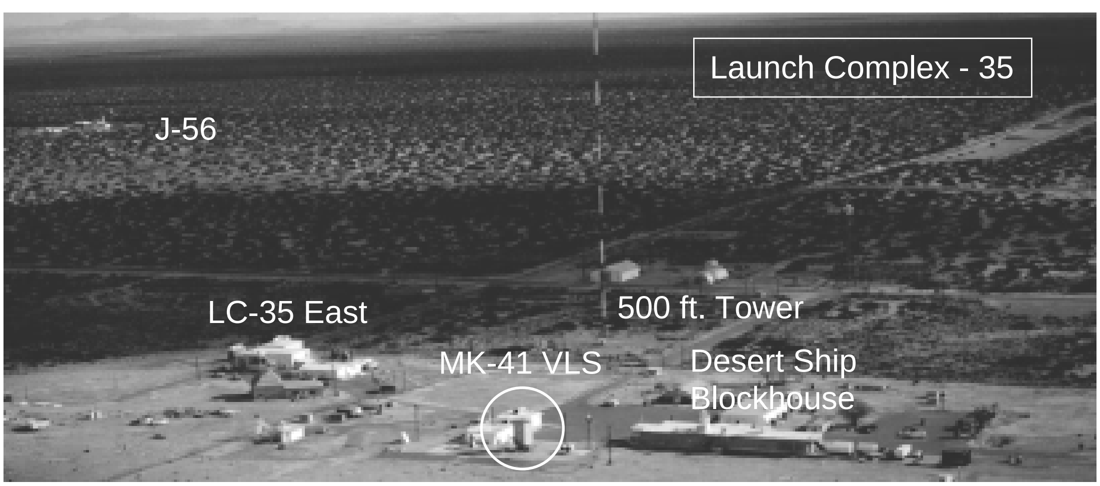
Navy Flight Tests face severe telemetry acquisition challenges in the launcher. The tactical MK-41 Vertical Launching System(VLS) shown following page is used at WSMR to launch several types of missiles. The launch canister serves as a magazine as well as the launcher. The canister is designed to serve as the entire interface to the missile, shielding it from the electro-magnetic environment. This feature also significantly complicates access to missile transmissions.





Canister multipath, at times, is so severe that missions may be aborted despite the high cost. Programs utilizing high bit rate telemeters are essentially deadlocked by these multipath conditions. The multipath spectra shown (above), clearly shows two nulls, each on either side of the transmitter center frequency, hence the receiver is unable to provide any usable data. Resolving this problem required the development of a close coupled probe, and in another case, the redesign of the canister and missile hardware to obtain telemetry data via hardlink. Next is the task of getting these signals to Range Control.

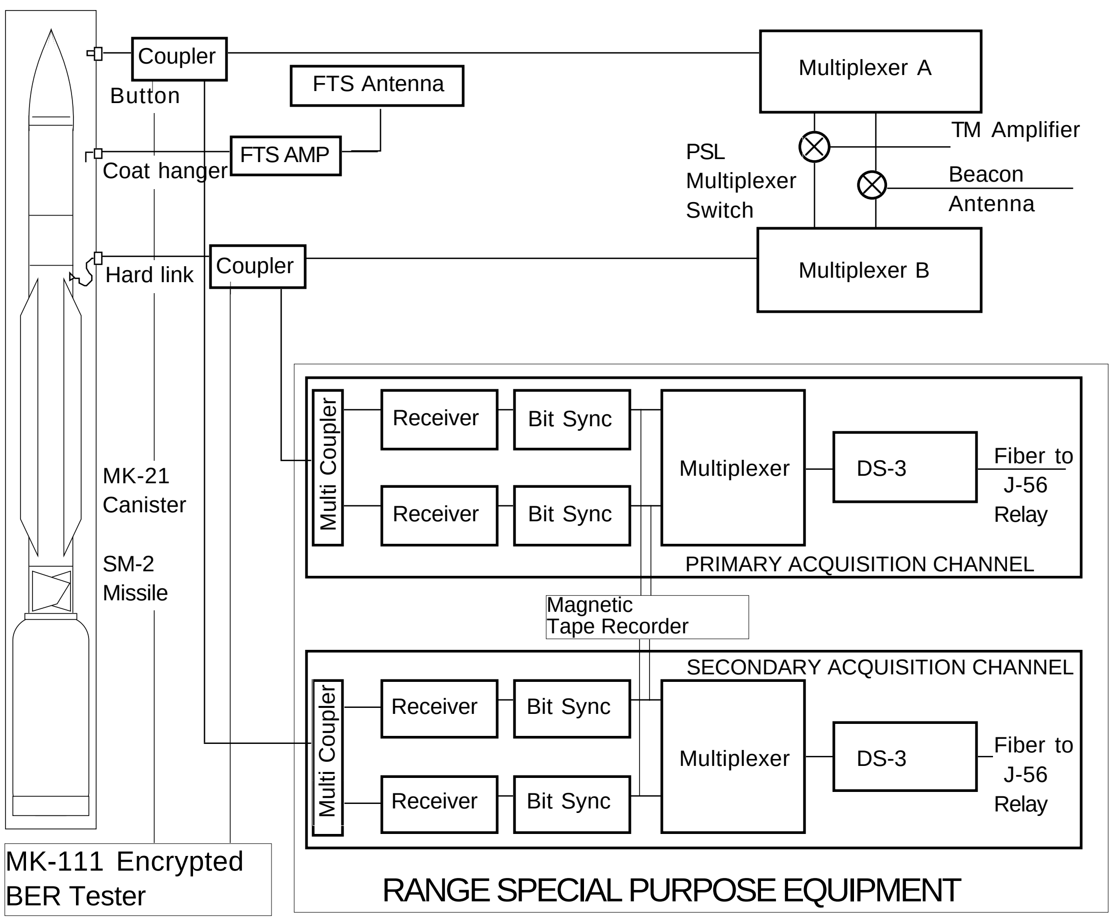
Launch Complex - 35 (LC-35) is a concentration of structures (below) with MK-41 VLS shown lower center. Because of building and structure obstructions, acquisition of the missile signals is difficult. A fairly complex re-radiation system has evolved which assists the acquisition of the radar beacon, telemetry data and the flight termination system. A joint Navy-WSMR effort resulted in a telemetry system for direct acquisition of the signals right at the launcher. This system is connected directly to the missile canister probes, and is designed to facilitate positive, reliable acquisition. Receivers acquire the missile telemetry directly and the bit decision is made right on the spot, with a high quality bit synchronizer. This system, called the Special Purpose Equipment (SPE), locally records the missile telemetry and relays the signals to the Range via digital fiber optics.



Bit Error Rate (BER) Testing -

Prelaunch acquisition has been the Achilles' heel of Navy testing at White Sands. Only in the past few years was the magnitude of this problem realized. A considerable investment was made by the Range and the Navy to field the telemetry acquisition system shown below. During BER testing the test signals are injected via patch panel, which is not desirable, because the system must be reconfigured to return to the flight test set up. The configuration shown below will be in place for future flight tests. BER testing will be conducted in the actual flight mission configuration.

Operationally, it's best for the system to always remain in the mission configuration. At this time, BER checks with the remaining field sites are conducted from this site through an additional steerable antenna. This check will be migrated to Range Control, to enhance configuration control of the entire system.




Launcher Telemetry Acquisition at LC-35

Bit Error Rate Test Design -

White Sands Missile Range is approximately 100 miles long (north to south)and 40 miles wide and is depicted in the graphic shown on this page. Several telemetry stations actually operate off of the Range. The field sites, as shown, span large distances and are a challenge to test.

- *FT. Wingate*

Classically system testing consists of end-to-end BER threshold measurements. A GDP 615 BER Test Set generates the standard 2047 code which is transmitted to each site. The transmitter output is attenuated until the link BER is about 1 X $10^{-6}$. This is the link threshold, which at WSMR typically 1 to 2 dB better than the IRIG Standard. Measurements taken were consistent whether tests were conducted at the Telemetry Data Center (TDC) or the test signal was transmitted from LC-35 acquired 50 mi. away at J-67 and relayed to the TDC. This demonstrates the entire system infrastructure is transparent, with no observable degradations.

Even so, prelaunch acquisition of the live missile remained unreliable, unlike the systems tests, these acquisition problems could not be explained. Since the missile telemetry was encrypted the decryption process became suspect, as the decrypters ,must be bypassed during BER testing.


Testing with actual missile telemeters, less missile, canister and launcher was disappointing. Virtually all of the telemeter words were zero or static, since there was no live or dynamic stimuli. Using the actual telemeter introduced more problems than were solved. The conclusion was that the best test would be the same end-to-end BER threshold test, but with the decrypter operating in circuit.

These findings were briefed to the Standard Missile Program Office and resulted in the development of the MK-111 Tester that incorporated encryption. The MK-111 Tester was developed at the Naval Surface Warfare Center, Dahlgren Division, VA.

Requirements for the MK-111 tester were set out and an encrypted BER test capability became a reality. The MK-111 tester could generate the standard 2047 code (or simulate a PCM telemeter), encrypt the signal then modulate a transmitter. The BER threshold test could now be measured with decrypters in circuit.

*The ESSM Program first to attempt encrypted testing, has adopted the method for all flight tests.*

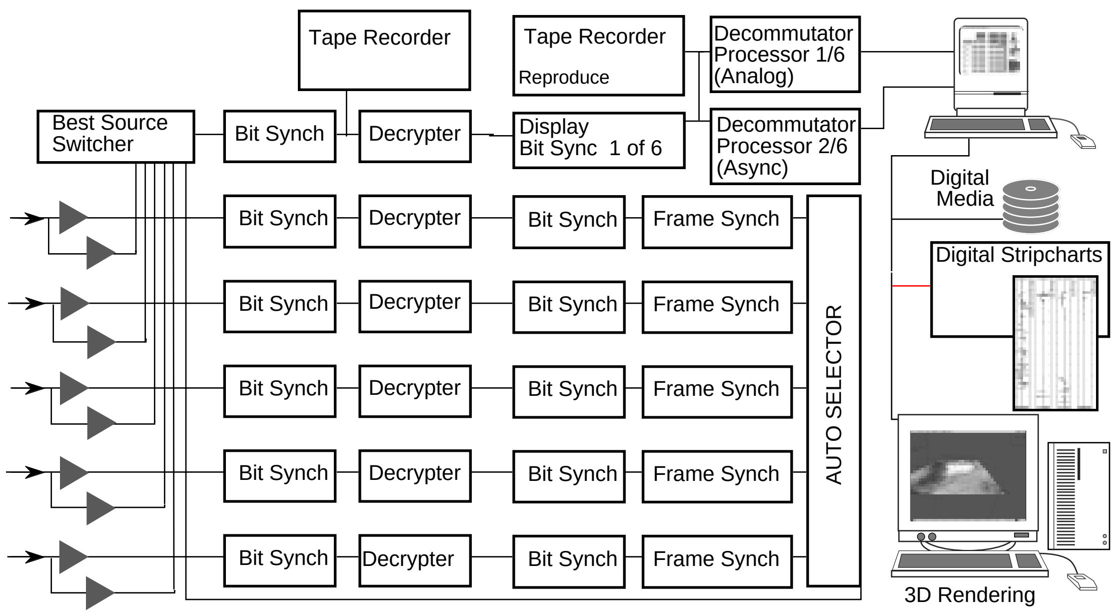
A few months after the tester arrived at White Sands, the Evolved Sea Sparrow Missile (ESSM) program was to conduct integration tests at WSMR. Testing was unable to commence because the telemetry acquisition was so severely degraded that in most cases frame synchronization was not achieved. The following day of trouble-shooting was fruitless. The Range system end-to-end tests were repeated with a Navy witness. The tests were normal, with threshold scores roughly 1 to 2 dB better than the IRIG Standards, consistent with past testing.

The ESSM Program, authorized encrypted BER testing and the MK-111 was stationed at the TDC to test the decrypters directly. A simple screen was devised, with the MK-111 feeding a standard receiver approximately 3 dB above threshold. A bit synchronizer followed as usual, with data and clock signals applied to the decrypter under test. A GDP 615 BER Test Set was used to measure the BER after the decrypter. One decrypter failed completely and a second degraded the threshold by 10 dB, both were replaced. A bit synchronizer failed to operate properly and was replaced. The remainder of the equipment at the TDC ( the terminal end) was processing properly. The MK-111 was then moved to the relay point (J-56). A video distribution amplifier was found not to function satisfactorily and was replaced. Finally the MK-111 was moved to the prelaunch acquisition system. Another bit synchronizer was replaced and finally, the first satisfactory end-to-end encrypted BER threshold test was complete. Afterwards a missile telemetry check was attempted, the resulting telemetry acquisition was successful and normal testing resumed. At the mission debrief the Data Analyst remarked about the lack of noise on the displays.

The encrypted BER test was better than anticipated. Exposing bad decrypters was expected, but to also expose bit synchronizers and drive amplifiers that were suitable was not. Our resulting supposition was that the jitter associated with a signal near threshold, stresses the bit synchronizer normally. The additional stress caused by encryption might be due to lengthy strings of consecutive ones or zeros, causing poor bit synchronizers to lose lock. The drive amplifier in question likely had poor DC response. This equipment previously passed the unencrypted BER threshold test and factory acceptance tests as well.

*The Encrypted system tests exposed weaknesses in the link equipment not found with traditional BER testing, as well poorly performing decrypters.*

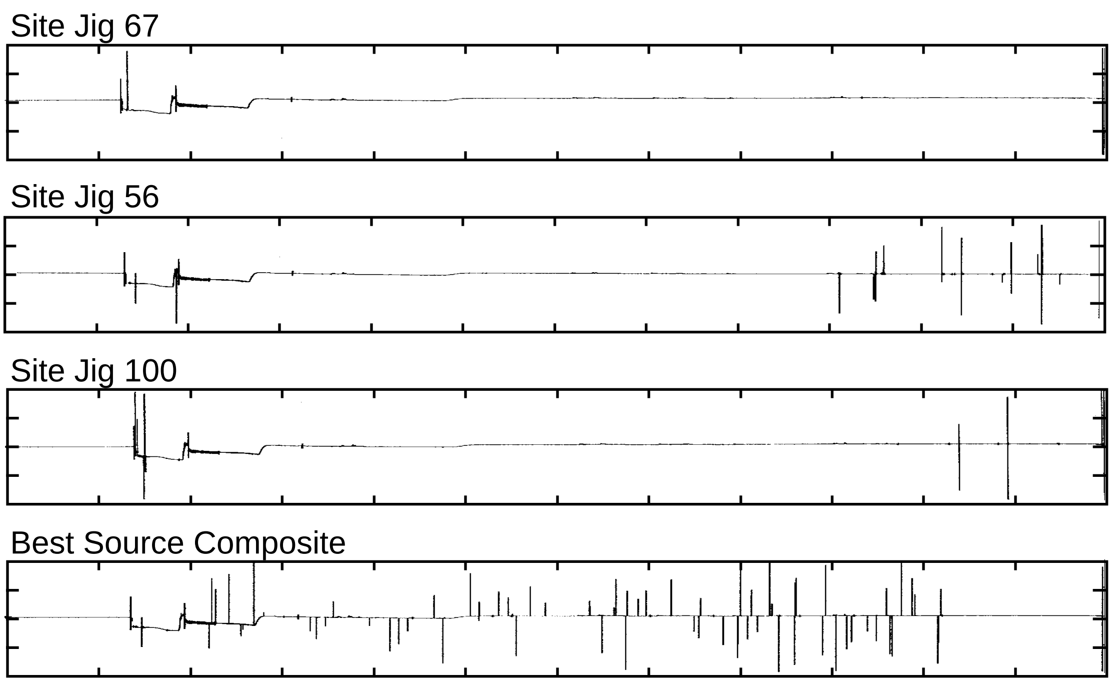
BER analyzers generate test signals and measure BERs. BER testing is designed into the White Sands architecture and BER equipment is deployed at each node of every path. Despite its limitations, the BER allows rapid fault isolation. Once encryption is in place, BER analyses may be performed at the decrypters only. In time inferior equipment will be screened out by the encrypted testing. Shown is a TDC TM processor equipped with six decrypters and related equipment. Five decrypters are equipped with decommutators for the purpose of performing best source selection. Decommutators 1 thru 5 are evaluated by the Autoselector. When a frame synchronization drop occurs, the source with the longest continuous frame synchronization history is selected.




TDC Telemetry Processor

The sixth decrypter processes the selected best source and drives the data processing equipment and all system displays (tape recordings, stripcharts, CRT displays etc). The Autoselector, implemented in analog, may be used to select any Time Domain Multiplex (TDM) including Pulse Amplitude Modulated (PAM) multiplexes or any TDM also frequency multiplexed. This elegant implementation handles most typical telemetry multiplexes. The best source selector switches encrypted data and sources the decrypters, so there are no correlation issues. This process does not deskew the time differences inherent with dissimilar path delays. As a note, up to 13 msec time differences between sources have been observed at WSMR.

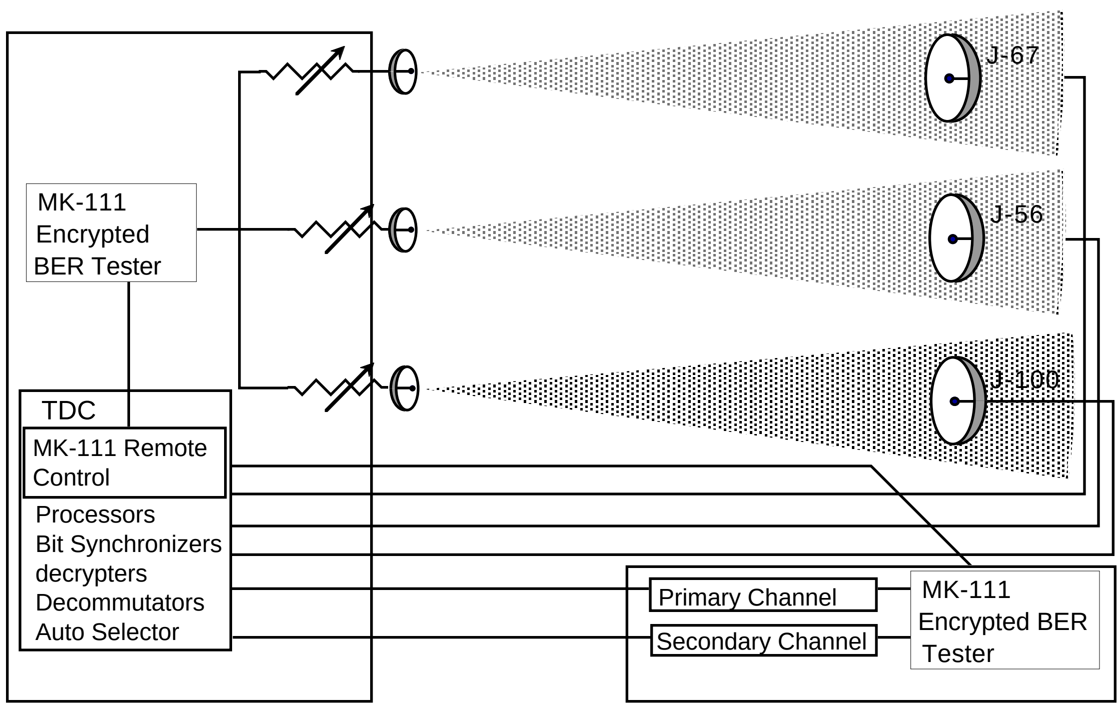
There is a weakness in the Autoselecter design which mars its performance. Problems in the best source path will show up unmitigated in all displays. During recent flight tests, intermittent degradations appeared in the best source data. A review of the field site tape recordings showed the noise was indeed artificial. Every source recorded clean data for most of the flight. Actual data is shown, the best source composite is clean prior to launch and prior to the end of the flight test. During the middle portion of the flight, the three sources exhibit no noise at all, yet the best source is heavily corrupted. In this case, the offending device was an intermittent decrypter, which was isolated on the next mission during encrypted BER checks. Any device in this path could cause similar effects or indications.




Comparative Flight Test Data

Better Systems Test Design-

Encrypted systems testing conducted at the Pacific Missile Range Facility (PMRF) Kauai, HI also encompassed system loading and interference tests. Planned (future mission) telemetry emissions were simulated to realistically load the system and to observe any interference. PCM telemeters were simulated by BER transmission at the appropriate bit rate, analog telemeters were statically generated, specifically in band target telemeters. Levels were varied to simulate typical variances. One of the signals is held at (or just above) threshold while the remaining signal power levels are raised until interference is noted. The margins measured to be 20 dB or more on most PMRF systems. Systems with lesser margins were found to have less than optimally aligned 2nd IF Filters. These systems deliver satisfactory BER threshold performance, but may be marginal during actual mission conditions. The BER Test alone cannot evaluate interference margin nor gauge system loading. Interference margin and system loading can be measured at the same time. During flight tests, interfering sources lie in the same antenna beam at intercept, the most critical test event. Space losses are the same, so variances then are mostly a function of missile and target attitude.




Closed Loop Testing

In the case of the Lance target all receiving stations are subjected to repeating antenna nulls due to its roll stabilization. Interference margin should be healthy to insure clean intercept data during the nulls. Missiles with multiple telemeters require similar consideration. The interference test, despite the complexity, makes sense as the foundation of a system readiness test. The BER threshold test alone might not expose intermodulation or poorly aligned receiving equipment. The diagram shown before depicts one possible configuration which would allow multiple transmissions, hence efficient, concerted testing of BER threshold, system interference and system loading.

Conclusion -

Confidence in the original assumption that decrypters are reliable and transparent can be achieved with adequate encrypted testing. One characteristic does blemish the otherwise transparent operation of a properly operating decrypter. The data and clock signals are not aligned, probably due to the units communications heritage. This was originally observed at bit rates well above the decrypters specifications. Aligning data & clock signals, adding line drivers and an IRIG randomizer would enhance any future implementation. NAWC PM demonstrated a simple logic circuit that realigns the data signal adequately. Refining its design and adding the features mentioned above would make it an essential add-on. Most bit synchronizers could be immediately reallocated.

Conducting a systems test a few days prior to a mission is fine, but the morning of the mission is better. It needs to be done in the hour or two the mission may allow. TDC personnel have recently programmed their decommutators to synchronize on the 2047 sequence. Each decommutator may now be used to perform BER measurements. By transmitting to all acquisition sites simultaneously from TDC, the tests are closed loop, highly parallel which simplifies communication and coordination dramatically. With all sites under test, the system is realistically loaded and interference margins can be measured in concert with the BER measurement. The MK-111 can be remotely controlled and since the TDC decommutators are computer controlled as well, the entire test may be easily automated. Interestingly, the entire test can be performed by one person in considerably less time than a BER check. *The right system test design offers potential benefits that a system manager cannot afford to ignore.*

Normally, after a system test the TDC would have to be reconfigured for magnetic tape playback checks. One hour prior to launch, the TDC would configure for a missile TM check. If any checks remained to be completed the TDC would have to reconfigure to perform those checks. Finally the TDC would be placed in the flight test configuration for the launch. This method is cumbersome, error prone and limits any flexibility the TDC may leverage in supporting a mission. If the checks were to use the MK-111's simulation capability instead of tape recorders, the desired flight test configuration would be actively maintained and tested throughout pre-mission checks. The tape recorder, in particular, is key equipment to be tested. There are yet further benefits that can be derived from this approach.

*There is real potential for reducing workload, cost, operational errors and providing an improved performance in unencrypted applications as well .*

Related Material -

System testing was recently completed at the Makaha Ridge Telemetry Station, Pacific Missile Range Facility by Ken Meeker NWAS, Gene Law NAWC, Rick Shrewsbury NSWC, Tam Tran PMRF and the Makaha Ridge Telemetry Team. The complete documentation is an excellent reference for any system tester. MK-111 info may be obtained from Rick Shrewsbury. Gene Law also mentors the White Sands team, and has authored many related technical papers. Tam Tran is the senior engineer at Makaha Ridge. They can be reached at: MeekerKC@corona.navy.mil, ShrewsburyRG@nswc.navy.mil, LawEL@navair.navy.mil and TranT@pmrf.navy.mil., respectively.

Authors Related Publications -

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| Real Time Telemetry Data Processing | ITC Proceedings, 1996 |

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Makaha Ridge Telemetry Station , PMRF, Kauai HI

inset: Kauai Chicken