TELEMETRY MODERNIZATION AT THE KWAJALEIN MISSILE RANGE

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ABSTRACT

Telemetry support has been a component of the instrumentation test support structure at Kwajalein Missile Range (KMR) for nearly 40 years. From a limited initial suite of manually pointed telemetry antennas, the Range has grown to include nine tracking antennas and four fixed receiving antennas. This paper describes the current modernization program at KMR that will include nine new telemetry trackers and five fixed antennas that will be networked and controlled via fiber optic links from a newly established telemetry control center on the island of Kwajalein. These upgrades will reduce operational cost and institute efficiencies, while continuing to meet Range Users' growing requirements.

KEY WORDS

Telemetry Modernization, Kwajalein Missile Range, Automation, Long Distance Remoting, and Multiple Antenna Remoting.

INTRODUCTION

The Kwajalein Missile Range (KMR) is located in the Marshall Islands, approximately 2300 miles southwest of Hawaii. Located approximately 500 miles north of the equator in the mid Pacific, KMR's location is ideal for supporting all aspects of space, strategic, theater and national missile testing. To enhance its mission support capability KMR has embarked on a modernization program [1] in which much of the Range instrumentation will be upgraded. Sensors are being configured to incorporate common architectures, where practical, resulting in common parts sparing, and reduced maintenance staffing. The new architecture also supports a high degree of automation, enabling instrumentation to be monitored and operated remotely. Sensor control and execution of missions will be from a central location, the Mission Control Center on Kwajalein. The primary objective of this modernization program is to reduce operating cost while continuing to meet Range Users' growing requirements. This objective will be reached by: (1) replacing obsolete high maintenance equipment with modern substitutes capable of fulfilling current and future customer needs, and (2) automating and remotely operating radar, telemetry and optics assets that are in remote locations. The major benefits to KMR are improved

efficiency and reduced cost of operation. High maintenance unique components will be replaced with commercial-off-the-shelf (COTS) equipment. This paper focuses on the modernization of the KMR telemetry assets.

As shown in Figure I KMR telemetry assets now include nine tracking antennas and four fixed antennas currently distributed over four islands in the Kwajalein Atoll. Supporting personnel are shuttled daily to their work sites by air and sea. Fixed wing aircraft and helicopters are used to transport personnel to and from their work site. Reconfiguring telemetry assets in preparation for a particular mission routinely requires moving components from site to site by air or sea.

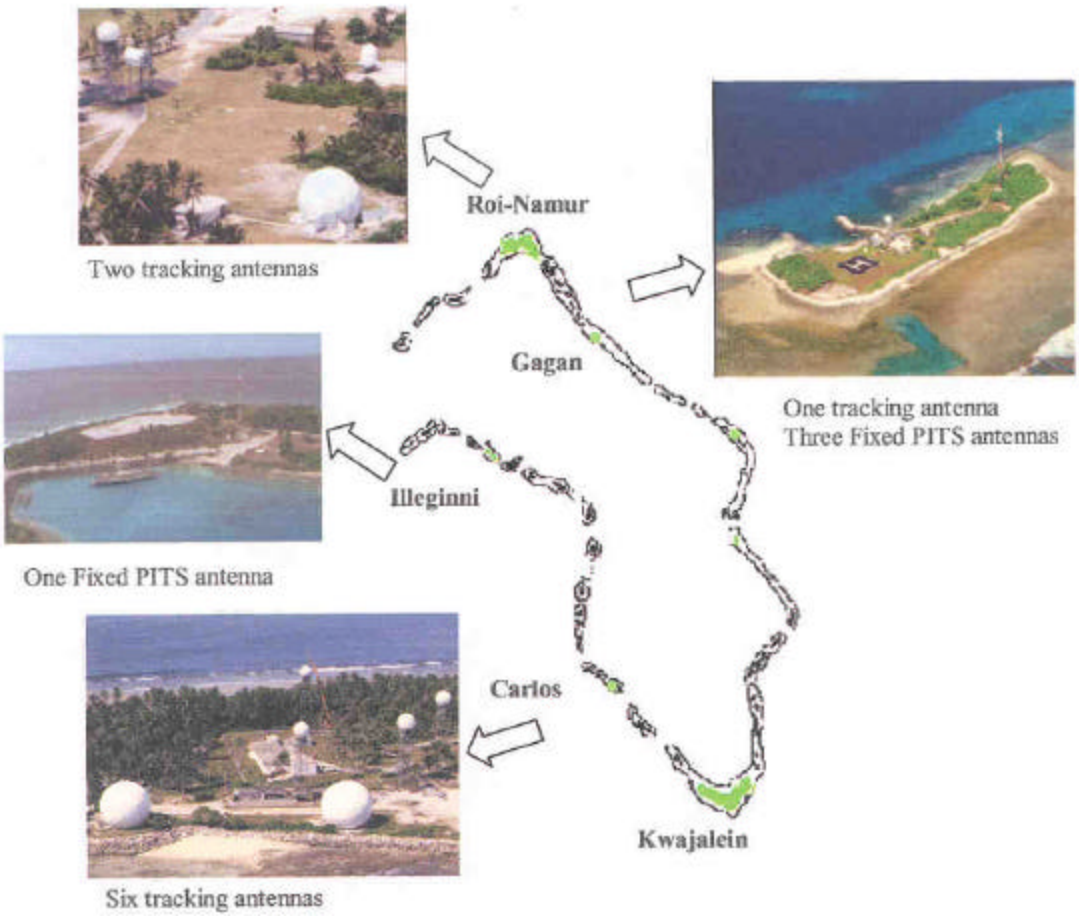

Figure 1. Pre-modernization Telemetry Instrumentation at KMR

KMR LEGACY TELEMETRY SYSTEMS

Telemetry support at the Kwajalein Missile Range spans a period of nearly 40 years. The first TM systems at Kwajalein were trailer-housed and arrived at the Navy's Pacific Missile Range Facility (PMRF)-Kwajalein in late 1961. The arrival of these assets was just in time to support the first Nike-Zeus launch from Kwajalein. Although initially installed on Kwajalein, these receiving and recording vans (with their manually positioned antennas) were subsequently moved to the island of Carlos, approximately 10 miles from Kwajalein, and one three-channel monopulse auto-tracking TM antenna was purchased and installed on a tower. The Army assumed command responsibility from the Navy in 1964 and four new auto-tracking antennas were purchased and installed in 1965-1966. A building was constructed to house the equipment relocated from the two vans and for the antenna tracking consoles plus other new equipment. Following the loss of the TM P-Band in the early 1970s, the four trackers were upgraded with single-channel monopulse S-Band tracking systems, which included polarization diversity tracking and data reception. These systems provided tracking, receiving, and recording for Anti-Ballistic Missile launches from Kwajalein (Nike-Zeus, Spartan) and Meck Island (Spartan, Sprint) as well as tests of ICBM Research and Development of nose cone materials and Operational Test and Evaluation (OT & E) of operational weapons systems.

During the next 15 years, two additional antennas were installed on Carlos, a tracker and fixed antenna were installed on Gagan, two tracking systems were emplaced on Roi-Namur and a fixed Post Impact receiving antenna and re-radiation system were installed on Illeginni. The relocation of telemetry assets from the west reef (Carlos) to the east reef (Gagan and Roi-Namur) reflected the movement of RV impact areas from the Kwajalein lagoon and near atoll areas to the Broad Ocean Area off the atoll's east reef and the need to collect telemetry data after impact of both MMIII and Peacekeeper reentry vehicles. Originally installed to support over land warhead fusing and impacts of MMIII reentry vehicles, the Illeginni re-radiation system subsequently supported fusing and impacts of the Peacekeeper MK-21 reentry vehicle.

Following the completion of ABM testing on Meck Island in the mid-1970s, KMR telemetry supported technology tests flown from both Vandenberg AFB and Roi-Namur. Subsequently, following the reactivation of Meck Island to support Strategic Defense Initiative Organization (SDIO), Meck Island became the launch site for HOE, ERIS and EKV vehicles. In the late 1970s, some minor modifications were made to the front ends of the tracking systems, and limited enhancements were introduced to the data processing capability at Carlos.

Throughout that period, KMR's primary data product was wide bandwidth analog tape recordings and paper strip charts. The advent of the Global Positioning System (GPS) satellite constellation resulted in the installation of a GPS Translator Processing System in late 1989 to support the ERIS program intercepts of target warheads. Upgraded to a Translated GPS Range System (TGRS) recently, interceptor and target vehicle locations are now available with excellent accuracy. The desire to offer the range customers real time data messaging, digital data recording, data processing and data transmission to CONUS, coupled with the increasing budgetary need to reduce operational cost and institute efficiencies wherever possible, led to the telemetry portion of the KMR Modernization and Remoting project. The various components of this project are described below.

MODERNIZED TELEMETRY

A major goal of telemetry modernization at KMR is to relocate and consolidate telemetry assets from the outer islands to the islands of Kwajalein and Roi-Namur, the major population centers of the Kwajalein Missile Range. This plan will reduce the facility support cost and optimize the requirements for personnel transportation across the atoll. The overall effort is carried out in three phases. During the first phase nearly 75% of the Roi-Namur modernization will be completed and the operation of legacy telemetry assets on Gagan Island will be remoted to Kwajalein via fiber optics. In the second phase, modernization of the Roi-Namur telemetry site will be completed and nearly 40 percent of the Kwajalein telemetry site will be modernized. During the third and final phase, the modernization of the Kwajalein telemetry site will be completed and the operation of the Illeginni post impact system will be remoted, via fiber, to Roi-Namur. All threemodernization phases will be carried out while maintaining telemetry support to the Range's customers. At the end of this effort KMR telemetry will consist of five tracking antennas on Kwajalein and four on Roi-Namur. Detailed descriptions of the modernization tasks at each site are given below.

Kwajalein Telemetry

The new Kwajalein Telemetry station will consist of three fixed and two mobile telemetry antennas, and a new telemetry control facility called the Kwajalein Telemetry Center (KTC). The new Kwajalein antennas replace five of six antennas presently located on Ennylabegan (Carlos). When completed, the new Kwajalein TM site will include one fixed 7-meter antenna, one fixed 5-meter antenna, one fixed 3.1-meter antenna and two mobile 3.1-meter antennas. The two mobile 3.1-meter antennas will initially be sited near the three fixed antennas and interfaced to the KTC (See Figure 2). Plans for a mobile ground station are currently under development to support deployment of the two mobile systems to remote geographic locations not supportable by KMR's fixed telemetry assets.

Figure 2. Final Kwajalein Telemetry Antenna Configuration

The preparation of the Kwajalein TM site is progressing well and on schedule. This effort is conducted in two phases. In phase I, two new telemetry antennas will be installed. These systems are currently on order and are expected to be delivered, installed, and become operational in December 2001. The first antenna is a 5-meter tracking antenna that will be installed on the northeast corner of Launch Hill as shown in the lower left hand corner of the photograph in Figure 2. The second antenna is a 7-meter tracking antenna to be located on the former FPQ-19 C-band radar mount. A second 7-meter antenna is also being procured in phase I to replace the existing 5.5-meter antenna on Roi-Namur. A limited amount of equipment will be relocated from the Carlos site to the Kwajalein site to support phase I of KTC Initial Operational Capability (IOC). Site installation and integration of these three antenna systems and the Carlos equipment is scheduled for completion near the end of this calendar year. Completion of the second and final phase of Kwajalein Telemetry Modernization includes procurement of the final three Kwajalein systems (one fixed and two mobile 3.1-meter systems) and will be accomplished during the last quarter of calendar year 2001. The installation of these systems is currently scheduled for 4QFY02. Figure 2 depicts the final configuration of the Kwajalein telemetry antenna site.

When the new Kwajalein Telemetry site is completed, the five new antennas and their associated tracking receivers and antenna control units (ACUs) will be located on Launch Hill. The antenna RF outputs will be connected to multicouplers and receiver/combiner sets in the KTC via a wideband fiber optic network. Gagan PITS [2] RF data will also be connected to the KTC via wideband fiber optics, and PITS system operation will be fully integrated into the KTC operation. Pre-mission calibration and maintenance activities will be performed by remotely operating the antennas from the KTC using a remotely configured ACU. Control of data receivers/combiners and digital recorders in the KTC will be accomplished via a central control computer. The Gagan PITS system will also be automatically controlled via computer, with the exception of analog magnetic tape recorders operation.

During phase two of the TM modernization effort, other new systems will be relocated to KTC and Roi-Namur. Two recently procured systems, the TGRS, comprised of four independent GPS tracking systems, and the Telemetry Bit Stream Processor (TBSP) decommutation systems, comprised of four PCM decommutation units with 4 bit stream capability, will be relocated from Carlos.

The TGRS is a common range system used in conjunction with a vehicle-based ballistic missile translator (BMT) and/or digital GPS translator (DGT) that provide very accurate position and velocity information from interceptor and target vehicles in real time. KMR telemetry systems will include two TGRS units on Roi-Namur and two on Kwajalein. These units are easily moved and can be all installed at Kwajalein or elsewhere on the range wherever there is a TM tracking system available.

The TBSP is a highly versatile PC based decommutation systems with integral bit synchronizers and high capacity disc drives for data storage. Current systems can receive and decommutate four independent PCM data streams at up to 20 Mbps NRZL each, with individual stream capacity of 30 Mbps. Two TBSP systems will be installed at Roi-Namur and two at KTC,

providing a total recording capability of eights20 Mbps data streams at each of the two telemetry sites. Both TGRS and TBSP systems provide a variety of displays for Range User viewing in real time and post mission. The TBSP systems can provide recorded data on tape or compact disc.

A separate Silicon Graphics computer will also be located in the KTC. This computer will be connected to an atoll-wide Ethernet sensor network and will provide the interface between the nine antennas and the Kwajalein Mission Control Center (KMCC). Specifically, this computer will (1) receive state vector designate data from the KMCC, (2) select the telemetry specific state vectors appropriate for each mission and (3) output Ethernet messages to each antenna's ACU containing its own state vector designate information. Each ACU will then coordinate transform the state vector into the azimuth and elevation pointing angles needed to designate ("slave") each antenna. The ACUs will output Ethernet status messages at a 10 Hz rate to the Silicon Graphics computer, which will receive and store the data for later retrieval, formatting and printout as an antenna tabulation post mission data product. Since the Silicon Graphics computer is connected to an atoll-wide sensor network, it will be capable of receiving and logging antenna status data from the antennas on Roi-Namur as well as on Kwajalein. As such, it will be capable of producing antenna tabulation reports for any or all of the KMR telemetry antennas.

Initially, a dedicated operator on Launch Hill will operate each antenna. Subsequently, engineering tests will be conducted using antennas (not committed to mission support) that are controlled remotely from KTC to shadow track targets with personnel closely monitoring system performance at the local ACUs. After validating the automation concept from KTC, more and more mission support will then be performed in the automated and remote mode.

Roi-Namur Telemetry

At the completion of the Telemetry KMAR project, the Roi-Namur Telemetry site will consist of four new telemetry antennas and a consolidated control center. The new Roi-Namur antennas will consist of two 3.1-meter antennas, one 5-meter antenna and one 7-meter antenna. Figure 3 displays the final configuration of the Roi-Namur telemetry antenna site.

Figure 3. Final Roi-Namur Telemetry Antenna Configuration

The Gagan antenna tower was disassembled, completely refurbished, and metallized to increase its corrosion resistance and repainted. The restored tower was reassembled in January 2001 in the location shown in Figure 3. The Gagan ground station equipment suite, including receivers, diversity combiners and 14-track analog tape recorders, was relocated from Gagan to the expanded Roi-Namur Telemetry control center in August and September 2000.

Three new telemetry antennas were procured for the Roi-Namur Telemetry site in April 2000. One new 5-meter tracking antenna was specified for a new ground location adjacent to the existing 5.5-meter antenna. A new 3.1-meter tracking antenna was specified to be installed on the relocated Gagan tower. A second, identical 3.1-meter antenna was ordered to replace the outdated antenna of similar size located on another tower adjacent to the control center building. These three antennas were delivered to KMR in January 2000 and have been successfully site integrated and tested. The fourth Roi-Namur antenna, a 7-meter system, was procured in December 2000 and will be installed in place of the existing 5.5-meter system to complete the Roi-Namur Telemetry antenna modernization effort.

When Roi-Namur Telemetry modernization is completed, four new antennas will be installed, and associated tracking receivers and ACUs will be located in the enlarged Roi-Namur control center. Pre-mission calibrations, BER tests and maintenance will initially be performed using the ACUs located in the Roi-Namur Telemetry building. Control of data receivers/combiners and digital recorders in the Roi-Namur Telemetry ground station will be accomplished from a central computer. Illeginni PITS RF data will be transmitted to Roi-Namur Telemetry via fiber optics, with data reception and recording integrated into the Roi-Namur Telemetry control center.

Figure 4. Installation of new 3.1-meter antenna on Roi-Namur

Figure 5. Installation of radome over new 5-meter antenna on Roi-Namur

A Silicon Graphics computer located in the Roi-Namur Telemetry control center, and similar to the one located on Kwajalein provides comparable directing data to the Roi-Namur TM assets. Similar to the computer on Kwajalien, the Roi-Namur computer is connected to an atoll-wide Ethernet sensor network and provides the interface between the Roi-Namur antennas and the KMCC. This computer

receives state vector designate data from the KMCC, selects the telemetry specific state vectors appropriate for each mission and outputs Ethernet messages to each antenna's ACU containing its own state vector designate information. Each ACU then coordinate transforms the state vector into azimuth and elevation pointing angles needed to designate ("slave") each antenna. The ACUs also output Ethernet status messages at a 10 Hz rate to the Silicon Graphics computer, which then receive and store the data for later retrieval and printout as a post mission data product. Provision has been made for the capability to fully remote the Roi-Namur telemetry site from the KTC via T1 communication data circuits. The capability to access and control this site computer from the KTC has also been provided and demonstrated, allowing the production of post mission Roi-Namur data products such as antenna tabulations from the KTC. The capability to remotely operate any of the Roi-Namur antennas from Kwajalein using a remote ACU connected to the sensor network has also been demonstrated.

Gagan Telemetry

The functionality of the Gagan tracking telemetry system has been relocated to Roi-Namur. The Post Impact Telemetry System (PITS), however, remains in place. The operation of PITS is remoted to KTC on Kwajalein via fiber optics [2]. The fixed disc-on-rod antennas of this system are equipped with azimuth rotators that can be controlled remotely by the operators via desktop computer. The same computer is used to remotely calibrate the antennas, measure the noise floor level, and set up the receivers. The RF signals received by all three antennas are multiplexed on fiber and transmitted to KTC for processing and recording. A fourth fixed antenna is also being added to the existing three.

FUTURE PLANS

When completed in FY02 the current modernization program for KMR telemetry will provide all new antenna systems with full remote operational capability of all telemetry resources on the islands of Roi-Namur and Kwajalein. Operational Tests and Evaluation (OT&E) flights of both the MMIII and Peacekeeper ICBM are fully supportable with the modernized systems without additional equipment upgrades. Future support of National Missile Defense (NMD) and Theater Missile Defense (TMD) missions will include upgrade of existing wide-band analog data recorders with high bit rate digital recorders in quantity.

Enhanced satellite data bandwidths will allow increased use of real time data relay from the interceptor and target vehicles to Range Users located at CONUS locations. Hard data products such as analog tapes and paper strip charts will be replaced with digital data products. Real time or post mission full bit rate data transmission to Hawaii and CONUS should be possible by FY04 or FY05. It should be noted here that, although limited, some data transmission bandwidth is currently available. Coincident with the reception and digital recording of high bit rate (20 Mbps and above) PCM data is a planned 3-D data display that will provide observers with visual indications of missile fly-out and warhead interception. Current plans will provide displays of two interceptors vs. two targets with expansion capabilities that could display four interceptors vs. four targets engagement scenarios.

Another important part of the modernization of KMR telemetry systems is the continuing efforts to provide diverse Range Users with mobile/transportable TM tracking and data collection systems. The two mobile trackers purchased in FY02 will be incorporated into a totally transportable suite that

includes wideband receivers, high bit rate digital recorders, data transmission systems, and real time data displays. The final number of mobile/transportable systems to be procured will be based on future year's requirements for TMD and NMD scenarios that include intercepts beyond KMR's RF horizon. Mobile systems transported to Wake Island, Johnston Island, Midway Island, or other remote locations by aircraft or ship will provide TM data collection, transmission and display for various users at reasonable cost.

As future mission load dictates, KMR plans to incorporate an extensive switching capability in the KMR Telemetry Center that will allow remote set-up, test and operations of the complete TM Center from locations in Hawaii or CONUS. The relocation of all TM resources except tracking antennas and wideband fiber optics data transmission systems from Roi-Namur to Kwajalein will allow a significant reduction in site personnel at Roi-Namur and provide increased flexibility associated with the expanded equipment suite at KTC. Cost savings associated with remote testing and operating should be significant.

SUMMARY

This paper has described the main features of the KMR Telemetry Modernization and Remoting program. The consolidation, commonality and maintainability of the telemetry systems achieved from KMAR will permit containment of KMR costs in the current and anticipated future austere budget environment. Although motivated from the point of view of achieving a dramatic reduction in the cost of operating and maintaining the Range telemetry sensors, the modernization is bringing major benefits to the user community. Among these benefits is mobile telemetry support, digital recording of the post-detected data, real time decommutation of the data streams thus allowing for real time metric tracking solutions, real time telemetry messaging around the atoll, and faster data reduction. In addition, the modern systems will have much greater flexibility to respond to new requirements.

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REFERENCES

[1] Ince, W. J., Potts, B., and Villeneuve, D., ”Kwajalein Missile Range modernization and support of BMDO testing,” Proceedings of the 7th Annual American Institute of Aeronautics and Astronautics/BMDO Technology Readiness Conference, Colorado Springs, Colorado, 3-7 August 1998.

[2] Abouzahra, M. D., and Robey, F.C., “Photonic remoting of the Kwajalein Missile Range post impact telemetry system,” Paper No. 99-08-1, Proceedings of the International Telemetring Conference, Las Vegas, Nevada, 25-28 October 1999.