# SOFT RECOVERY RECORDING SYSTEM FOR INTERIOR AND EXTERIOR BALLISTICS CHARACTERIZATION

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Add your abstract here. It should be between 150 and 250 words.
The US ARMY, ARDEC; in cooperation with AMCOM AMRDEC, Missile Guidance and Engineering Directorates; the Office of Naval Research; Naval Surface Fire Support; and the Naval Surface Weapon Center, requires multiphase development of a common, low-cost, high G survivable, high accuracy, Micro Electro-Mechanical Systems (MEMS) Inertial Measurement Unit (IMU) and Common, Deeply Integrated, Guidance and Navigation Unit (DI-GNU) for DoD gun launched guided munition and missile applications. The challenge for the Precision Munition Instrumentation Division (PMID) was to develop a Telemetry System to record the interior and exterior ballistics of a M831 TP-T projectile, which will be used as a carrier for soft recovery testing of IMUs and GNUs. This valuable data that would help The Government and contractors develop and validate multiple MEMS IMU design efforts, culminating with live fire verification performance test of pre-production in the Army's 155-mm Soft Recovery Vehicle (SRVs) and missiles airframes.

## INTRODUCTION

The US ARMY, ARDEC in cooperation with AMCOM AMRDEC, Missile Guidance and Engineering Directorates, the Office of Naval Research, Naval Surface Fire Support and the Naval Surface Weapon Center requires multiphase development of a common, low-cost, high G survivable, high accuracy Micro Electro-Mechanical Systems (MEMS) Inertial Measurement Unit (IMU) and Common, Deeply Integrated, Guidance and Navigation Unit (DI-GNU) for DoD gun launched guided munitions and missile applications. The challenge for the ARDEC Precision Munitions Instrumentation Division (PMID) was to develop a Telemetry System to record the interior and exterior ballistics of a M831 TP-T projectile, which will be used as a carrier for soft recovery testing of IMUs and GNUs. This is valuable data that would help The Government and contractors develop and validate multiple MEMS IMU design efforts, culminating with live fire verification performance test of pre-production products in the Army's 155-mm Soft Recovery Vehicles (SRVs) and missiles airframes.

## TEST REQUIREMENTS AND OBJECTIVES

The test requirements for the telemetry system were to survive multiple firings, which include; to survive the set back during the gun launch up to 25,000 Gs and set forward at the impact up to 10,000 Gs and to record acceleration in three orthogonal directions during all phases of flight: in-bore, in-air and impact.
The primary objective of the test was to measure acceleration of the projectile in-bore at the muzzle exit, during the flight and impact with the hay bales used as Soft Recovery Bed. Other primary objectives were to demonstrate structural integrity of the test articles (IMU, GNU) verified by post-gun fire hardware inspection and testing.

## TEST ASSETS

The M831 TP-T is a modified 120mm tank round that is used as the Soft Recovery Vehicle (SRV) test projectile for the OBR (On-Board Recorder) and Units Under Test (UUTs)[1].

- The ARRT-123 Telemetry System (1)
- IMU Housing Assembly (2)

Figure 1 is a cross sectional view of the M831 (modified) test projectile with ARDEC Telemetry in an All Up Round (AUR) configuration highlighting the test items and On-Board Recorder housed in the projectile warhead cavity.

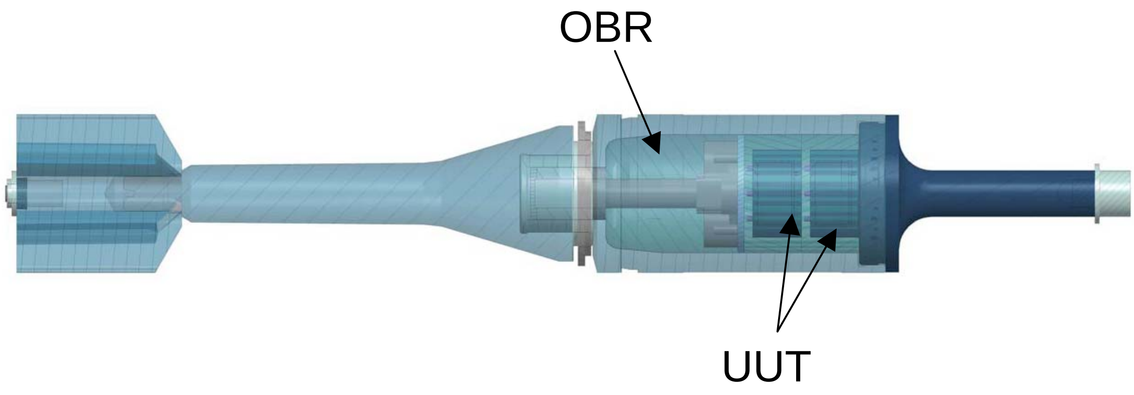


Figure 1. Cross Sectional view of the M831 test projectile.

## TELEMETRY SYSTEM OVERVIEW

The design of ARRT-123 Telemetry is based on Model 64 IES Digital Data Recorder integrated in the specially designed aluminum housing shaped to fit the M831 TP-T projectile warhead cavity with other systems components. The sensors suite consists of three Endevco 7270 accelerometers orthogonally mounted on the block and two G-switches; six Lithium-Polymer rechargeable battery cells are used as the power supply; one MDM 15 pin connector is used as housekeeping and computer interface port.

- The Model 64 is a fully programmable, microprocessor controlled, miniaturized, high shock, solid-state, 4 analog channels and 1 digital channel recorder, designed to acquire transducer data in shock environments of up to ±50,000 Gs. Channel gain, bias, trigger levels, and speed options can be programmed into the Model 64 via a computer. Three analog channels were programmed to capture about 2 seconds of acceleration data including 35mSec of pre-trigger data at the rate of approx. 116 KHz per each channel. The data recording would start on the G-switches closure at approx. 400 Gs during the set back. The digital channel was set-up to monitor the G-switches state.

- Three Endevco 7270 accelerometers: 60 KGs in axial (Z) direction and two 20KGs in orthogonal (X and Y) directions were mounted on the block, secured in one of the cavities. The scale and the range of Z axis accelerometer was programmed to measure 30 KGs in the positive direction during the setback and

12 KGs in the negative during the set forward and impact. The scale and the range of X and Y axis, was programmed to measure 9 KGs in the positive and negative directions.

- Two G-switches (used for redundancy) were used as data recorder trigger to record and save data. G-switch closure would occur at the launch event at approx. 400 Gs shock.

- The power supply consists of two stacks of three Li-Po rechargeable cells, provides 290 mAh of power at nominal voltage of 11.1V (12.6Vmax).

- The ARRT-123 housing is made of aluminum to meet the mass requirement.

- The MDM 15 pin connector is used for battery charging and OBR communication.

## TELEMETRY SYSTEM ASSEMBLY OVERVIEW

The ARRT-123 data recording system was designed and built to enable easy replacement of accelerometers, batteries, or any other part in the event of failure during tests. The battery cavities were filled with two part epoxy just high enough to cover the battery stacks and lining was used to reduce epoxy adhesion to the walls; the remainder of the cavity was used to accommodate most of the wiring and was filled with wax later. The accelerometers cavity was filled with wax only and sensors interface board with G-switches was floating in wax above accelerometers block. The recorder was accommodated along the center axis of the housing, and finally, all remaining gaps were filled up with wax. Four systems were built this way and air-gunned at 32,000 Gs out of 5” gun at Picatinny Arsenal as part of qualification testing before live firings at Yuma Proving Ground (YPG). A ”battery save” mechanism was implemented using a removable jumper to avoid unnecessary battery discharge during storage and transportation. This jumper would be soldered in prior to the test series before charging the batteries and covered with electrical putty and Mylar tape.

## LIVE FIRING TESTING

Total four live firing test series were conducted at YPG KOFA range during 2005 – 2006 timeframe. In average, fifteen M831 TP-T rounds instrumented with the ARRT-123 Telemetry System were fired during each test series. All the systems successfully recorded acceleration data from all the shots. Figure 2 shows the layout of the test site. The Instrumented projectiles with the test items were fired out of a M256 120-mm Cannon with Thermal Shroud and Bore Evacuator straight into three stacks of hay bales 3m apart of each other located 1400m down range. On-ground instrumentation and recovery of rounds was provided by YPG personnel.

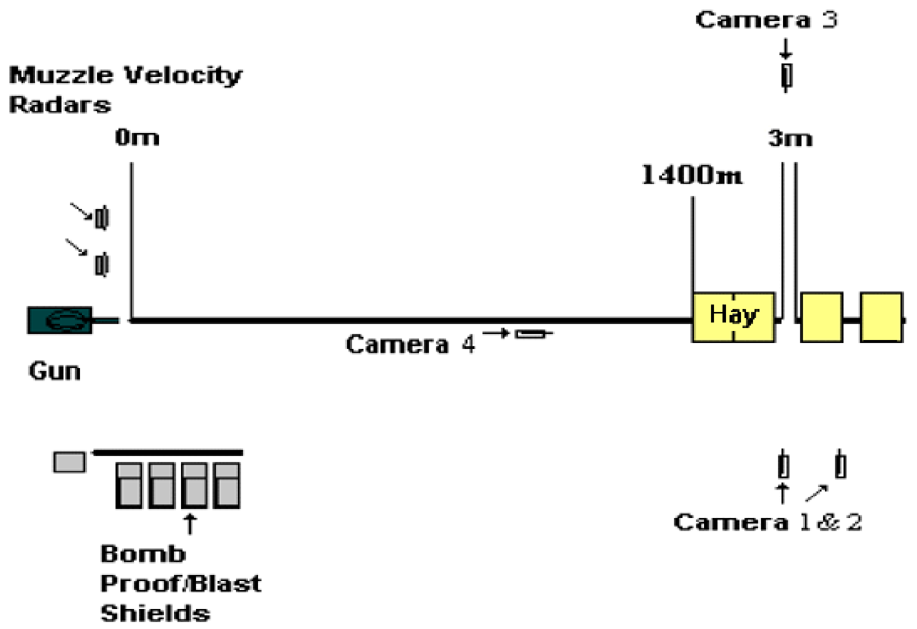


Figure 2. Layout of the test site [2].

The OBRs were configured with one and two hour delays to allow time for the assembly process and transportation of the rounds to the gun site. This delay configuration disables the trigger mechanism for the pre-set amount of time so it would be safe to handle the OBR without false triggering during assembly and loading process. After the warming and spotter rounds were fired to establish proper muzzle velocity and gun aiming test rounds were rammed one by one at least five minutes before the delay expired and fired at least five minutes after the delay expired. This “time buffer” ensures that the OBR would not trigger during the ramming process or fired before the delay expires, which would prevent the OBR to record the desired data. After firings the rounds where visually located using high speed camera filming and recovered from hay bales when firings were completed; recorded data was downloaded, batteries were charged and delay was set for the next firing.

## DATA COLLECTED

Below there is a series of plots showing some samples of the data collected in the field from different firings [3].

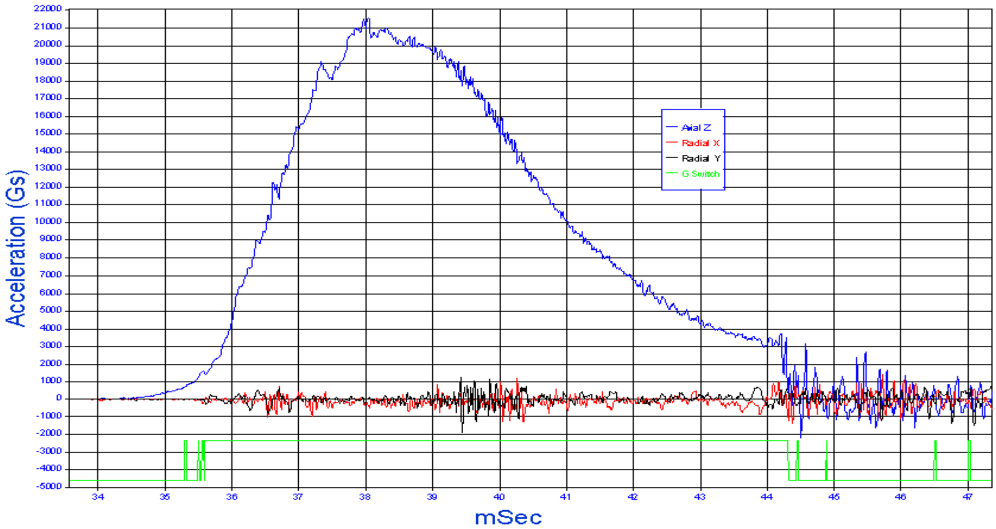


Figure 3. Axial and radial in-bore acceleration data.

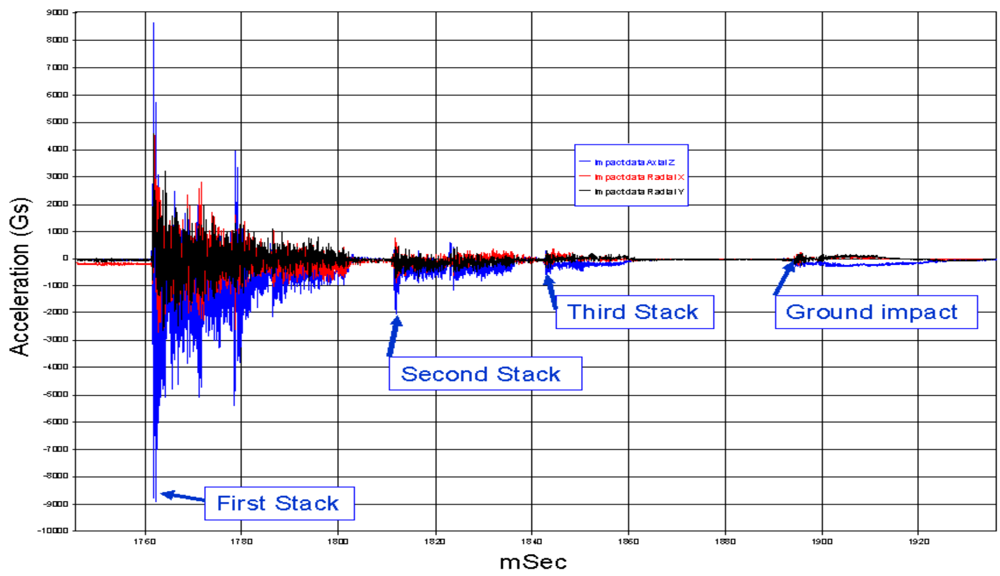


Figure 4. Impact into the hay bales, and ground impact.

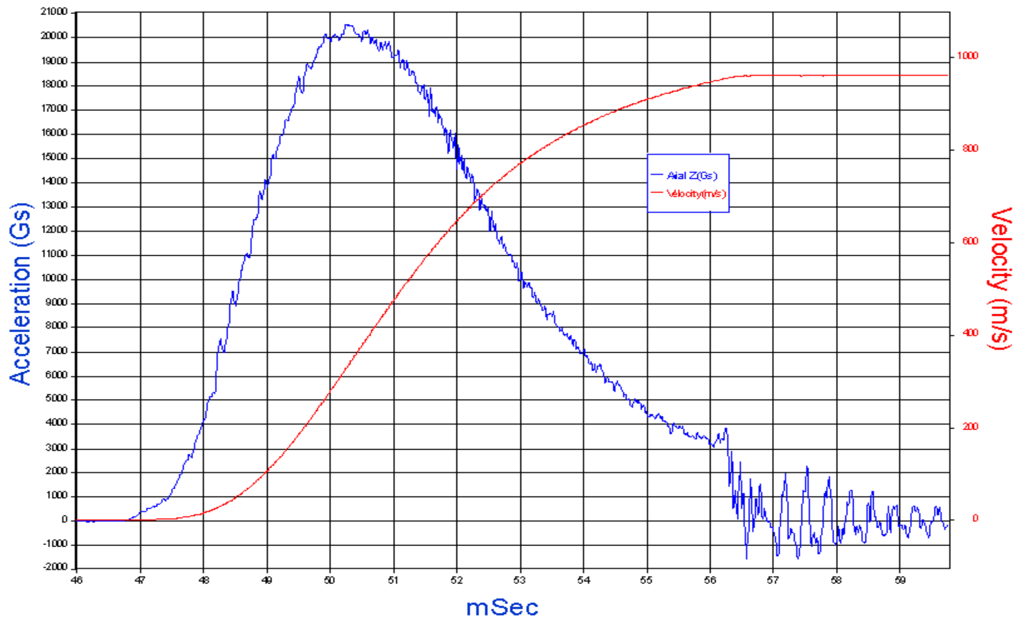


Figure 5. Average velocity at muzzle exit was about 960m/s.

## CONCLUSIONS AND RECOMMENDATIONS

Figure 4 shows ground impact of the round. This is not very common. The idea of soft recovering the rounds is that the stacks of hay prevent the round from flying ballistic downrange with the least damage to the round. However, sometimes, rounds would go through the hay and find their way out. From previous tests we noticed that having the stacks of hay closer to the gun (i.e 500m) would make the round experience very high G shock at impact causing accelerometers to fail. So it was recommended to position stacks of hay further downrange at about 1400m to reduce set-forward shock. All four ARTT-123 Telemetry Systems built by the PMID at ARDEC survived multiple gun launch and successfully collected data of about sixty shots to date. All data collected with the ARRT-123 systems matched simulation models and data collected by YPG instrumentation personnel. All these facts show the robustness of the ARRT-123 and how the PMID with over 50 years of experience is committed to produce high quality telemetry products and field support. The ARRT-123 Telemetry System was intentionally built with a very flexible design and other versions of it could be adapted to meet specific customer needs.

## REFERENCES

[1] Potucek, J. *M831 IMU Soft Recovery Test Plan*. Armament, Research, Development & Engineering Center. Picatinny Arsenal, NJ, 17 August 2004 Rev B

[2] Attili, B. *High G Test 3 report***.** U. S. Army Yuma Test Center Yuma, AZ, 28-29 June 2005

[3] Guevara, M.; Flyash, B. *120mm Tank Round OBR Data.* Armament, Research, Development & Engineering Center. Picatinny Arsenal, NJ, 07-08 February 2004

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