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Malcolm Baldrige National Quality Award 2007 Award Recipient

ARMAMENT RESEARCH, DEVELOPMENT AND ENGINEERING CENTER PICATINNY ARSENAL, NJ

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Bore Elevation and Azimuth Measurement System (BEAMS)

Prepared for Joint Armaments Conference, Exhibition & Firing Demonstration 17 May 2012

by Robert P. Pinto, Fire Control Systems & Technology Directorate

Purpose

- Designed in response to a request from the Naval Surface Warfare Center (NSWC), Crane Division and PM Mortars for
  - A low-cost means
  - Verify the **elevation and azimuth** weapon pointing accuracy requirements
    - Navy 81mm Mortar Fire Control
    - 120mm M150/M151 Mortar Fire Control Systems – Dismounted
  - In a field-test environment

Bore Elevation and Azimuth Measuring Apparatus And Method
U.S. Patent 7,856,729 December 2010

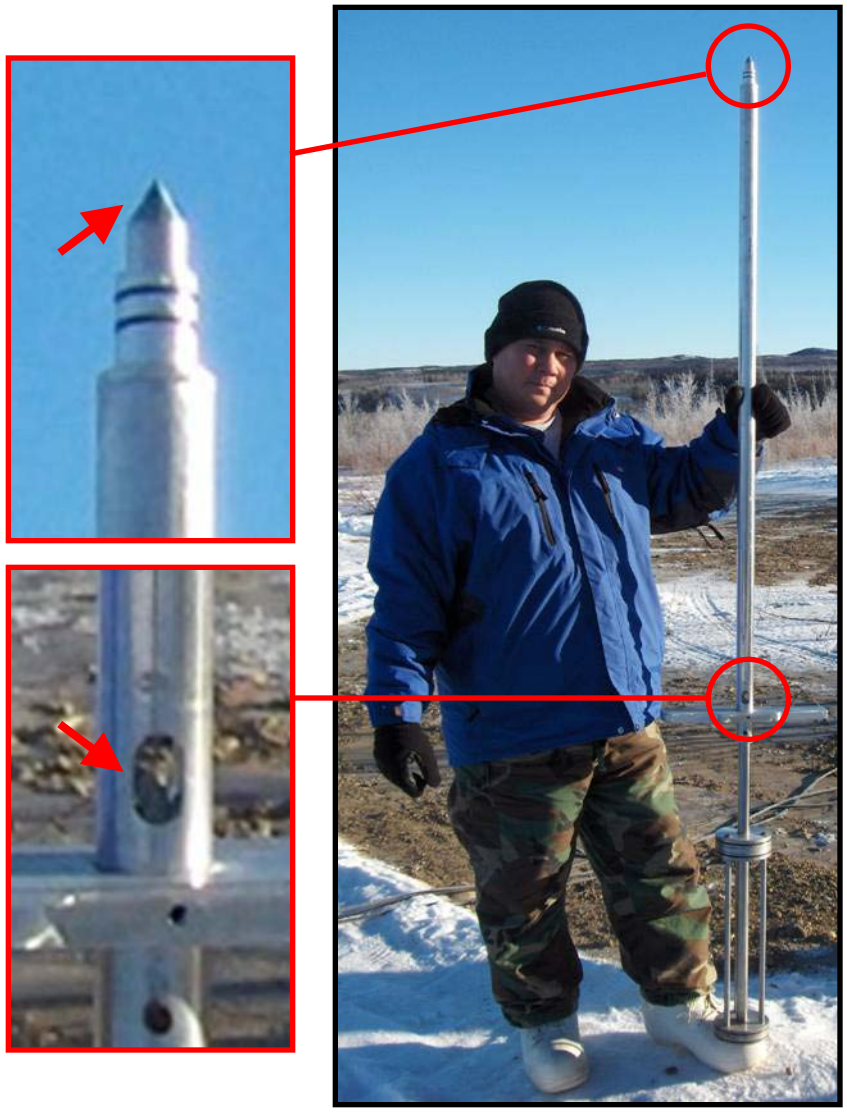
http://www.google.com/patents?q=7856729

Purpose (continued)

- Provides a means
  - For the fixture to self-center in the weapon tube
  - To calibrate and verify that the projection of the tube axis is coaxial to the tube axis
  - To measure and/or remove bias from the fixture
  - To make measurements
    - In **elevation and azimuth**
    - High accuracy
    - Utilizing conventional survey procedures
- All of which may be accomplished in an engineering field-test environment

Description of Prior Measurement Techniques

- Artillery and mortar weapon azimuth pointing measurements used a fixture inserted in weapon tube
- The fixture extends the axis of the tube so it can be observed by a single theodolite
- The vertical reticle line of the theodolite must align to **both** the tip and lower reference point at the **same time**
  - Very difficult to do,
    - especially at high quadrant elevations



Description of Prior Measurement Techniques (continued)

- Fixtures tend to be
  - Long
  - Subject to damage from bending
  - Cumbersome to use
- Alternatively a line is scribed on the outside of the weapon tube
  - Drawn parallel to the tube axis
  - Scribe lines are difficult to accurately establish
  - If the outer tube wall is not parallel to the tube axis
    - Tube cant measurements need to be made
    - Correction equations for non−parallelism of lines to the weapon axis need to be applied
- Sighting down the side of the weapon tube is also used but
  - It is difficult do
  - Error prone since weapon tubes have varying cross sections

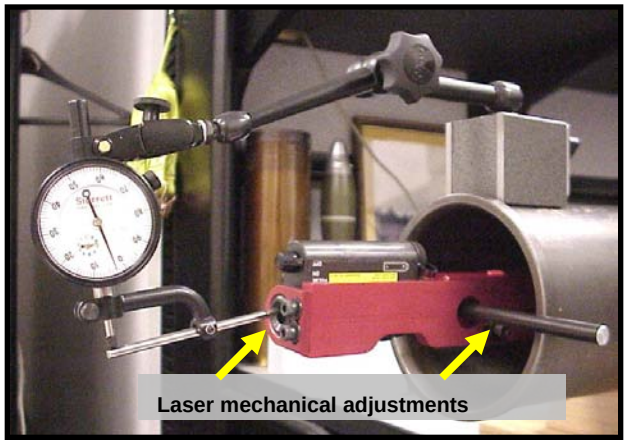
BEAMS Laser Fixture

- Incorporates interchangeable lobes which
  - allow for use with any weapon tube caliber, and
  - spring loaded plungers and
  - non-marring brass pads which
  - allow the fixture to self-center on the weapon tube axis

120mm, 81mm, and 60mm Mortar Lobes

BEAMS Laser Fixture (continued)

- Mechanical adjustment allows laser aperture to be positioned on-axis with the weapon bore
  - Dial Indicator measures run-out as fixture is rotated in 180-degree increments
  - Mechanically adjust until run-out is eliminated



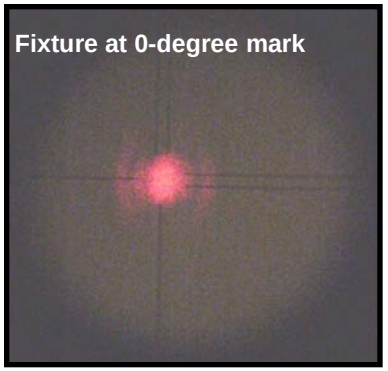
BEAMS Laser Fixture (continued)

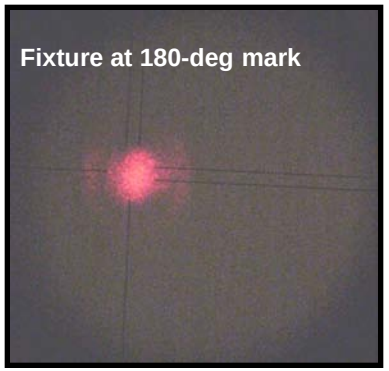
- Eye-safe AN/PEM-1 Laser provides projection of the tube axis
  - Designed for aligning sights on numerous weapon systems
  - Hundreds currently in-use
  - Designed to be viewed with magnifying optics
  - Contains integral up/down left/right beam adjustments

AN/PEM-1 Eye-safe Laser

BEAMS Laser Fixture (continued)

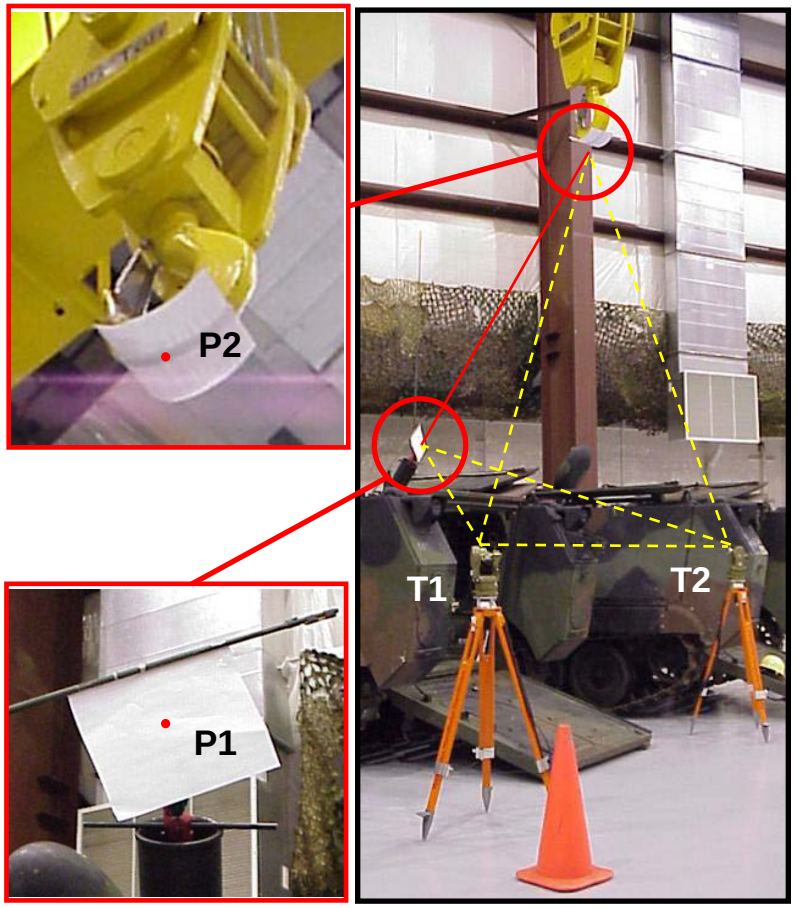
- Laser beam adjustment allows laser to be positioned on-axis with the weapon bore
  - Theodolite views run-out as fixture is rotated in 180-degree increments
  - Beam is adjusted until run-out is eliminated





BEAMS Measurements

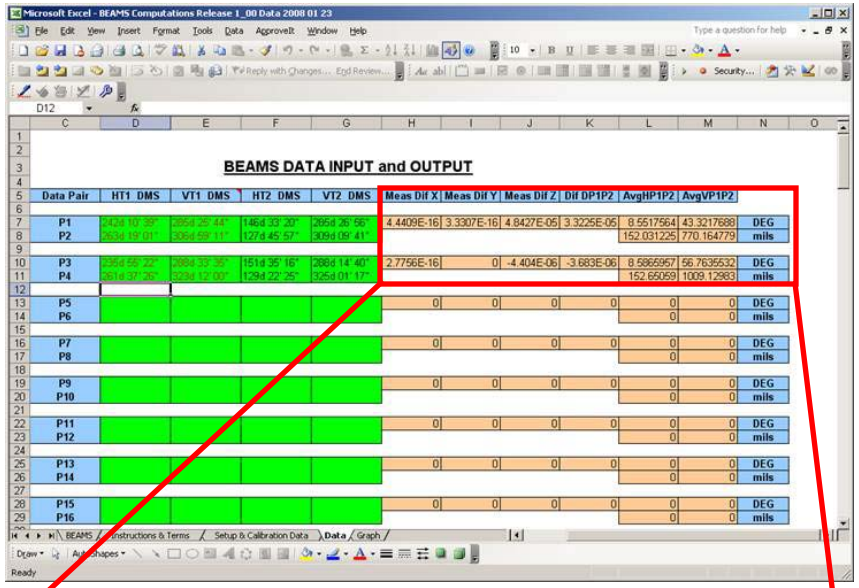
- Two theodolites, T1 and T2, measure Horizontal (H) and Vertical (V) angles to:
  1. The other theodolite (once per set-up)
  2. The laser spot, P1, on the first screen
  3. The laser spot, P2, on the second screen
- Laser spots can be viewed on a simple paper or Mylar® screen or any convenient surface
- The horizontal angle to the point measured from the opposing theodolite is proportional to the distance
  - That is, the distance from T1 to P is proportional to H of T2
- The vector from each theodolite defines a 3-Dimensional XYZ coordinate of laser point P
- From two points, P1 and P2, the elevation and azimuth of the laser is established



Laser spots enhanced for clarity

BEAMS Computation

- The computations are automated in an Excel® spreadsheet
- Output shows
  - Elevation,
  - Azimuth
  - Magnitudes of measurement errors
  - Intermediate computations
- If fixture is not calibrated -
  - Rotate laser fixture 180-degrees in the bore without moving the tube
  - Make another set of measurements
  - Average of before and after elevations and azimuths are the proper values



BEAMS Applications/Adaptations

120-mm MFCS Dismounted testing, April 2008

Light Armored Vehicle Foreign Military Sales pointing accuracy test, June 2009

BEAMS training at Picatinny Arsenal, March 2009

BEAMS adaptation to M119A2, June 2008 – March 2009

M119A2 Inertial Navigation System Bid Sample Test, September – November 2009

Rapid Response Force Projection System (R2FPS) Mortar Boresight, December 2010

M119A2 Howitzer Adaptation

- Worked with PM Towed Artillery Systems to adapt BEAMS to the 105mm M119A2 Howitzer
  - Laser fixture for rifled cannon
  - Calibration and measurement procedures
  - Howitzer Onboard Optical Target Imaging Screen (HOOTIS)
  - Rear Yoke Position Laser (RYPL)
  - Trained Yuma Test Center (YTC) personnel in BEAMS operation

M119A2 Howitzer Adaptation (continued)

- LaserGlow Technologies LBS−532−TD−5 laser
  - Extremely high visibility
    - Green is 5-10 times more visible than a red laser
    - Green is not filtered-out by theodolite optics
  - Output power <5 mW
  - Low divergence at working distances

LBS-532-TD-5 Eye-safe Laser

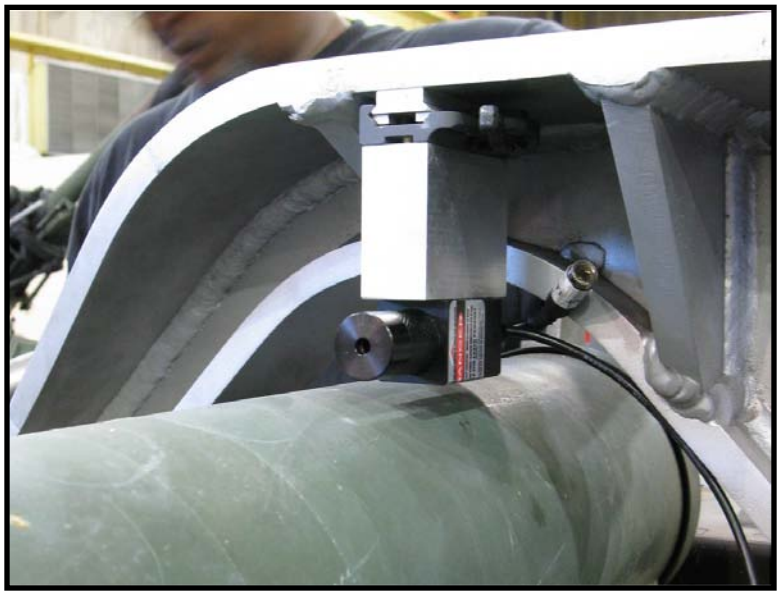
M119A2 Howitzer Adaptation (continued)

- Howitzer Onboard Optical Target Imaging Screen
  - A convenient device to hold two translucent Mylar® screens
  - Screens are used to view the laser spot
  - Screen closest to muzzle flips up so laser can strike second screen
- HOOTIS is placed on the muzzle after laser is inserted in bore

M119A2 Howitzer Adaptation (continued)

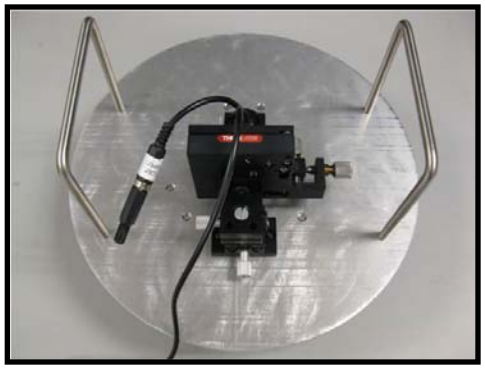
Rear Yoke Position Laser (RYPL pronounced ripple)

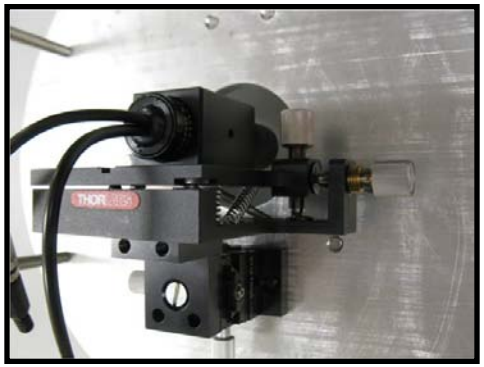
- Provides an independent check of the angular relationship between the Inertial Navigation Unit (INU) mounting plate and the cannon bore
- Utilizes Picatinny Rail for quick-release
- Angular deviation predicted failure of the rear yoke



Paladin Laser Fixture

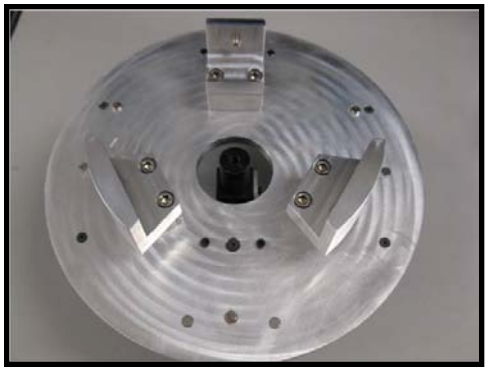
- Breech fixture using the same principles as original mortar fixture
- Three optical stages provide lateral adjustment in Y and X as well as pitch and yaw of the laser
- The optical stages are mounted on a circular plate
- Same LaserGlow Technologies laser proven on M119A2 Howitzer application





Paladin Adaptation (continued)

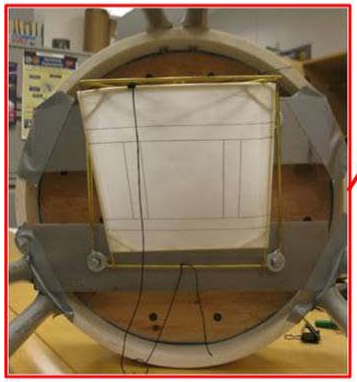
- Reverse side of plate supports
  - Three high-pull neodymium magnets contact cannon face
  - Three lobes contact the cannon wall
    - Two lobe assemblies machined to match the radius of the cannon bore
    - Third lobe fitted with a spring loaded plunger
    - Maintains self-centering of the fixture
  - Laser mechanical and optical run-out adjusted similar to the mortar fixture
  - Laser can be adjusted to 0-mils QE when cannon muzzle flat is at 0-mils

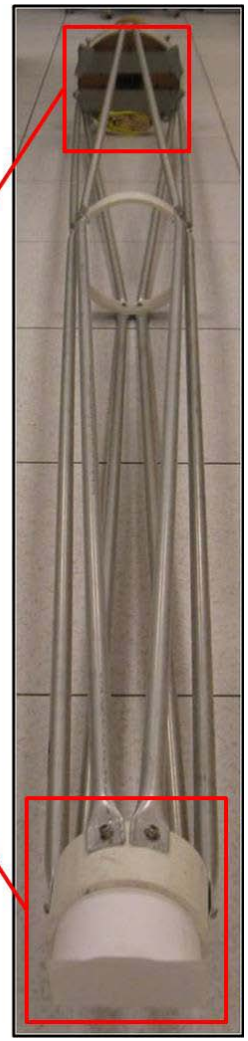


Paladin Adaptation (continued)

Paladin HOOTIS

- Truss section weighs less than six pounds
- 12-foot distance between screens
- Mandrel allows HOOTIS to be rotated for better viewing





Paladin Adaptation (continued)

Integrated BEAMS (iBEAMS)

- Incorporates direct digital communications between the control computer and each of the two theodolites
- Provides automatic data collection from each theodolite
- Directly populates data into the appropriate cells of the iBEAMS Excel workbook
- Eliminates human data transcription errors
- Greatly speeds the measurement process

BEAMS Summary

- A compact laser fixture
  - Accurately self-centers in weapon bore
  - Scales to any caliber weapon system
  - Calibration & verification that the projection of the tube axis is
    - Coaxial with the tube axis, or
    - At the same QE and azimuth
  - Includes a means to measure and/or remove bias from the laser fixture
- Theodolites may be placed at virtually any arbitrary position
  - Theodolites remain in the same place for all testing
- Provides a clearly defined theodolite aim point
  - Utilizes conventional surveying practices
  - Makes precision measurements with an accuracy greater than other current methods – 0.1-mils, 0.05 is achievable
  - Measures **elevation and azimuth** at the same time

Questions

Visit BEAMS at the RDECOM Booth