US ARMY RDECOM

U.S. Army Research, Development and Engineering Command

Malcolm Baldrige National Quality Award 2007 Award Recipient

ARMAMENT RESEARCH, DEVELOPMENT AND ENGINEERING CENTER PICATINNY ARSENAL, NJ

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

History of Fire Control and the Application of Implementing Technologies

Victor Galgano & Ralph Tillinghast

May 2012

Outline

- Fire Control definition
- The “early years”
- The need for Fire Control
- The application of technologies
- Integrated systems and their advantages
- The Future

What is Fire Control?

- Acquisition of the target and the implementation of the functions necessary to maximize the effects on target
- The functions
  - Target Acquisition
  - Sensing the environment
  - Computation
  - Gun / Launcher / Sight Control
  - Munitions Interface / Tracking / Data Link
  - Network Interface

The Fire Control Functions are Universal

Functions are the same for all weapon systems - their implementation varies as a function of sophistication and automation through the application of technology.

In a basic engagement:

- The human performs all functions
- But is
  - Limited in range capability
  - Limited in low light and poor weather conditions
- And is
  - Stress dependent

The Early Years

Pre – 1800s

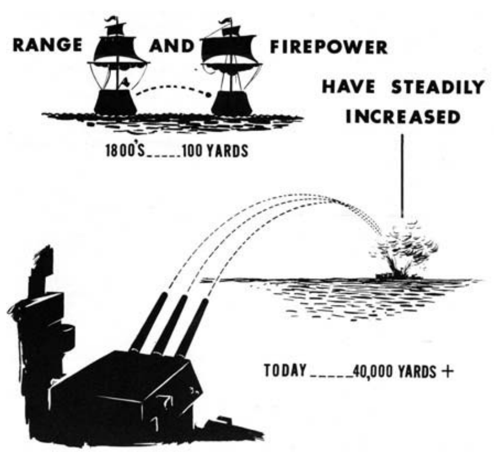
- Line of sight engagements
- Gunner's quadrant invented
- Primitive optical aiming aids
- Adjustment after fire
- Some crude mechanical aids

1801 - 1900

- No fire control inventions at the system level
- Trend toward automation extended to naval gunnery
- Telescopic Rifle Sights introduced

1901 - 2000

- Firing Table development (WW I)
- Introduction of mechanical computers in ships 1915
- Causes for errors began to be studied
- System addressed as a whole – error budgets
- Significant application of technology in last half of century

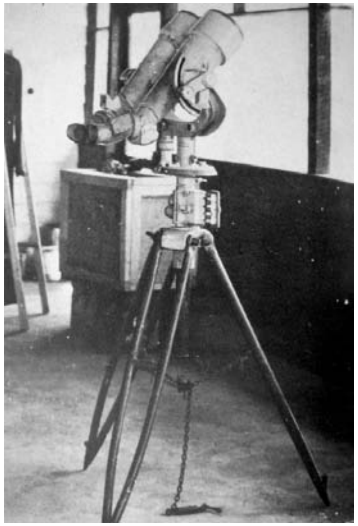


The Need for Fire Control

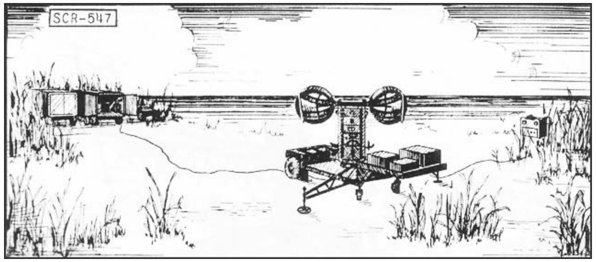
- Early conflicts occurred at essentially “point blank” range
  - Monitor vs. Merrimack – 100 yards
  - Gettysburg – 200 yards and less
- Increased ranges up to 10,000 yards at the end of the 19th century placed new demands on
  - Target Acquisition
  - Accuracy

Target Acquisition Evolution

- Human Senses (Eye, Ears, Nose)
- Technologies
  - Daylight Optics
  - IR Active
  - IR Passive
  - Thermal (1960s; Army Common Modules 1970s;)
  - Radar
  - Acoustics



Active Infrared light source and viewing telescope



The Effect of Increased Ranges

- Inaccuracies introduced due to
  - Target Range estimation errors
  - Effect of weather on longer flight times – *e.g.* wind
  - Drift caused by Rifled barrels
- Increased importance of previous relatively minor effects
  - Atmospheric temperature and pressure
  - Propellant weight and temperature
  - Barrel erosion (effect on Muzzle Velocity)

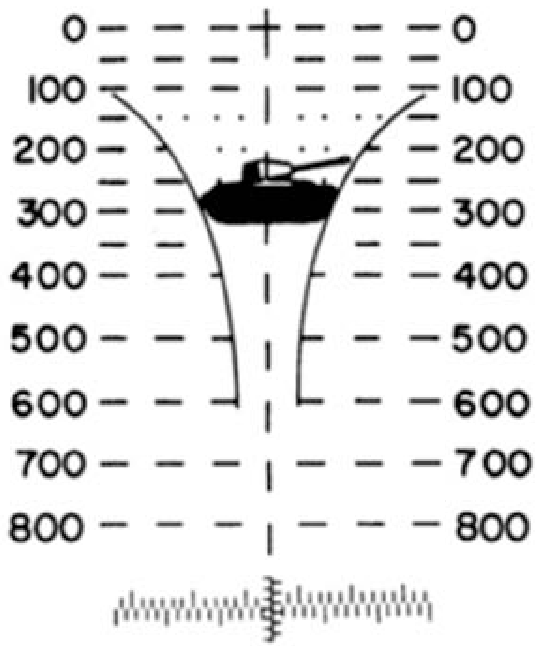
Compensating for Range

- Range estimators
  - Human - approximately 21% of range
  - Stadiametric - 12-18%
  - Optical - Coincidence, Stereoscopic – good accuracy (1% @ 2000M), but time consuming
  - Laser –Ruby (mid 60s); Nd Yag 1.06u (1970s); Erbium (eyesafe) (1980s), <5 meters

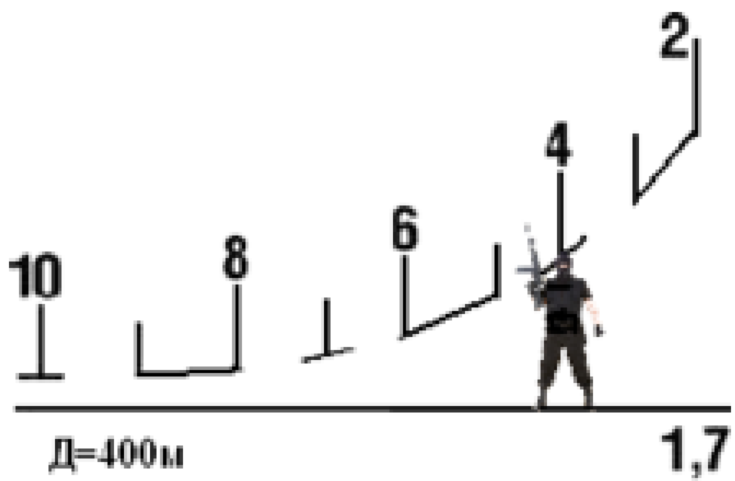
Stadiametric Ranging/ Ballistic Reticle

Stadia lines imposed in ballistic Reticle

Know target sizes “choked” between stadia lines results in required superelevation

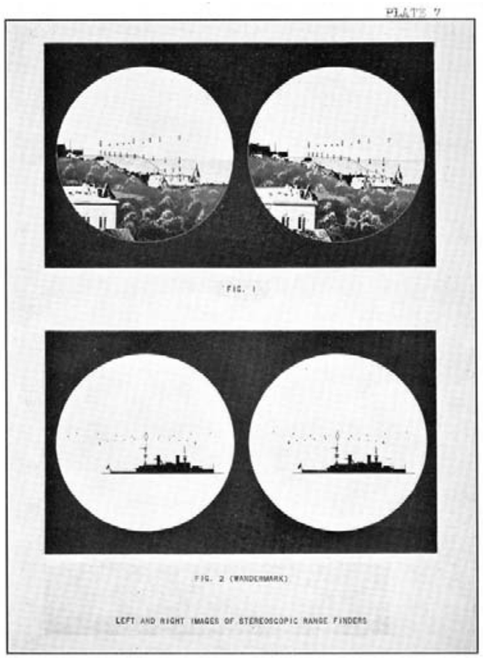


Tank size target



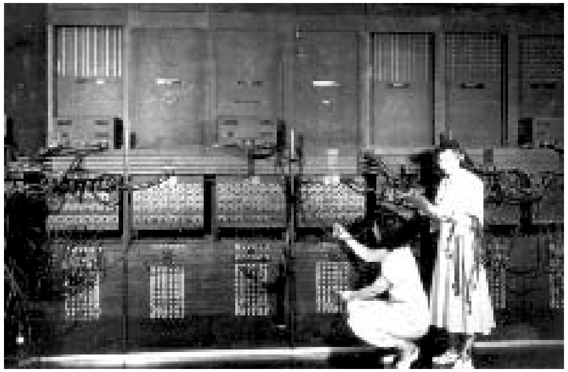
Man size target

Coincidence Rangefinders



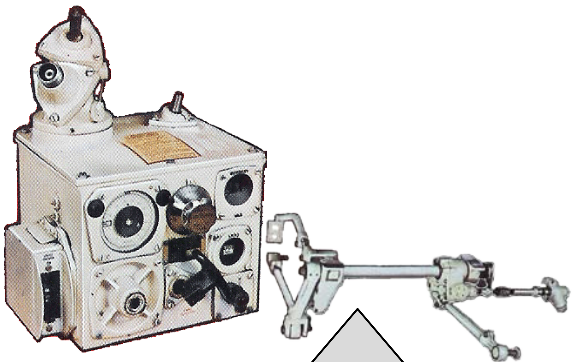
Computation of Ballistics

- Exclusive use of Firing Tables 1900 -1935
- Initial use of computers for FT generation 1930s – WW II
  - *e.g.* Bush Differential Analyzer 1935
  - Unable to keep with volume
- ENIAC & EDVAC for FT generation – WW II
  - Provided necessary accuracy and flexibility
  - Sparked the computer age



- Computers in a field environment – 1970s to present
  - Continuous enhancements in computing capability and memory
  - Ability to interface with and automate sensor inputs
  - Associated Improvements in Trajectory Models
    - Modified Point Mass Solution (1960s)
    - NABK (1990s)
    - Expansion of NATO Kernels – NAMK, NIFK, NAGIK (2000-present)

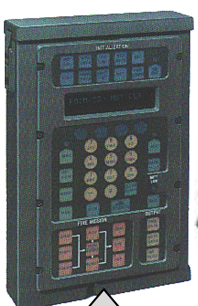
Computational Hardware



M13 Mechanical Computer & Linkage

Field Artillery Digital Automatic Computer

Advanced Field Artillery Tactical Data System (AFATDS)



M23, Mortar Ballistic Computer

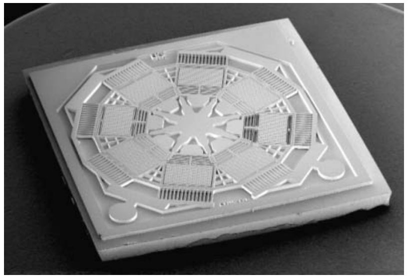
M32,Lightweight Handheld Mortar Ballistic Computer (LHMBC)

Smart Phone

Mortar Fire Control System Computers

Inertial Pointing Systems

- Accurate pointing <1mil
- With computers, enabled automated laying with no external aids
- System Types
  - Fluid gyro
  - Spinning mass gyro
  - Fiber optic gyro
  - Laser ring gyro
  - MEMs
  - Celestial



Indirect Fires before Digitization "Glass and Iron"

- Initially "Line of Sight" only
- Aiming Circles/Aiming Stakes/Collimators
- Sight Units on Weapons reference aiming circles
- Voice Communication only
- Instrument leveling
- Maps/Charts/Protractors at FDC
- Manual Positioning of Weapon
- Adjusted Fire Technique

Advantages of Integrated Digital Systems

Digital technology provides significant improvements to Indirect Fire systems

- Digital Link To Fire Support Network
  - Call for Fire
  - Met data
- On-board Ballistic Computation with sensor inputs
- GPS for on-board navigation and location systems
- Accurate auto gun orientation
- Self alignment and orientation
- Automatic Weapon Drives & Control

Enhanced Responsiveness, Accuracy and Survivability

U.S. Artillery & Mortar Digitization

1992 - Paladin Continuous upgrades to present

2003 1064 Mortar Carrier

2004 Stryker Mortar Variant

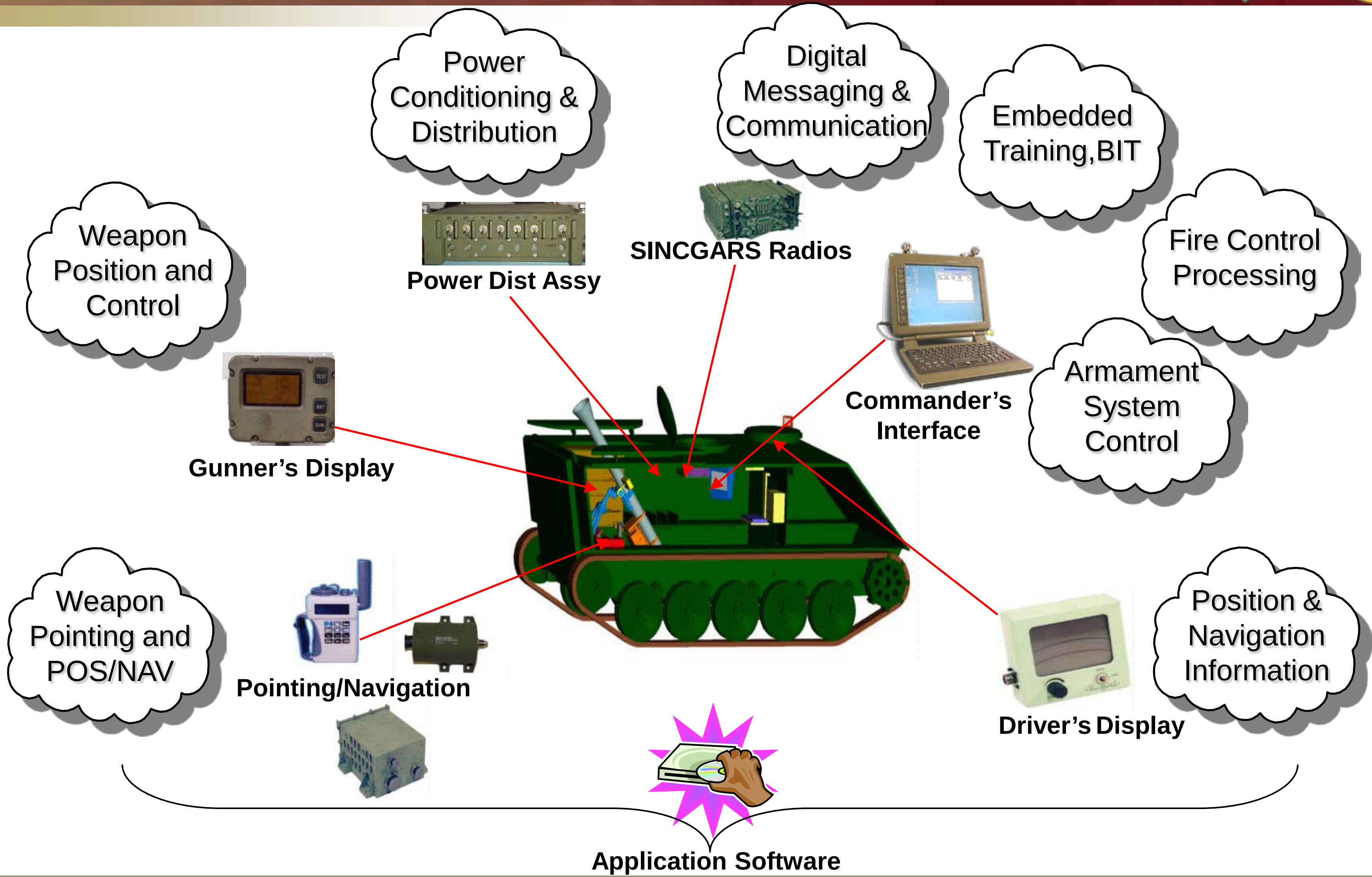
2007 M777

2007 Portable Excalibur Fire Control

2009 Dismounted 120mm

2013 M119A3 Digital Fire Control

Modern Indirect Fire Control System



Digitizing the M1064 with Mortar Fire Control System – M95

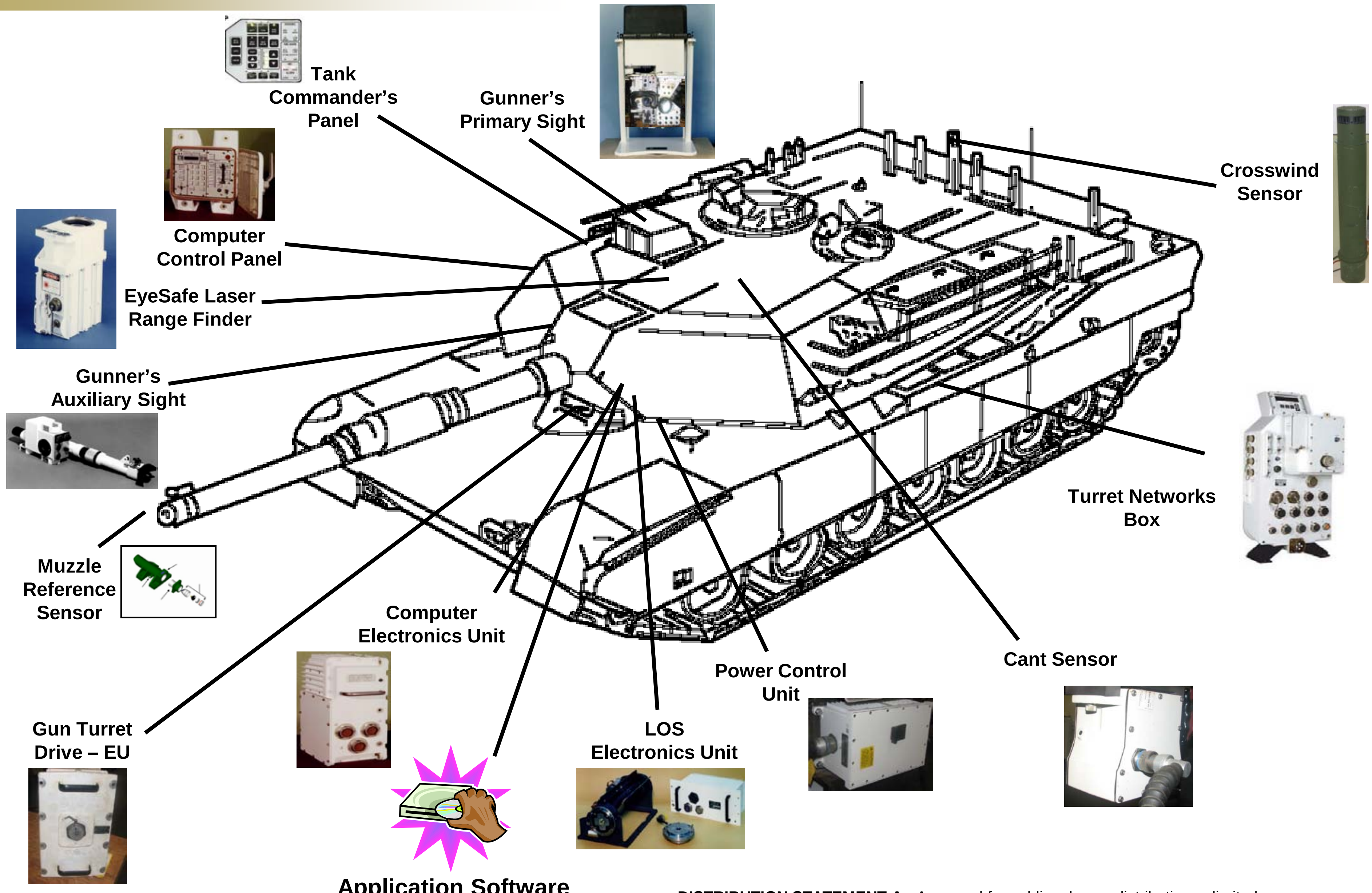
Tank Fire Control Evolution

	50's	60's	70's	80's	90's	2000 to Present
FIRE CONTROL COMPUTER	Ballistic Reticle	Mechanical Computer	Analog Computer	Digital Ballistic Computer	Digital Architecture Hunter/Killer	Ammo Data Link (VSMC)
SENSORS						
• **RANGE**	Optical		Ruby	NdYag		
• **ENVIRONMENTAL**			→	→		
• **MUZZLE REFERENCE**				Optical (Manual)		
• **TRACKING**			Rate			
ACQUISITION	Hard Optics	Image Converters	Image Intensifiers	Thermal; 1st Gen. FLIR	2nd Gen. FLIR	
STABILIZATION			Gun	Sight (1 Axis)	Sight (Dual Axis)	

Malcolm Baldrige National Quality Award 2007 Award Recipient

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Modern Direct Fire System
M1A1 Abrams FC



The Future

- Emphasis on software algorithms/networking
  - Battlefield Decision Aids
  - Information Fusion
  - Sensor Fusion
- Tracking and commanding smart munitions
- Emphasis on SWAP
  - Reduced size, weight and power, *e.g*. MEMs
  - Efficient functional and physical integration
  - Large system capabilities available for dismounted Soldier

Contact Info:

Victor Galgano

Manager, Business Planning & Development
Fire Control Systems & Technology
US Army ARDEC, RDAR-WSF-B
973.724.6021
victor.galgano@us.army.mil

Ralph Tillinghast

Collaboration Innovation Lab
Lab Director
Fire Control Systems & Technology
US Army ARDEC, RDAR-WSF-M
973.724.2095
ralph.tillinghast@us.army.mil

Questions?