Introduction to Directed Energy System Engineering Challenges

A Practical Case Study of Introducing Disruptive Technology

by
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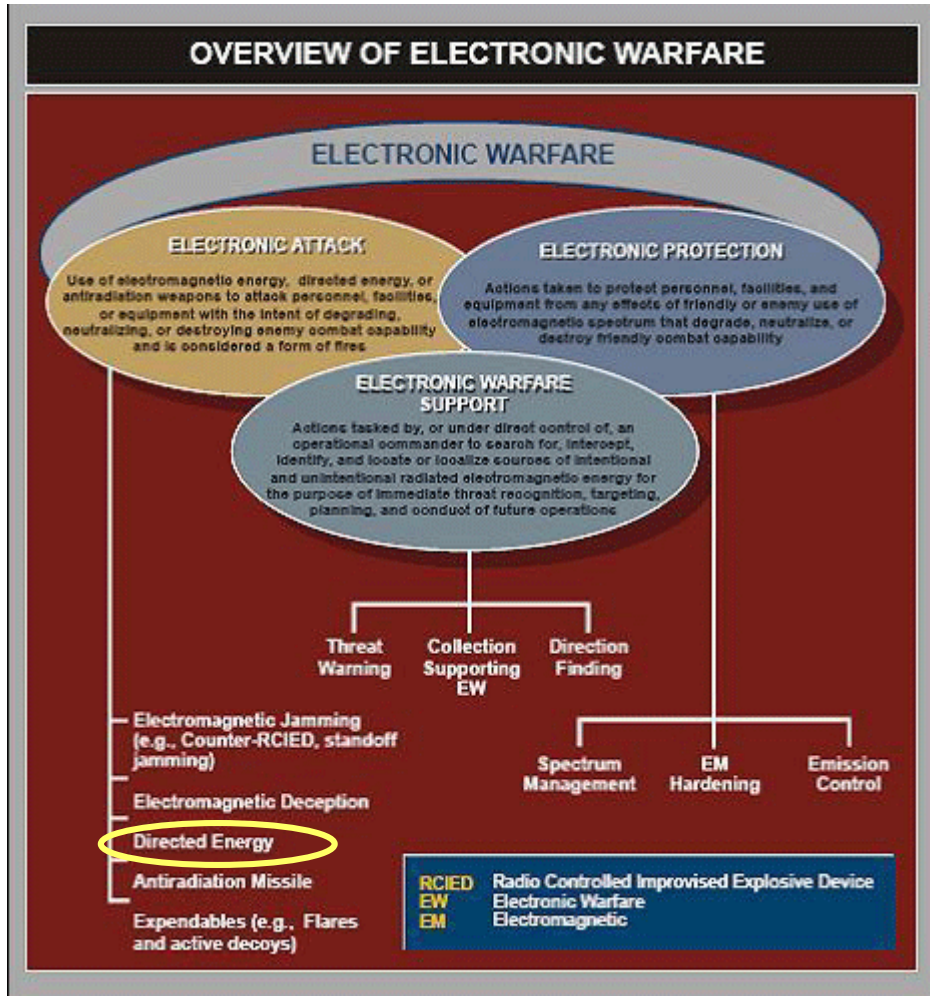
I have one simple request.
And that is to have sharks with frickin' laser beams attached to their heads!

My First Exposure to Real High Energy Lasers (~1978)

Directed Energy DoD Definition



IAW JP 3-13.1 Joint Electronic Warfare: EW doctrine includes the following three major subdivisions; electronic attack (EA), electronic protection (EP), and electronic warfare support (ES):

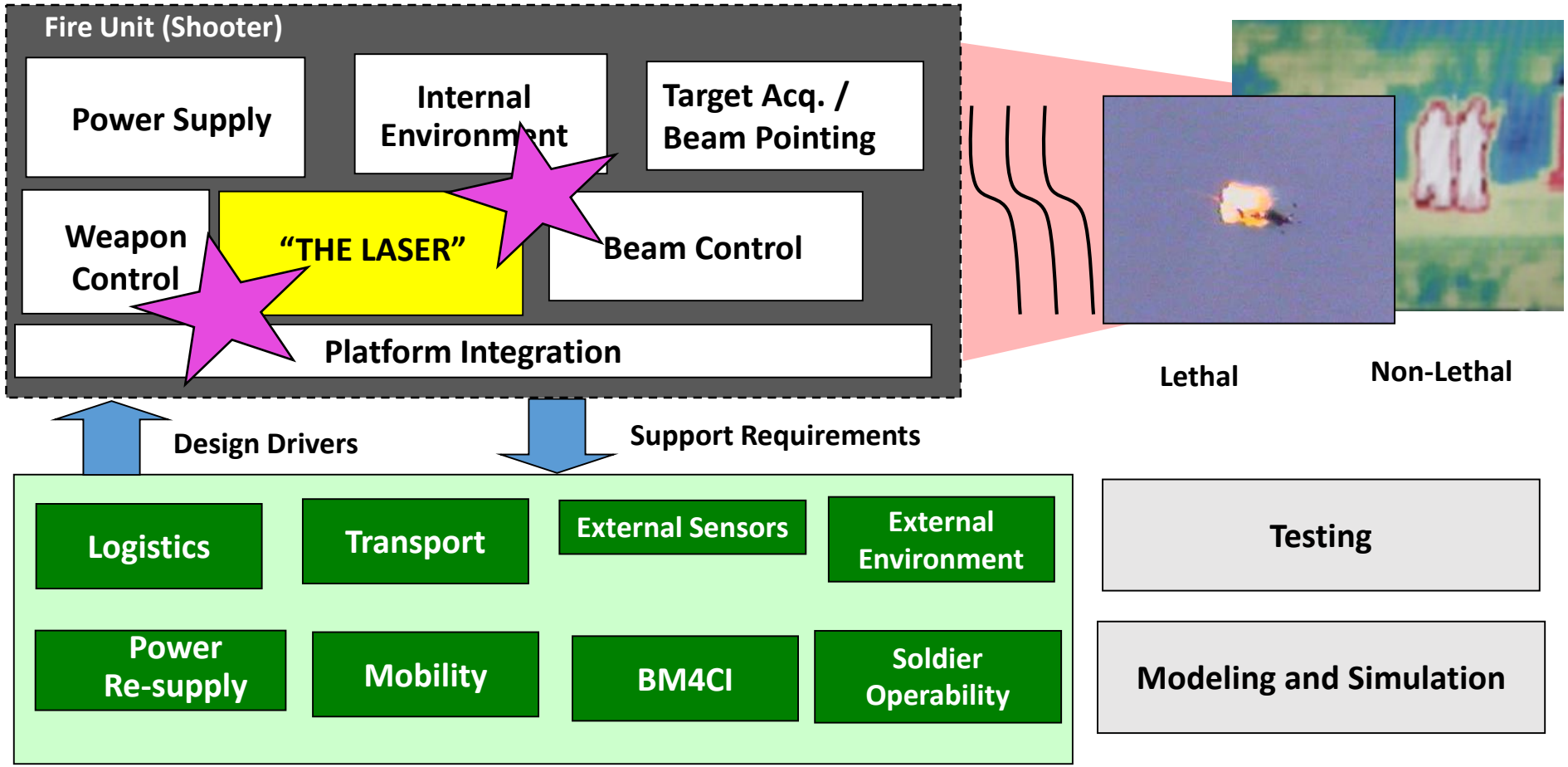
Electronic Attack (EA), which involves the use of EM energy, directed energy, or anti-radiation weapons to attack personnel, facilities, or equipment with the intent of degrading, neutralizing, or destroying enemy combat capability and is considered a form of fires.

Electronic Protection (EP), which involves actions taken to protect personnel, facilities, and equipment from any effects of friendly or enemy use of the electromagnetic spectrum that degrade, neutralize, or destroy friendly combat capability.

Electronic Warfare Support (ES), which involves the actions tasked by, or under direct control of, an operational commander to search for, intercept, identify, and locate or localize sources of intentional and unintentional radiated EM energy for the purpose of immediate threat recognition, targeting, planning, and conducting of future operations.

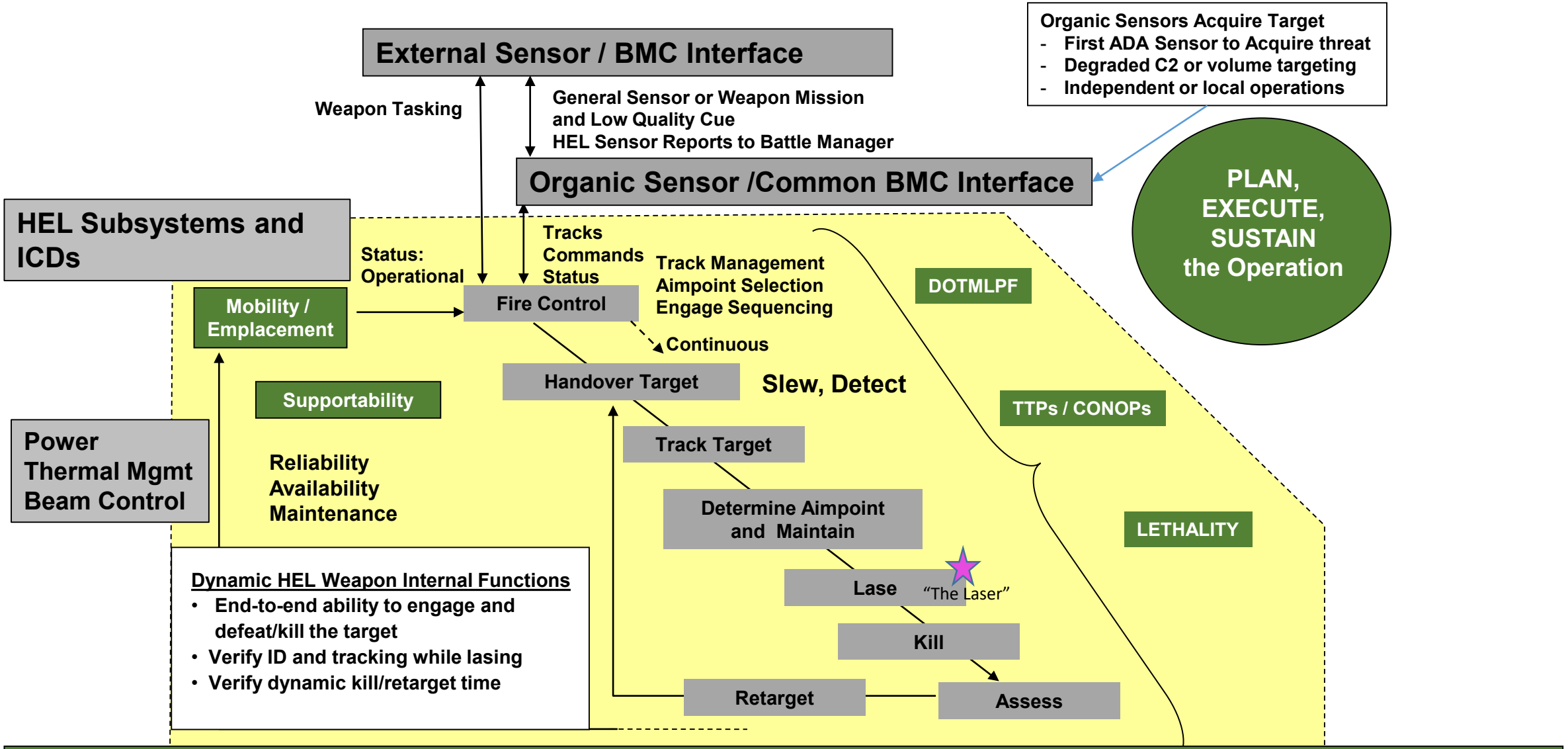
DOD defines Directed Energy as an element of Electronic Attack and is a form of Fires

High Powered Laser is an HEL Weapon System Sub-Element



High Energy Laser Weapon System Integrate, control and apply HEL technologies to achieve a militarily significant effect

Integrated HEL Weapon System



High Energy Laser Weapon Systems integrate into Operational Capabilities

Addressed the Classical Engineering Design Loop

- Identify the Challenge (Problem), Requirement or Objective
- Research to understand the challenge and associated issues/stakeholders
- Brainstorm
- Identify possible solutions and define the Constraints
- Develop a strategy/plan to address the challenge
- Resource ($, people, facilities, etc.) the plan
- Develop/Prototype
- Test, Analyze the results, optimize
- Evaluate
- Present

Identified The Challenge

How to protect deployed US Forces

and reduce the number of American Combat Casualties?

Did The Research

What caused the most American Combat Casualties?

World War I Casualties

- Artillery 73%
- Machine gun 12%
- Grenade, mortar, bomb: 8%
- Rifle bullets 5%
- Chemical - fewer than 1%

World War II Casualties

- Artillery 73%
- Machine gun 12%
- Grenade, mortar, bomb: 8%
- Rifle bullets 5%

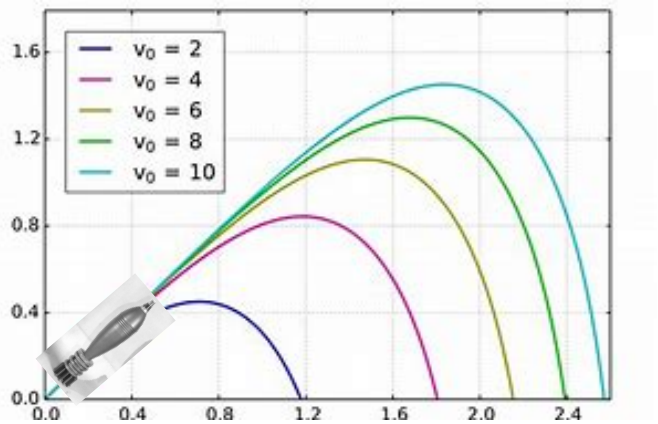
Vietnam Casualties

- Small Arms, Rifle/MG bullets 51%
- Artillery 36%
- Grenade, mortar, bomb: 11%
- Other means 2%

Research found that > 70 % of American Combat Casualties in the 20th Century was caused by Artillery, Mortars and Rockets (RAM)

Defined the RAM Characteristics

- Large number of rocket, artillery and mortars
- Stockpiled around the world
- Available to all militaries and terrorists groups
- Easy to use
- Can launch/fire from protected locations
- Relatively cheap
- Short time of flight
- Small
- History shows they are highly effective



Mortars

60mm
81mm
120mm

Rockets

57 mm **240 mm**
107 mm **330 mm**
122 mm

Identified the options to address the RAM Challenge

- Create RAM survivable infrastructures and vehicles
- Pre-emptive Counter Fire to destroy the launcher
- Warning System
- Defeat the RAM after it has been launched
- Other options?

Brainstormed the Engagement Options

- Missile
- Gun
- Laser
- Other?

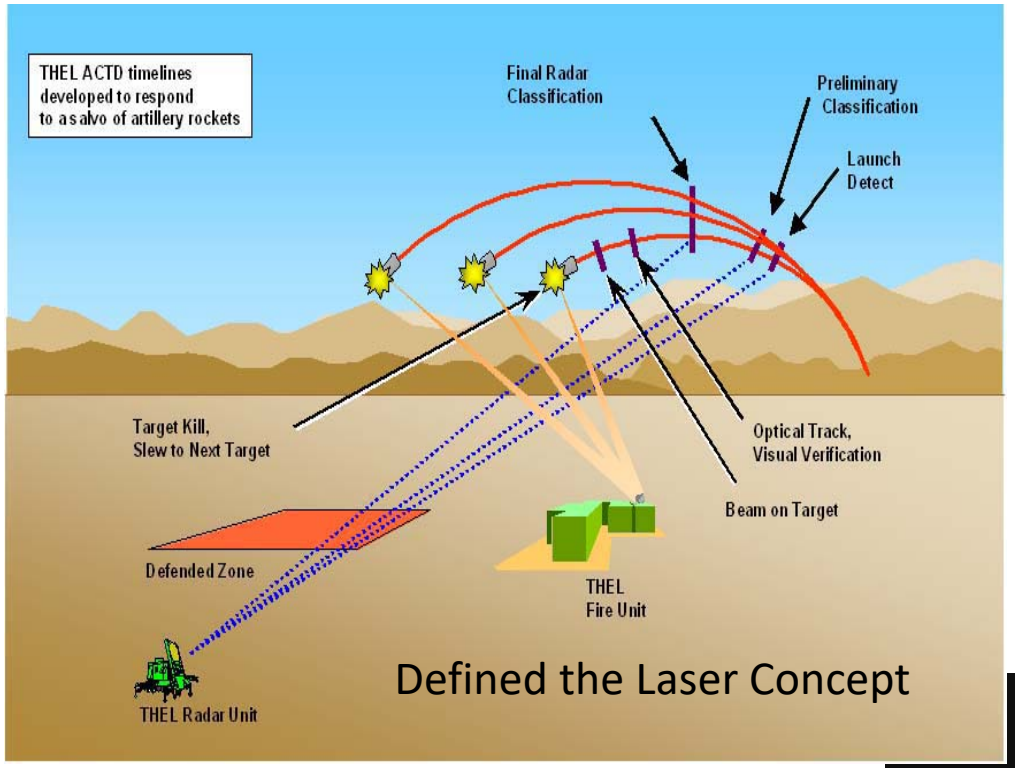
Defined the Engagement Constraints

- Responsive (fast, quick response, fast retargeting, etc.)
- Robust (sustainable deep magazines and ability to address large number of targets)
- Accurate
- Low Cost
- Easy to operate and maintain/resupply in an austere environment
- Safe to operate and maintain
- Cannot cause damage to people or things in the area
- Other constraints?

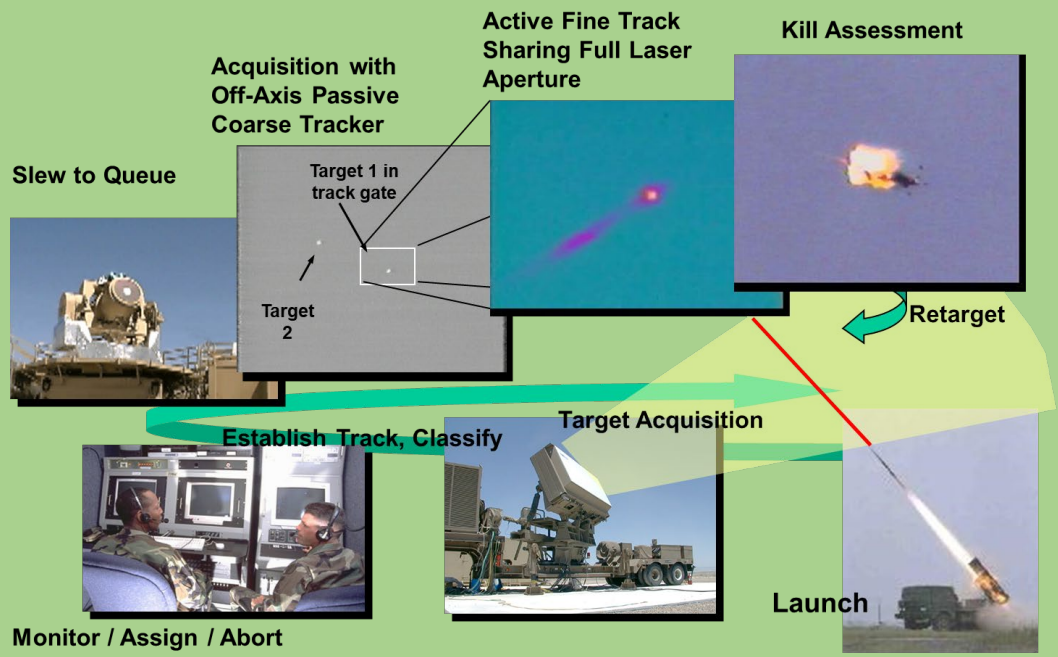
Avoid these types of solutions!

Developed The Laser Weapon Option

- Defined how to defeat a rocket, artillery or mortar round in flight
  - How much energy is needed – thermal soak testing
  - How to find and track and defeat rockets in flight– Nautilus test



Defined the Laser Concept



Defined technical processes to operate a laser weapon prototype

The Laser Option Evaluation and Refinement

- Evaluated the test results against operational needs to protect American Soldiers and Citizens
- Based on the test results and evaluations develop a prototype 
  - Tactical High Energy Laser Advanced Technology Demonstrator Capability concept (sensor, command and control and laser weapon)
  - Present the test results, assessment and resulting refined mobile concept to leadership to resource the optimized prototype design and development
- In 2005, based on ongoing conflicts, RAM was envisioned to be next "Arms Race"
  - Rockets became the symbol of the war as a means to overcome sophisticated enemy
  - Rockets are the airpower of the guerilla force
  - Learned that early warning is priceless but need active defense as part of the combination of efforts and protecting the citizens is militarily significant

Based the classical system engineering model and demonstrated successes coupled with the increased threats, I can confidently conclude the US has multiple HEL weapon systems developed and deployed.

. . . . But the Army did not have an approved “Requirement” to counter RAM at the time.

Result: Terminated the program.

Reflections

- Unique position to work through the HEL weapon potential capabilities and processes
  - Operational experience as Armor, Mortar, Scout and tactical unit maintenance officer
  - Logistics and Maintenance planning experience from tactical to strategic levels to include wartime planning
  - Field and depot experience provided detailed understanding of ADA systems
  - MS Applied Physics in optical mechanical design
  - Army 6T Equip the Force Officer – Technology Integrator (6.3b and beyond) vice R&D Developer (6.1-6.3a)
  - Direction to make a proposed stand alone Industry Concept HEL weapon work => Developed the Tactical High Energy Laser Advanced Concept Technology Demonstration concept
- Virtual environment experimentation and system developmental tests indicated High Energy Weapons may have operational impacts
- First step in successful DOD program development is a well defined and understood requirement
  - Worked with the Force Development communities and Combatant Commands to develop the CRAM mission
  - Learned that “Requirements” are based detailed operational understanding of the capability
  - There has not been an robust operational prototype(s) with the right SWAP for operational communities to develop the needed “hands on” understanding of DE based weapons
  - How does one require something they don’t know much less understand?

Reflections

- In 2003, successful deployed an HEL based device
  - Unit CONOPS and TTPs need to be developed prior to unit deployment to develop confidence in the system before using in an unknown hostile environment
  - Trained crews with accepting leaders did not deploy with the system
  - Rapid unit turn over required repetitive unit training in country
- As an operational unit commander
  - Units don't automatically accept new technology and "capabilities" proposed by Army engineers and scientists
  - The solution has to be ultimately accepted by the combat Soldier and unit leaders
- Learned that technology or engineering by itself does not "sell"
  - A technology does not equate to a weapon system
  - A weapon system does not equate to a combat capability

Need to develop a "hand on" learning experience and formalize integrated CONOPS for Army, Soldier and unit leader acceptance

"It must be considered that there is nothing more difficult to carry out, nor more doubtful of success, nor more dangerous to handle than to initiate a new order of things. For the reformer has enemies in all those who profit by the old order, and only lukewarm defenders in all those who would profit by the new order, this lukewarmness arising partly from fear of their adversaries, who have the laws in their favor; and partly from the incredulity of mankind, who do not truly believe in anything new until they have had actual experience of it."

- Machiavelli, The Prince

Directed Energy embodies a new order of revolutionary capabilities and the Army needs a process for the solider to “experience” it

Disruptive Technology (DT) Requires a Different Development Process

Incremental development:

- Identify the "known and understood" threat, capability gap or requirement by proponent
- Prioritize the mission and need
- Develop AOA and preferred material solutions
- Resource the preferred solutions IAW prioritized needs and missions
- Assign responsibility and execute

- Note: incremental process is designed to "weed out" "disruptions"

Disruptive development:

✓Identify process as disruptive and a potential real threat

⇒Determine the strategic significance
  - Assessment, test, validation, and education processes

The next step

- Identify initial applications and proponents
- Create independent disruptive technology development process and organization
  - Requires senior leader champion
- Keep the disruptive organization independent

Elements of a Military Revolution

Military Revolution: A major change in the nature of warfare brought about by the ..innovative application of new or even existing technologies.. which when combined with dramatic changes in military doctrine, operational and organizational concepts, fundamentally alters the character and conduct of military operations.

- Operational Change or Shortfall
- Technological Change
- System Development
- Operational Innovation
- Organizational Adaptation

To Create Effective and lasting Revolution in Military Affairs Takes the Entire Military Infrastructure and not just an introduction of new technology

Capabilities vs Technology

- Gaps are filled by capabilities not just technology or materiel solutions
- Development of a “Capability” to address a specific gap requires cultural adaption
  - Requires acceptable Non-materiel and supporting integrated solutions across the DOTMLPF domains
  - Effective Tactics, Techniques and Procedures
  - Effective Operational Concepts of Operations and Integration into the overall arsenal
- Current focus of “Transformation” is on information-led “network-centric warfare”
  - A system of ISR systems, precision weapons, and “sensor to shooter” links
  - Still relies on historic architectures and non-materiel cultures
- Militaries need to adjust to the emerging “Electronic Age” architectures and cultures
  - Will result in new concepts of firepower doctrine, new weapon systems, new missions, and new culture will be part of RMA
  - DEW, as a component, will force militaries to change how they conduct military operations and character of warfare in the 21st Century
  - Enables greater emphasis on the subtleties of precise, scalable, responsive fires on military effects, rather than mass or overwhelming effects

You Will See DE When..

- There are motivated users with the resources to incorporate DE into their force structures.
  - *They must codify their requirements and provide advocacy to support acquisition*

- We stop waiting for the "around-the-corner" DE solution.
  - *Release technology from the S&T sandbox. Operationally viable DE systems can meet shortfalls NOW.*

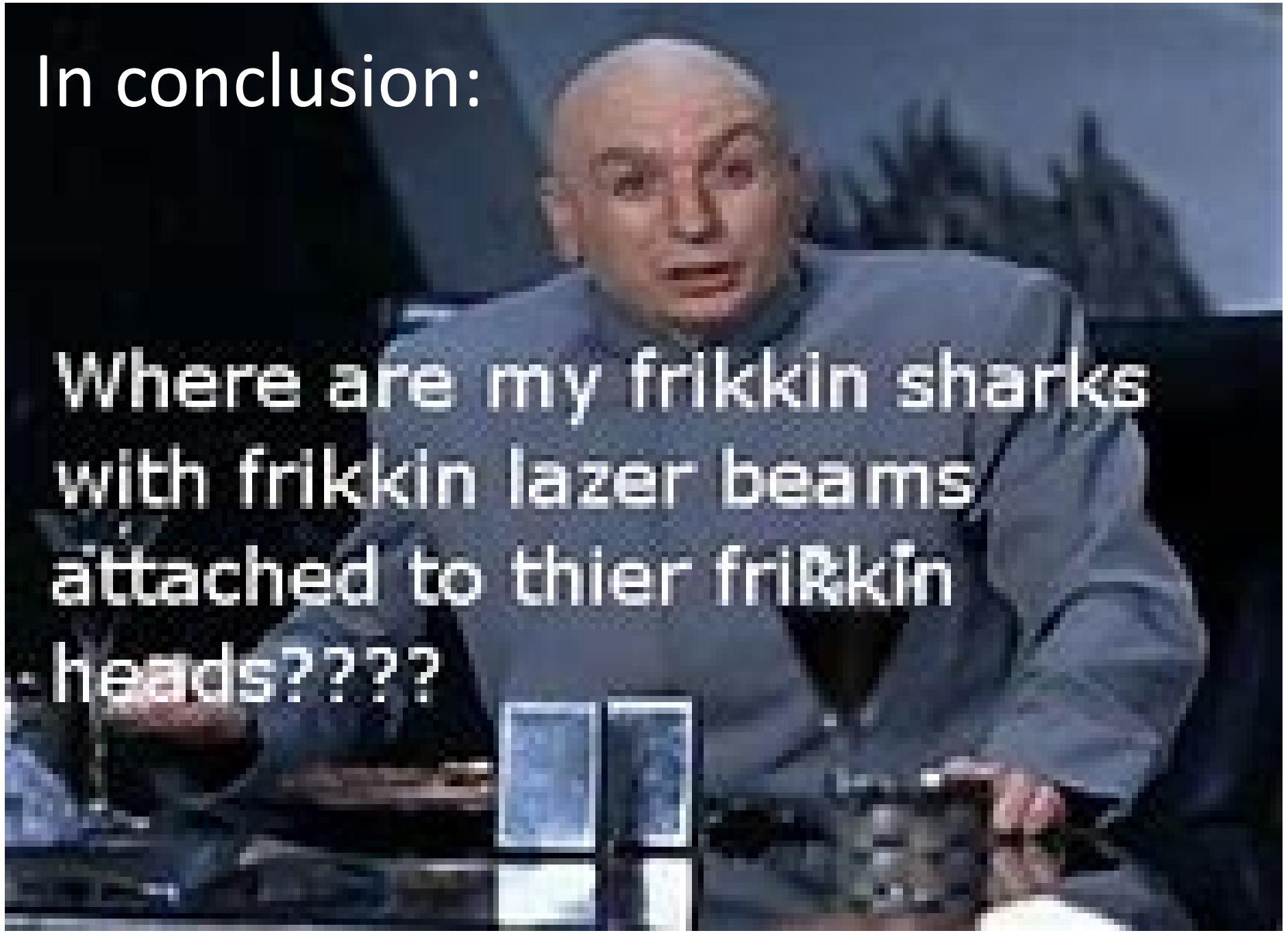
- The Acquisition process works as intended to allow capabilities to reach the warfighter sooner
  - *Provide ground-laying resources to bridge the "valley of death" between S&T and System Develop and Demonstration (MS B).*

The Good News

- Counter-RAM is a recognized DOD and Army mission and directed energy concepts are considered a viable option
- DOD has an approved process to introduce Directed Energy weapons into military operations
- Senior Army leaders recognize that directed energy is a disruptive technology requiring an Whole of Army development effort
- Senior Army leaders identified and resourced a Directed Energy Champion to develop robust prototypes
  - Learn the operational capabilities and limitations of directed energy based weapons
  - Learn the integrated DE weapon system engineering and sustainment requirements
  - Developing the military and system engineering understanding for requirement development in order to cross the Valley of Death from the laboratory to a Program of Record

Addressing the rest of the SE challenges

- The Army is beginning to identify the cultural and organizational elements to integrate a directed energy technology based weapon
  - DOTmLPF-PL: Doctrine, Organization, Training, materiel (integrating and supporting technologies), Leadership, Personnel, Facilities, Policy and Legal
  - Operational Concepts (CONOPS)
  - Tactics, Techniques, and Procedures (TTPs)- the Solider and unit leader "how we fight a DE weapon" and unit tactics, techniques and procedural standards
- But we have a long way to go using a ***disciplined System Engineering process for final Soldier and leader acceptance*** . . . . and final integration of Directed Energy weapons into the overall military infrastructures, unit CONOPS and the US Arsenal sustainment systems.


In conclusion:
Where are my frikkin sharks with frikkin lazer beams attached to thier frikkin heads????