Multi-Mode Precision Strike Weapons

Agenda

- **The Need for Multi-Mode Guided Weapons**
  - **Definitions – what do we mean by multi-mode?**
  - **60+ years of increasing precision – but we're not there yet**
- **Identifying the Gaps in Capability**
  - **Target Set Coverage**
  - **Targeting infrastructure performance**
  - **Precision engagement of movers in weather, clutter & ROE – the Holy Grail**
- **Filling the Precision Strike Gap**
  - **Precision Self & 3rd Party targeting**
  - **Multi-mode seekers**
  - **Weapon Data Links**
- **Implications and Issues**
  - **What technology, with the right TTP, might provide solutions?**

Single & Multi-Mode Precision Weapons

- **Single Mode**
  - **Semi-active Laser**
    - **GBU-12/16/24, etc.**
  - **GPS/INS (CSW)**
    - **GBU-31/32 JDAM**

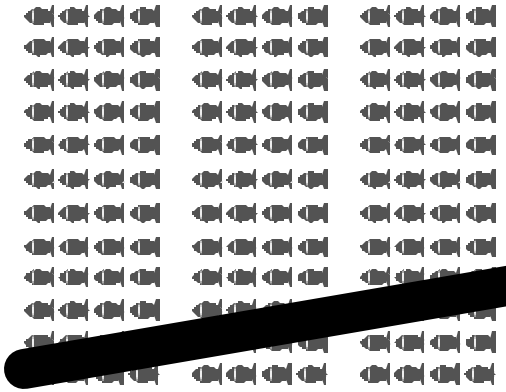
- **Multi-Mode**
  - **Semi-active Laser + GPS/INS**
    - **Enhanced Paveway II/IV**
    - **Laser JDAM**
  - **IR terminal seeker + GPS/INS**
    - **JSOW Unitary**
  - **DSMAC+GPS/INS+Datalink**
    - **Tactical Tomahawk**

Air Armament: A Capability Transformation Success Story

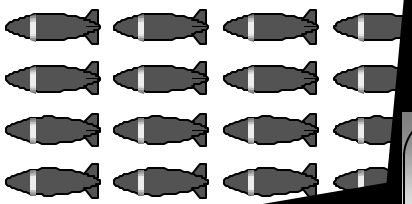
Dispersion:

~100 mils	~20 mils	~0.6 mils	0 mils
1943	**1970**	**1991**	**1999**

1500 B-17 sorties
9000 bombs (250#)
3300 ft CEP
One 60' x 100' target
W.W.II



30 F-4 sorties
176 bombs (500#)
400 ft CEP
One Target
Vietnam



1 F-117 sortie
2 bombs (2000#)
10 ft CEP
Two Targets per Sortie
Desert Storm

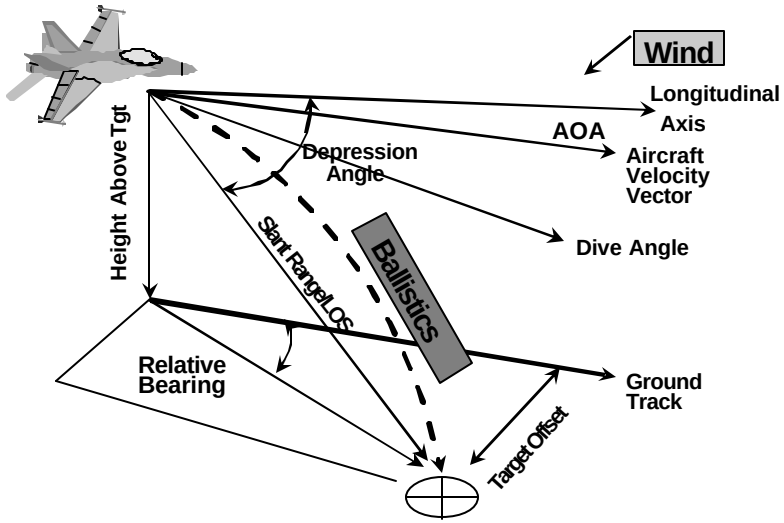
1 B-2 sortie
16 bombs (2000#)
20 ft CEP
16 Targets per Pass
All Weather

Revolutionary Technologies

Laser Guidance

GPS Guidance

Dispersion in Aerial Gravity Bombing



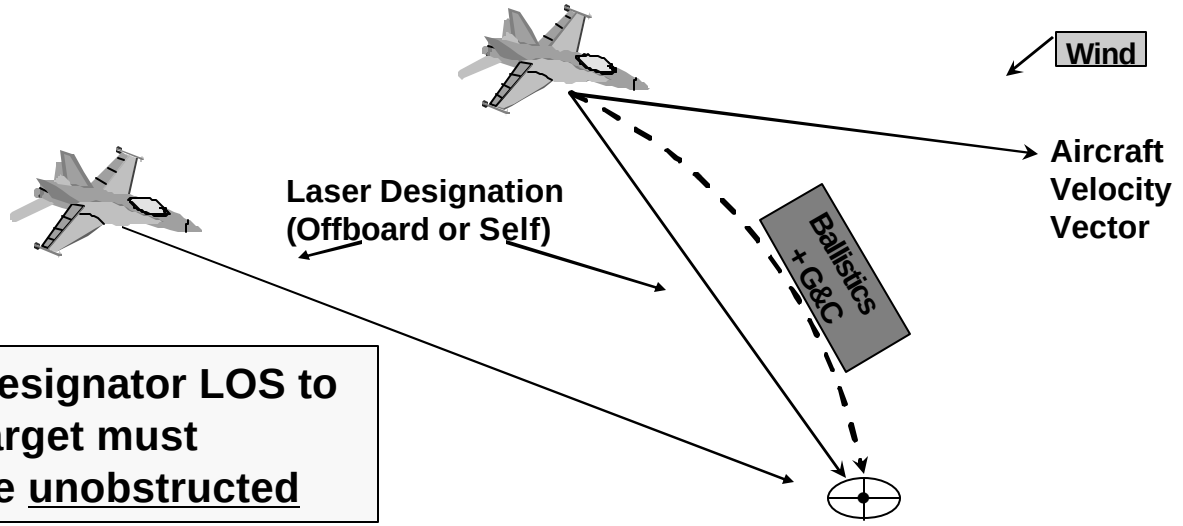
Goal:
Release when ballistic path intercepts target

Typical Bombing System Error Sources for "Dumb" Bomb Delivery

- **Wind error**
  - Pre release
    - INS Velocity error
    - TAS errors
  - Post release
    - Shear
    - Atmospheric model vs. actual conditions
- **Dispersion error**
  - Ballistic table errors
  - Weapon manufacturing variability
  - Ejector rack timing/velocity
- **Angle, range or velocity measurement error**
  - Boresight error
  - Incorrect aimpoint by crew
  - G or sideslip
  - INS velocity, TAS or Altitude error
  - Range sensor errors & limitations
    - Beam width, graze angle, FOR, resolution, pointing, etc

Typical automated freefall bomb system dispersion today is ~ 6 mils

Dispersion in Laser-Guided Bombing



If release occurs within kinematic envelope and LGB kit functions, kit corrects for wind and dispersion

Designator LOS to target must be unobstructed

- **Wind error**
  - Pre release
    - INS Velocity error
    - TAS errors
  - Post release
    - atmospheric model vs. actual conditions

- **Dispersion error**
  - Ballistic table errors
  - Weapon manufacturing variability
  - Ejector rack timing/velocity

- **Angle, range or velocity measurement error, designation error**
  - Boresight error
  - Incorrect aimpoint designation by crew
  - INS velocity, TAS or Altitude error (out of kinematic envelope)
  - Range sensor errors & limitations
    - Beam width/dispersion, graze angle, FOR, resolution, pointing, stabilization, etc

Typical automated LGB system dispersion is ~ 0.6 mils

- ~1 Order of magnitude improvement in effectiveness for cost of FLIR + LGB kit

Dispersion in GPS Guided Weapons (CSWs)

- **CEPs for GPS/INS guided weapons are a function of targeting accuracy, current local GPS performance, and weapon kit guidance & control performance:**

Generally, CSW CEP = $\sqrt{(TLE)^2 + (GPS)^2 + (G\&C)^2}$

Difference between target's actual location and provided coordinates

(Preplanned JDAM spec ≤7.2m CEP_{TLE} for 13m weapon CEP)

GPS accuracy at the time/place of the attack

Ability of weapon to hold the commanded flight path

- **GPS weapons are designed to guide to a coordinate location**
  - ✍ **They do not "detect" or "track" a target in the conventional sense, so ultimately, the weapons *must have* target coordinates**
  - ✍ **Same in future with Galileo or other positioning systems**
- **But the advantages are: all weather capability, and no dispersion (Fixed-target CEP is essentially the same regardless of range)**

Strike Planning Begins with Target Set Analysis

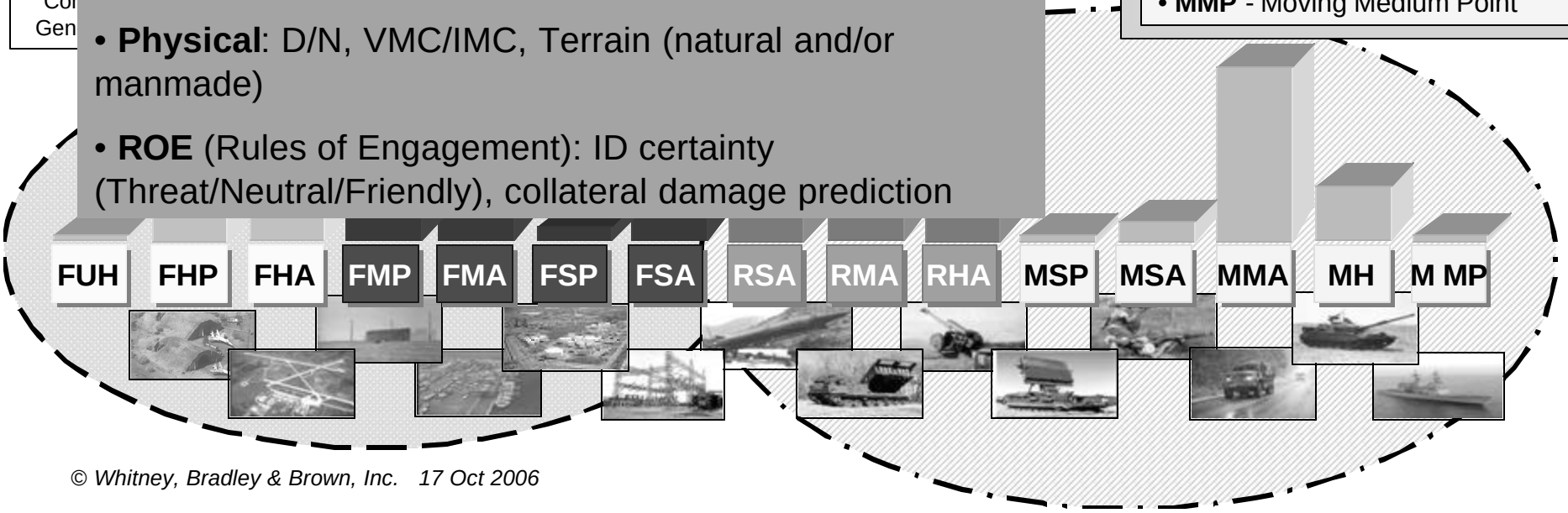
- **Binning targets as a function of their characteristics**

Mobility	**Hardness**	**Size**
Fixed	Hard	Point
Relocatable	Medium	Area
Moving	Soft	

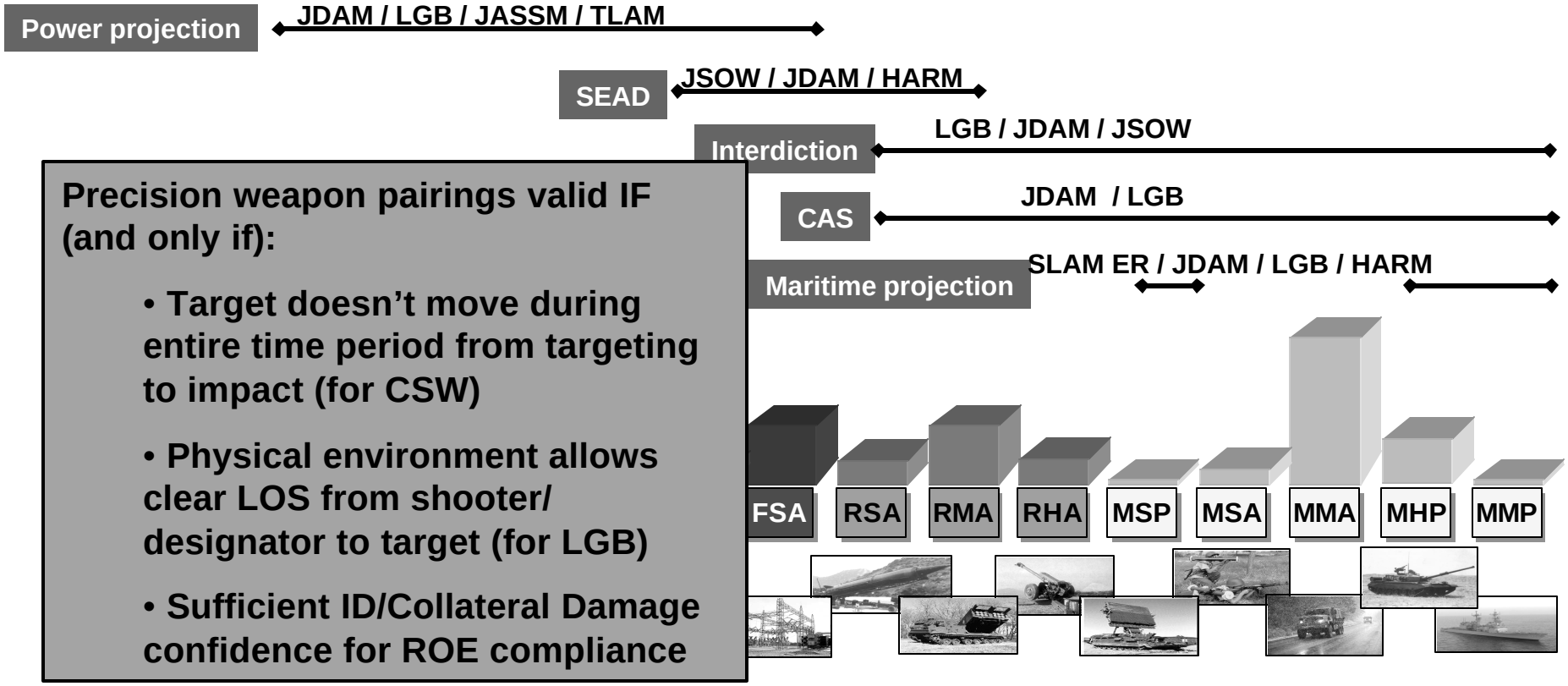
- **But the planner must ultimately consider the mission environment**
- **Threat:** Survivability of delivery platform, designator and weapon
- **Physical**: D/N, VMC/IMC, Terrain (natural and/or manmade)
- **ROE** (Rules of Engagement): ID certainty (Threat/Neutral/Friendly), collateral damage prediction

19 Target Classes

- **FUH** - Fixed Ultra Hard
- **FHP** - Fixed Hard Point
- **FHA** - Fixed Hard Area
- **FMP** - Fixed Medium Point
- **FMA** - Fixed Medium Area
- **FSP** - Fixed Soft Point
- **FSA** - Fixed Soft Area
- **RSA** - Reloc. Soft Area
- **RMA** - Reloc. Medium Area
- **RHA** - Reloc. Hard Area
- **MSP** - Moving Soft Point
- **MSA** - Moving Soft Area
- **MMA** - Moving Medium Area
- **MHP** - Moving Hard Point
- **MMP** - Moving Medium Point



Target, Weapon, & Mission Pairings Follow



Precision weapon pairings valid IF (and only if):

- **Target doesn't move during entire time period from targeting to impact (for CSW)**
- **Physical environment allows clear LOS from shooter/ designator to target (for LGB)**
- **Sufficient ID/Collateral Damage confidence for ROE compliance**

Precision munitions currently cover the entire fixed target set, but can engage movers only with favorable target behavior and mission conditions

The Real Mission Environment:
Weather in Operation Iraqi Freedom (OIF)

- **70% cloud free only 30% of time**

- **17 of 31 days good weather (clear to scattered clouds <10K ft)**

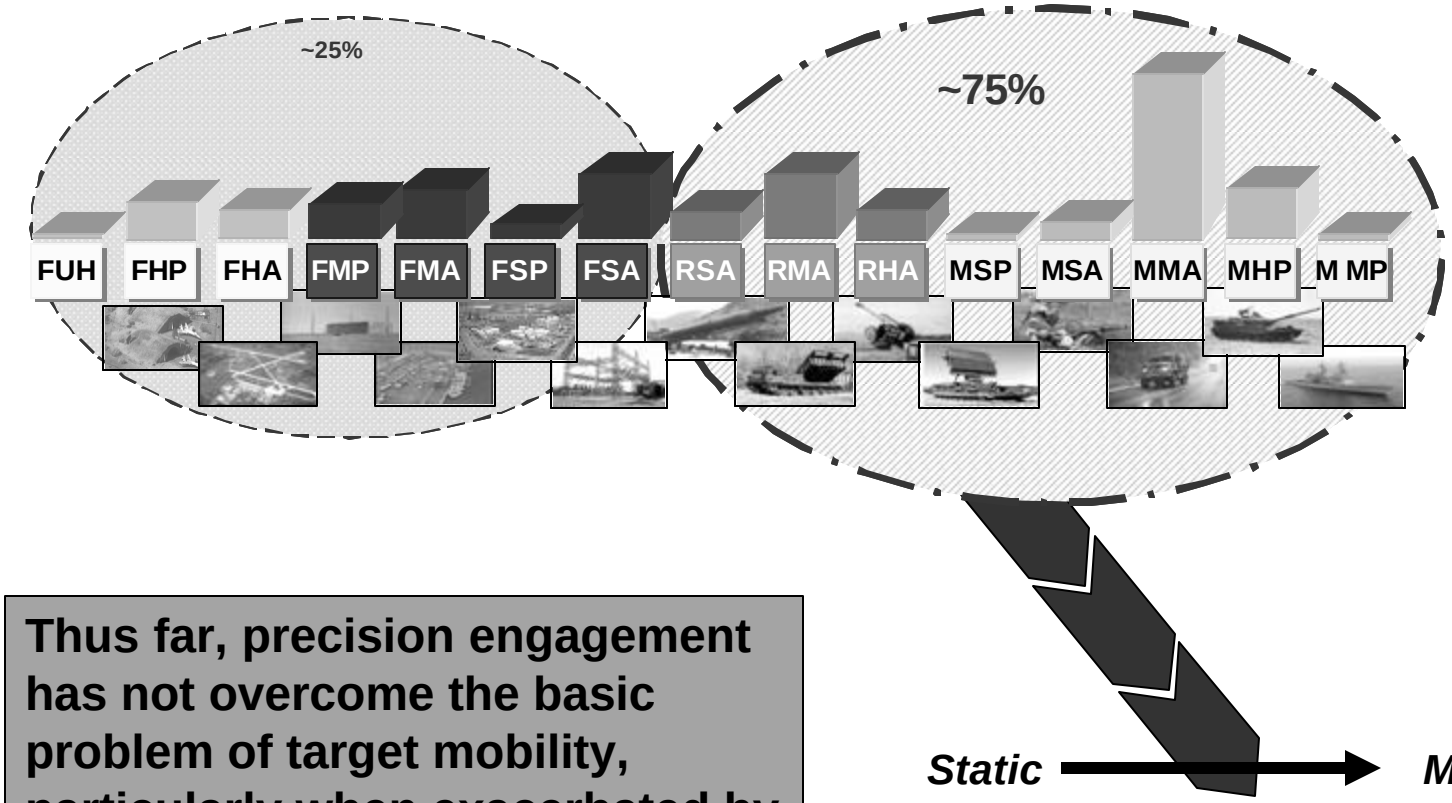
Ref: CENTAF "OIF By the Numbers", 30Apr03

Currently Deployed Multimode Weapons Primarily Improve Engagement of Stationary Targets

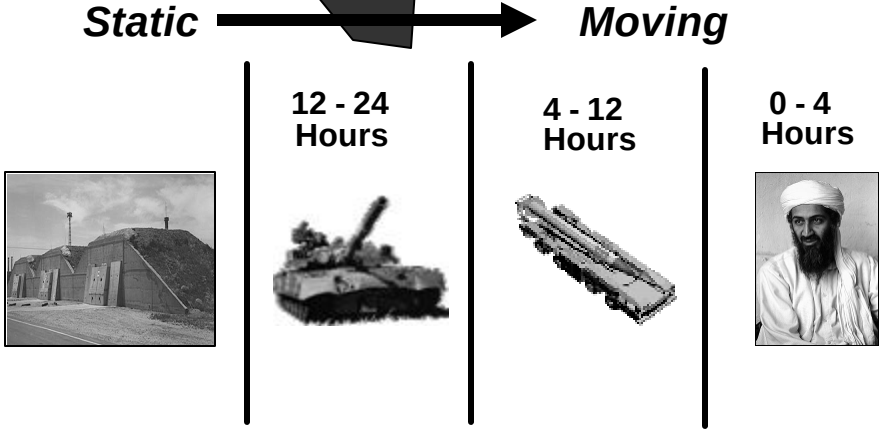
- **Requirements derived from current mission environment**
  - ✍ **Frequent bad weather, many targets of opportunity**
- **In Operation Enduring Freedom/Afghanistan:**
  - ✍ **U.S. aircraft carried mixed LGB/JDAM loads**
  - ✍ **In clear weather used FLIR to self- target and designate LGBs**
  - ✍ **In IMC used ground controllers to supply target ID & coordinates**
- **Could run into one or both conditions on a single mission**
  - ✍ **If one, only half the bomb loadout was usable**
- **Created US requirement for Enhanced Paveway II/Laser JDAM multimode (Laser+GPS/INS)**
  - ✍ **Already in UK service**

The UK has been well ahead of the US in both recognizing this multimode requirement and procuring a solution

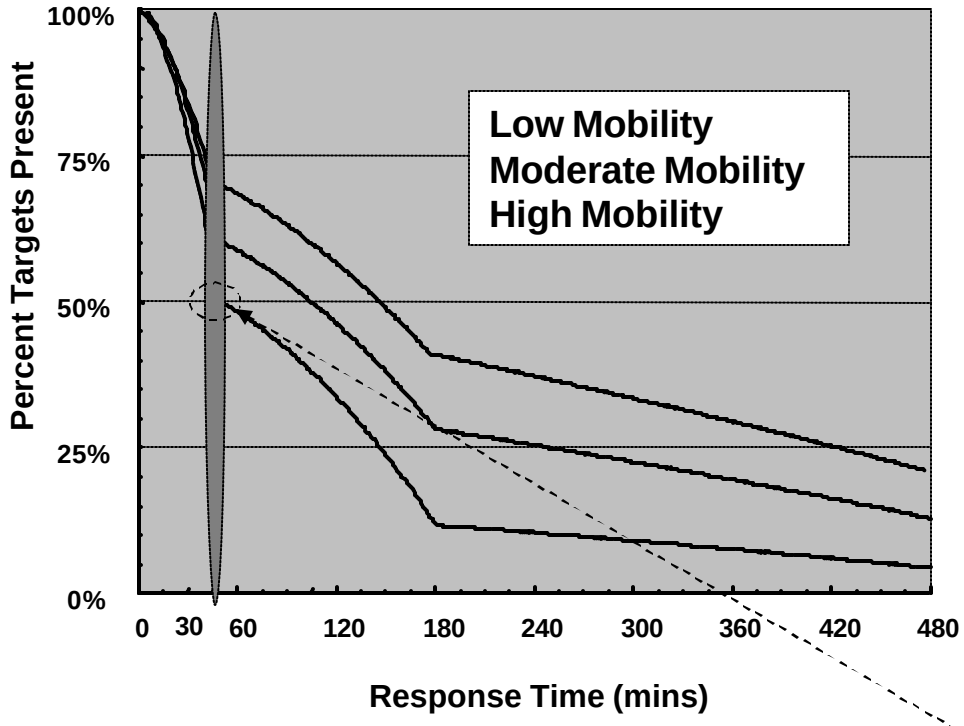
The Challenge of Mobile Targets



Thus far, precision engagement has not overcome the basic problem of target mobility, particularly when exacerbated by adverse mission conditions (bad weather, clutter, restrictive ROE)



Implications of Target Dwell Time



- US Army study for the ATACMS AoA classified mobility of moving targets by three characteristics
  - High - Moderate - Low mobility
- Study analyzed the response time necessary to put weapons on a target given an assumption as to its degree of mobility
  - Study assumed stable speed and direction of target movement
- 50% of high mobility target set has an expected dwell time of < 45 minutes

Current targeting infrastructure and methodologies are not responsive enough for short-dwell targets (let alone movers)

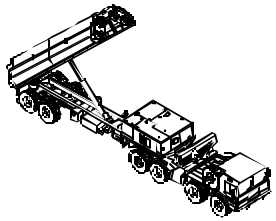
Key Capability Gaps:
What Must be Addressed to Reach "The Grail"?

- **Stationary targets:**
  - **Imagery mensuration or intel-based precision targeting:**
    - **Is too slow, not portable/fieldable, requires connectivity from controller/delivery platform to limited number of centers**
    - **Requires highly-trained targeteers with expensive equipment**
  - **Real-time coordinate generation in the field:**
    - **Is too imprecise at operationally useful ranges**
    - **Uses equipment that is expensive, heavy or both**
    - **Through-the-weather sensors lack sufficient resolution for positive ID, especially in clutter**
- **Moving targets:**
  - **Historical solutions (area/cluster weapons, stopping motion by striking choke points), cannot meet the high ROE standards we have set with fixed-target precision strike**
  - **Real-time precision tracking has same problems as with stationary targets, but more acute**
  - **Laser designation may require excessive exposure**
  - **Must be able to do many-v-many**

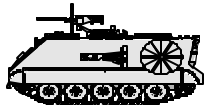
What Sensor Resolution is Required?

Discrimination Requirements for Mobile / Relocatable Targets

Tank
T 80: 24 x 11 x 5



SAM TEL
SA-10: 41 x 10 x 12



APC
BMP 3: 22 x 11 x 8

Critical airborne dimension

*** Required number of pixels on target "critical dimension" for a particular level of discrimination**

Confidence factor

Detect

- Contact
- Clutter

Classify

	80%	90% *
IR	1.5	2
Radar	3	4

- Tracked
- Wheeled

Recognize

- Tank
- APC
- ADU

Identify

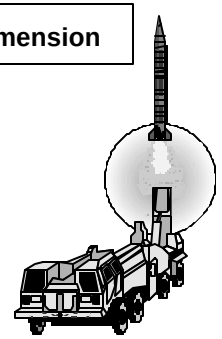
	80%	90% *
IR	12	16
Radar	24	32

- T80
- M1A1

IFFN

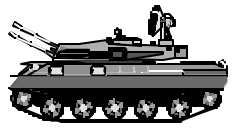
- Enemy
- Ally

Extracted from text on Johnson Criteria and Army field targeting



TBM TEL
SCUD: 44 x 12 x 10

Truck
ZIL 24 x 9 x 9

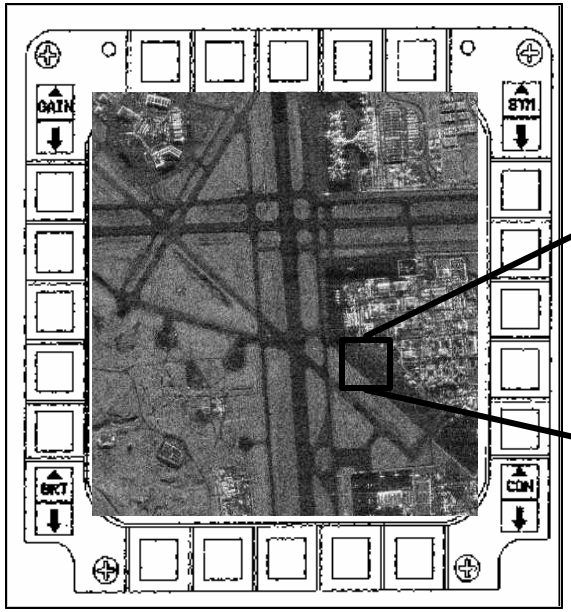


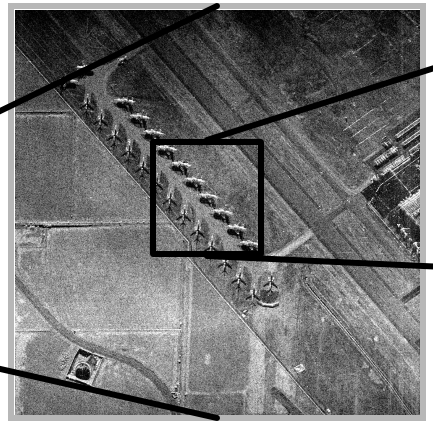
Artillery/AAA
ZSU 23/24: 21 x 10 x 7

ID requirements generally exceed performance of currently fielded systems

Dimensions in "feet"

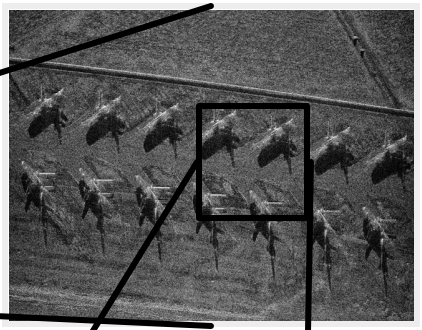
SAR Displays vs. Resolution





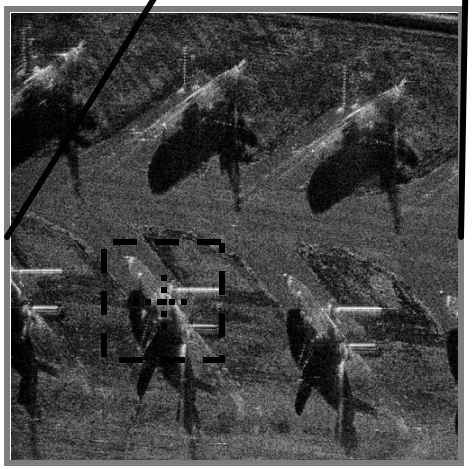
2.5 Foot Strip

Find



1 Foot Spotlight

Localize

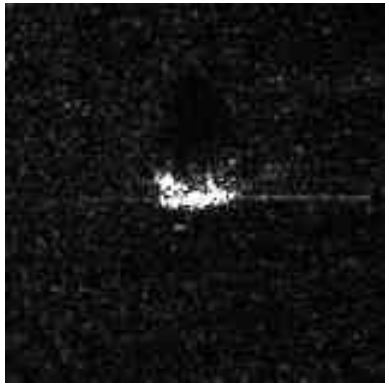


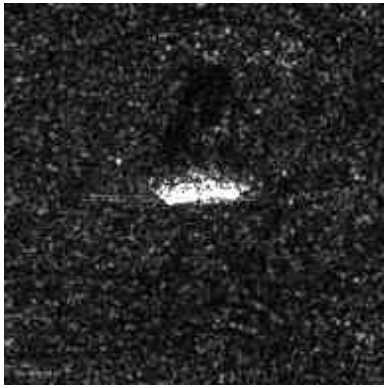
ID / Target

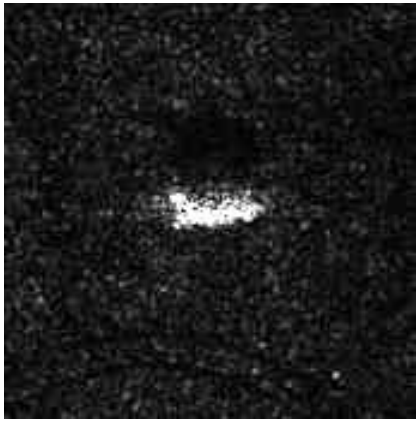
6 Inch Spotlight

Even with high resolution, SAR requires precision velocity reference to achieve precise TLEs, and targets must be stationary

What Is It? Is It the Same Object?







ZSU-23/4

Zil-131

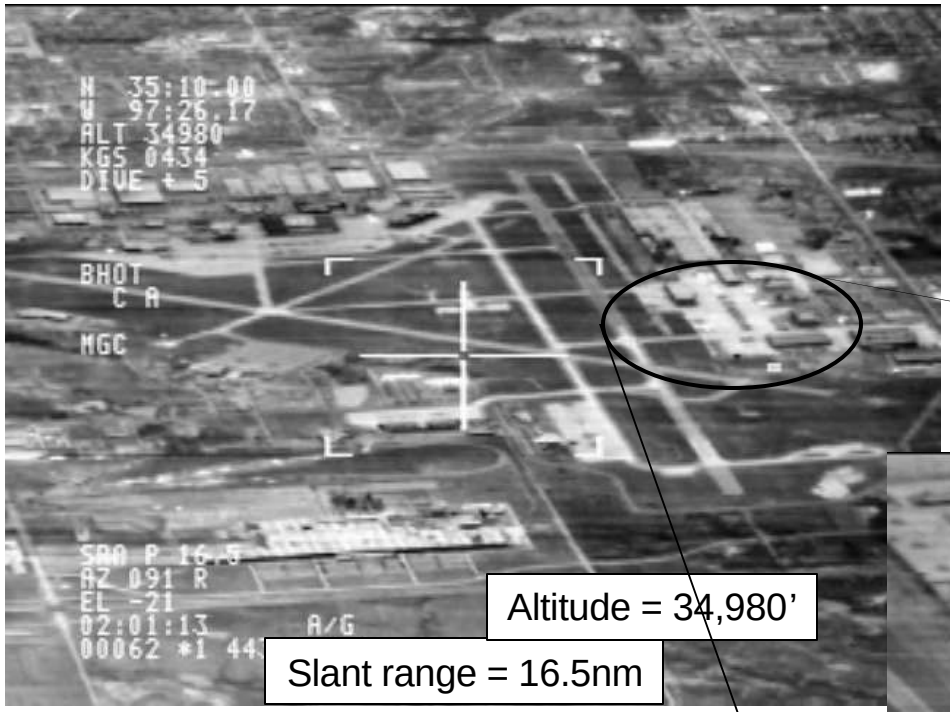
T-62

MSTAR Data Collection
By Sandia Nat'l Laboratory

- **1 foot SAR**
- **X-Band**
- **15 depression angle**
- **Spotlight mode**

FLIR Image – Resolution Example

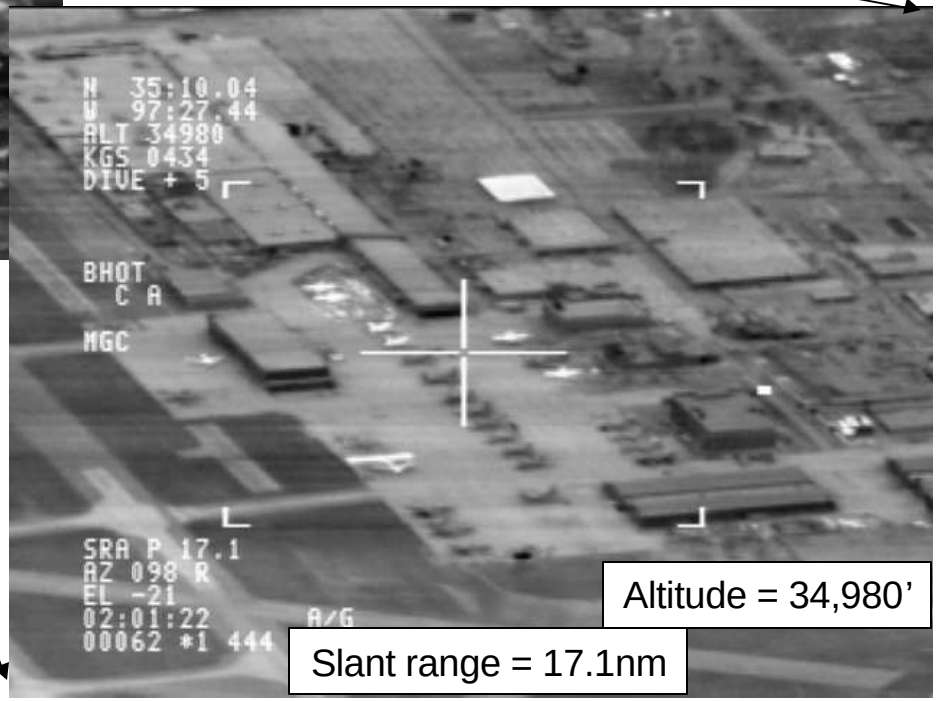
Wide Field of View



Altitude = 34,980’

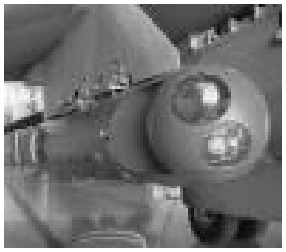
Slant range = 16.5nm

Narrow Field of View



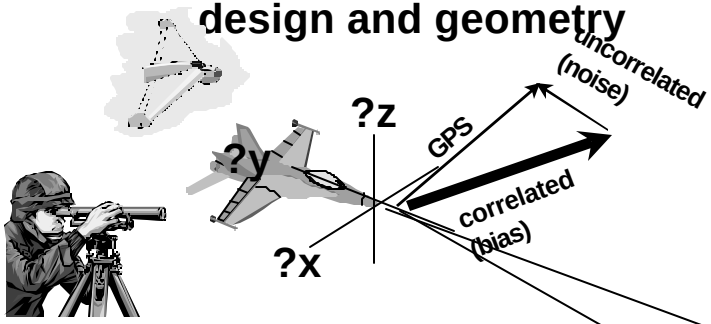
Altitude = 34,980’

Slant range = 17.1nm



Relative or Self Target Coordinate Generation

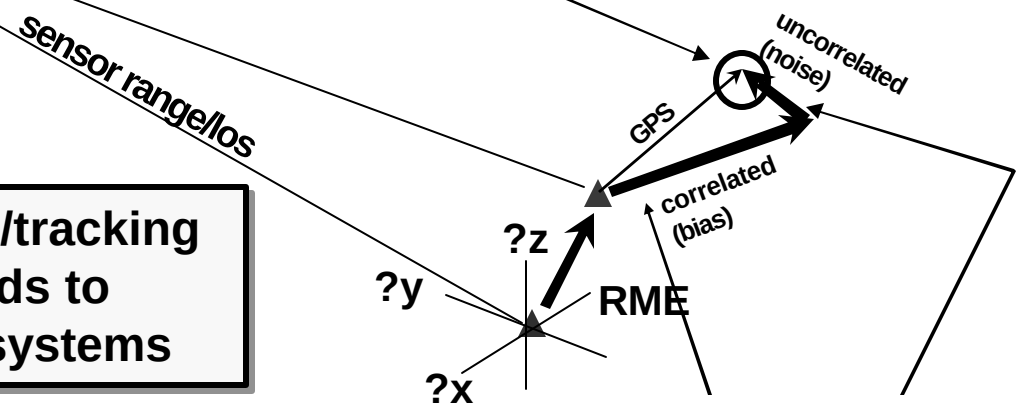
- **Targeting occurs in local GPS coordinate reference, relative to sensor position or another ground point (OAP or offset aimpoint)**
  - **Relative TLE will include both measurement error and current GPS error – results require mensuration to obtain absolute WGS84**
  - **Relative measurement error (RME) is difference between actual and measured position relative to targeting platform, and includes errors due to sensor type, design and geometry**



$$TLE = \sqrt{(RME)^2 + (GPS)^2}$$

Target GPS coordinates (x,y,z)
- **Calculated by adding sensor-to-target ?x, ?y, ?z to current GPS position**

RME has many error components & limitations that vary with range, geometry and sensor design and performance

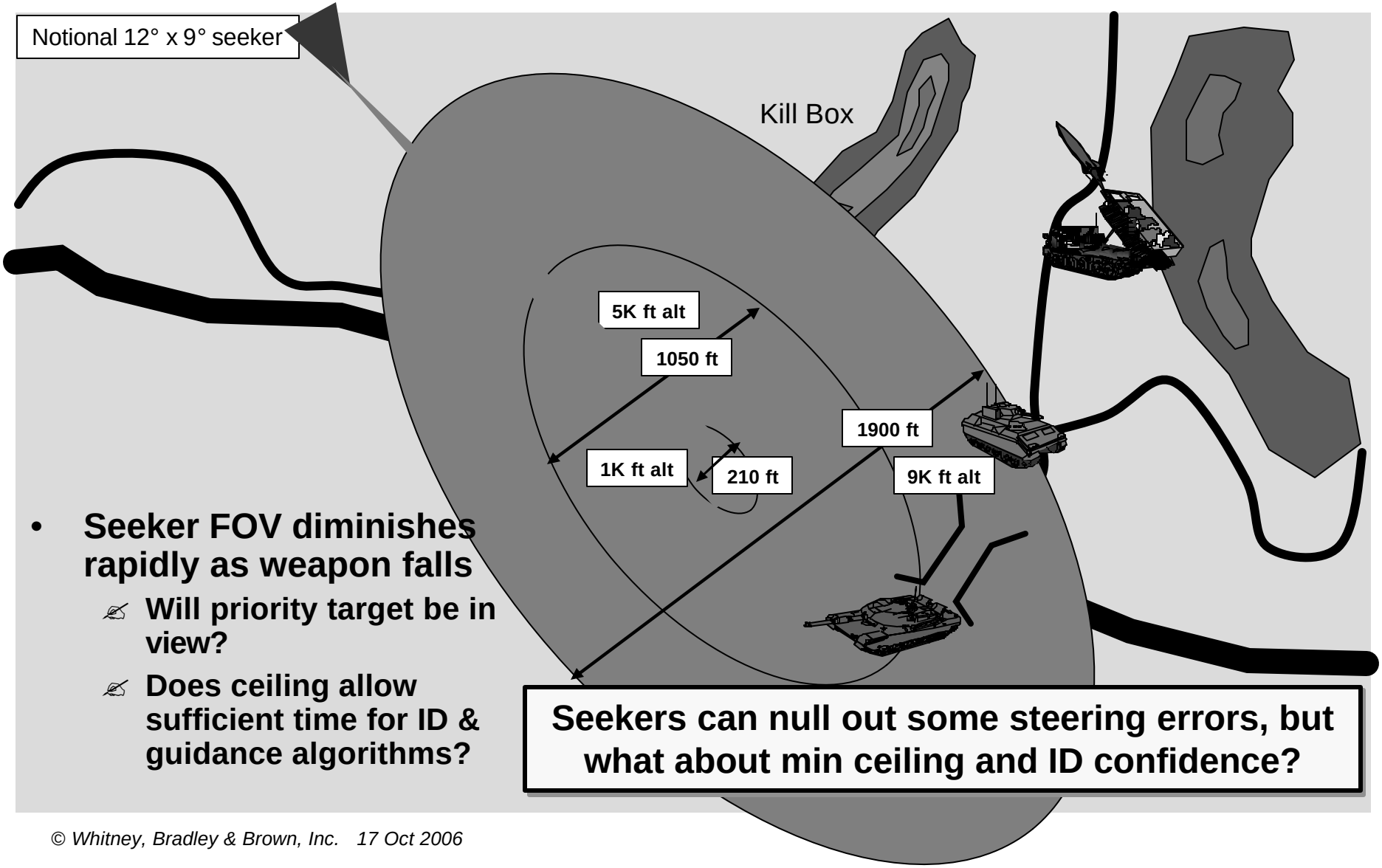


Adding precision location/tracking to ID requirements adds to complexity of targeting systems

Solving the Target Motion Problem in a Difficult Mission Environment

- **Analogous to air-to-air engagement in slower motion, except:**
  - ✍ **Shooter & weapon cannot maneuver below target**
  - ✍ **Huge increase in clutter**
- **Leads to two basic approaches:**
  - ✍ **Continuously track target, provide position updates to weapon at suitable rate using one or more data links (like tail control AAM)**
    - **Can be done with one or more onboard or off-board sensors**
      - **AMSTE program (Affordable Moving Surface Target Engagement) has demonstrated a direct hit on 30+ MPH truck using both JSOW and JDAM, using JSTARS & TACAIR or UAV tracking**
      - **Future networks could also enable ground tracking (e.g. UAV coupled with a weapon data link)**
  - ✍ **Add terminal seeker to weapon, use GPS to navigate into seeker acquisition box (like AMRAAM or Advanced Paveway)**
    - **Proposed by Joint Common Missile, probable for SDB Phase II**
    - **Positive ID in clutter <u>still a problem</u> if no MITL datalink is used**

Notional Seeker – Are Seekers the Answer?



- **Seeker FOV diminishes rapidly as weapon falls**
  - **Will priority target be in view?**
  - **Does ceiling allow sufficient time for ID & guidance algorithms?**

Seekers can null out some steering errors, but what about min ceiling and ID confidence?

Resolution vs. ID Confidence
Complicated by a Clever Enemy

- **Operation Allied Force**
- **"At night, when these groups heard a Predator or AC-130 coming, they pulled a blanket over themselves to disappear from the night-vision screen. They used low-tech to beat high-tech."**

  - **>50% Cloud Cover >70% of the Time**
    - **Unimpeded Airstrikes Only 24 of 78 Days**
  - **Extensive Enemy Use of Deception Techniques and Concealment**

If a human observer at close range is uncertain about ID, how well can a remote sensor or seeker perform?

Interim Solutions:
Litening Pod Downlink & ROVER

- **Sensor downlink from Harrier and Hornet**
  - **Developed by US Marine Corps for offensive air support missions (CAS, ground aided strike)**
  - **Supplies GCE video feed of aircraft targeting sensor or UAV**

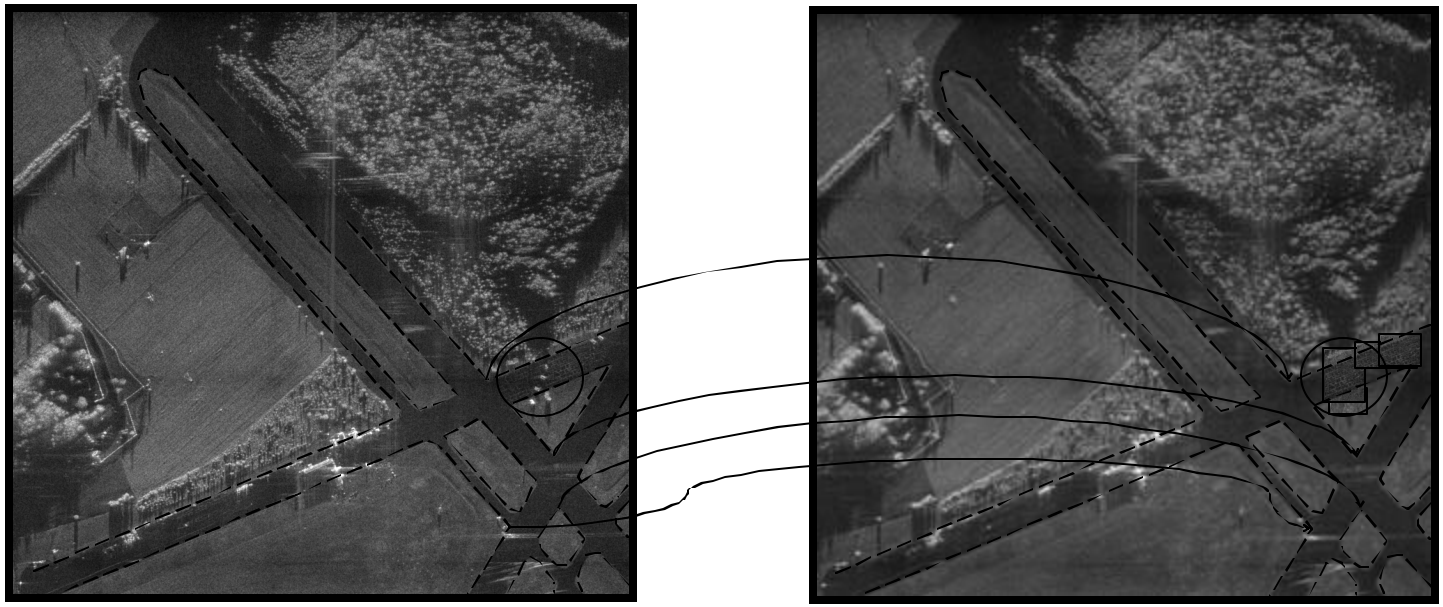
Litening Pod Video Downlink Capability

- **USMC downlink Litening Pods in OIF**
  - ✍ **5 Pioneer/9 Predator Pods**
- **43 Rover stations in theater**
  - ✍ **Other organic receive stations (MRS, RRS,GCS)**
  - ✍ **Access to UAV feeds**
- **New ways to employ**
  - ✍ **Convoy Escort / ISR (1000+) combat missions**
- **Benefits**
  - ✍ **Rapid & positive target ID**
  - ✍ **Increased GCE SA (Situational Awareness)**
  - ✍ **Very effective against stationary targets**

Actual ground display

In-flight or Field Registration of Tactical Imagery

- Registration software ID's common features in two images
- Tactical image "controlled" to reference via edge/feature matching
- Algorithm identifies and links image "tie points"

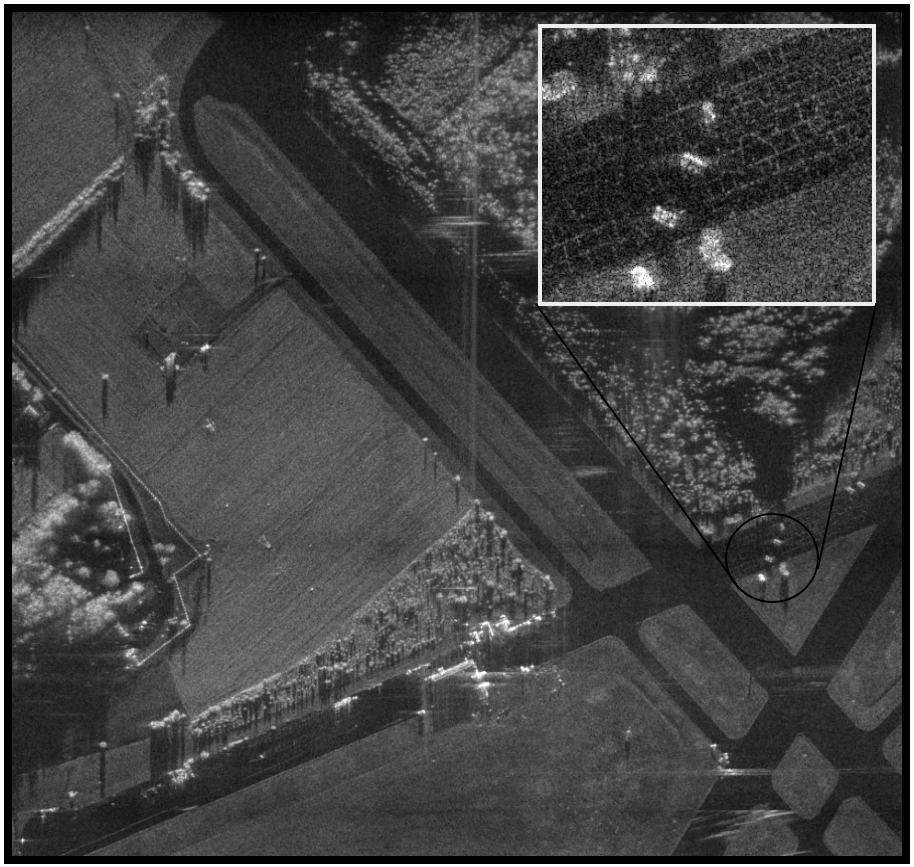


Tactical Image

Reference Database Image

Precise geo-coordinates of any tactical imagery feature available once controlled to reference image

Current Application:
Precision Strike Suite for Special Operations Forces (PSS-SOF)

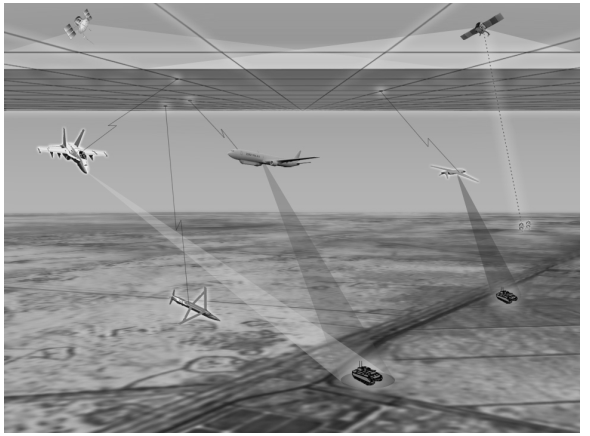


Auto Mensuration of Tactical Image
- ~10 minutes
- Targets present/observable
- ~10 meter TLE for field forces

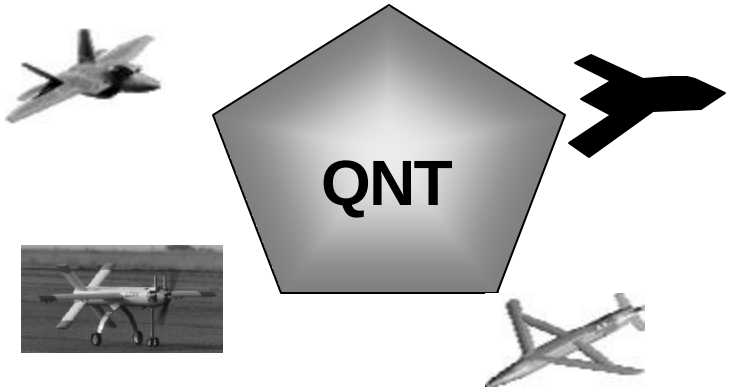
Reference Database on Laptop
- Targets not present
- Created/uploaded prior to deployment
- Precisely geo-referenced

What About the Future?
Building a Networked System of Systems

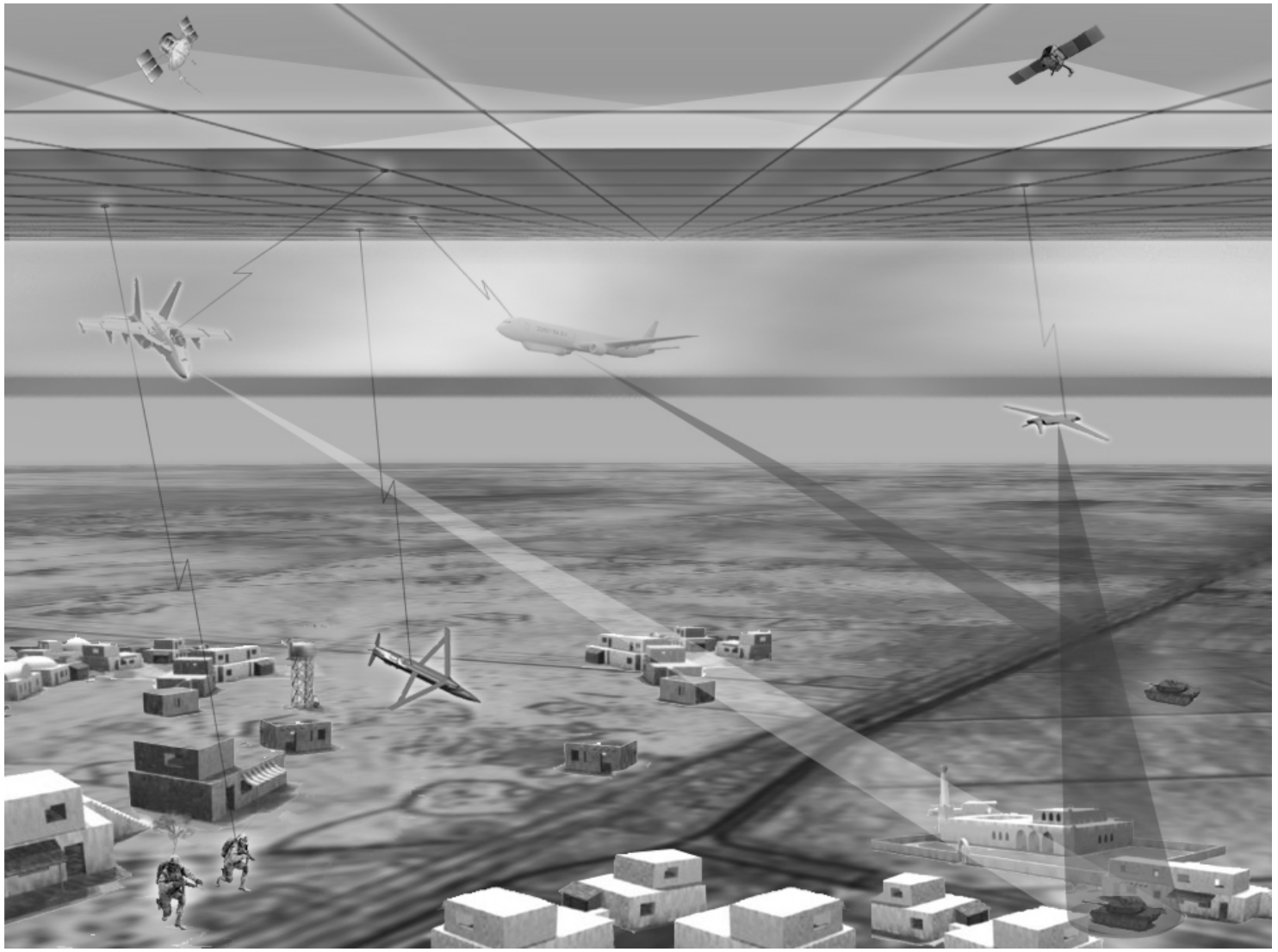
- **Joint AF/Navy Weapons Data Link Network ACTD – Desired capabilities:**
  - **Weapon In-Flight Target Update**
  - **Weapon Retargeting**
  - **Weapon In-Flight Tracking**
  - **Weapon Bomb Impact Assessment (BIA)**
  - **Weapon Abort**



- **DARPA Quint Network Technology ACTD – Hardware and architecture to link:**
  - **Tactical Aircraft**
  - **Dismounted ground forces**
  - **Small UAVs**
  - **Armed UAVs**
  - **Precision weapons**



How Achieving “The Grail” Could Look



Conclusions

- **In the end, MultiMode weapons are only part of the answer for moving and relocatable targets**
- **Must be able to target & track movers precisely, ID confidently, with acceptable Collateral Damage, through the weather, in cluttered environments, with many v. many engagements at once**
- **Over & above the weapons, this will require:**
  - **Persistent observation at high resolution**
  - **Precise track generation**
  - **A common network between ground observers, targeting and delivery platforms, and weapons**
- **We have some distance to go**
  - **But programs such as the DARPA Quint Networking Technology (QNT) ACTD could be a fair start**