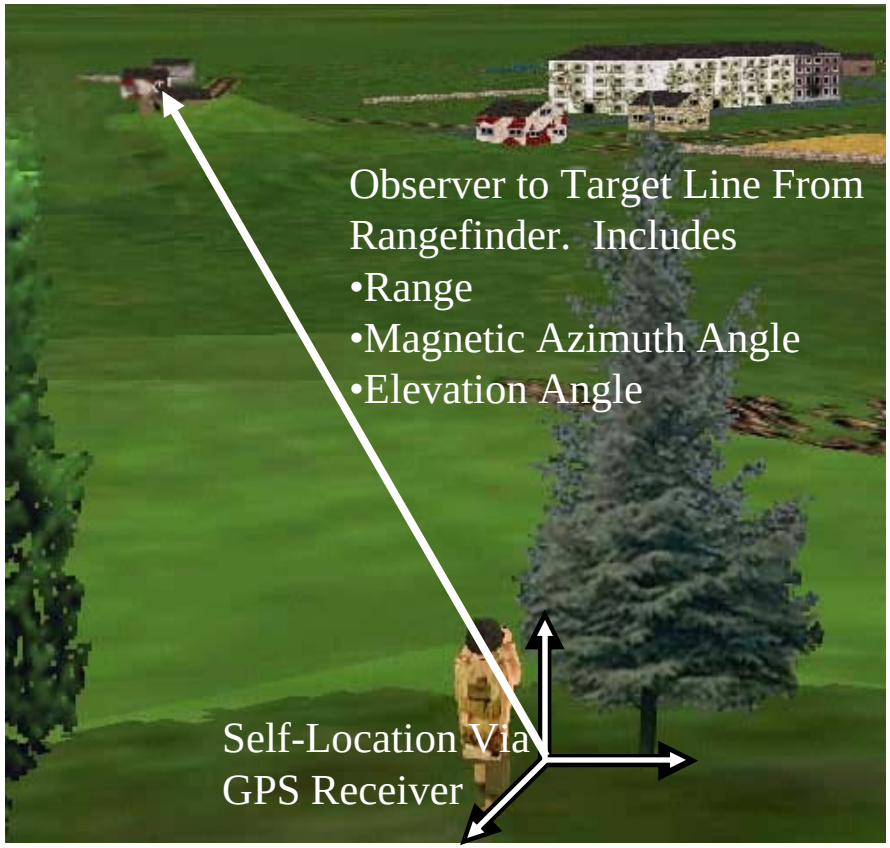
A Target Tracking Algorithm that Reduces Designation Time

"Increasing Weapon Effectiveness
and
Operator Survivability"

3/29/2006

Targeting By Ground Forces



Used to call for fire from artillery, GP bombs, JDAM's, Laser Guided Bombs

Will call for fire from ERGM and Excalibur in the future

Current Equipment Suite

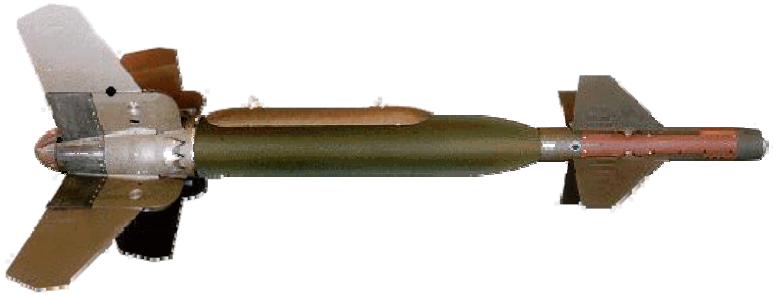
USMC Common Laser Range Finder

PLGR GPS Receiver

Rugged Handheld Computer running Target Handoff Software

Description of Problem

- During Operation Desert Storm, Laser Guided “Smart Bombs” (LGB) were the weapon of choice for precision bombing
- Due to the cost of LGB’s and the weather limitations of the Paveway II LGB, GPS guided Joint Direct Attack Munitions (JDAM) bombs are now favored for most missions



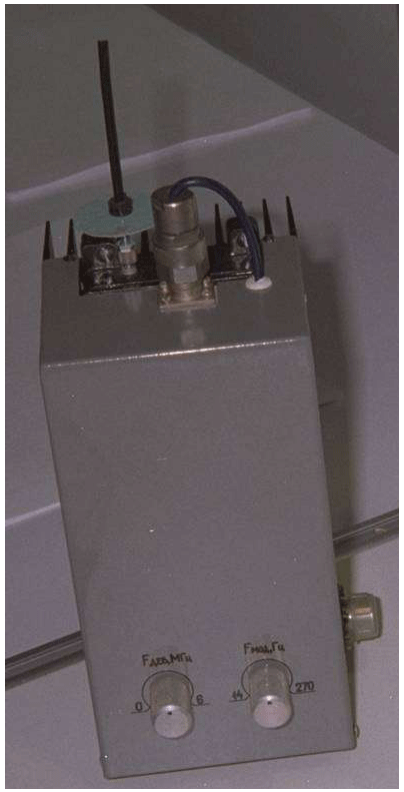
GBU-24 PAVEWAY-III LGB

GBU-32 JDAM GPS Guided Bomb

Description of Problem

- JDAM relies fully on GPS, and TLDHS relies heavily on GPS to determine target coordinates
- TLDHS can be used without GPS, but only with older, far less accurate methods such as using a map
- GPS Jammers will become better and more widely available
  - Saddam Hussein purchased several Aviaconversia GPS jammers to try to thwart the US GPS weapons
  - While not effective during Operation Iraqi Freedom, GPS jammers will get better and cheaper
  - GPS jammer plans are readily available on the internet
  - GPS jammers are particularly problematic for ground forces

The Soldier on the Ground has no easy way to deal with GPS Jammers!



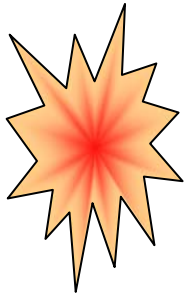
Russian GPS Jammer made by Aviaconversia

*Ref: Scientific American Articke:http://www.sciam.com/print_version.cfm?articleID=00079DD3-DAA0-1E96-8EA5809EC5880000

Description of Problem

(GPS Guided Weapons)

- When GPS is jammed, TLDHS depends on imprecise self positioning methods (resectioning, maps, etc.) to solve for target coordinates. The Target Location Error (TLE) tends to be much larger without GPS. (The TLE is not so hot even with GPS, but that's a topic for another time…)
- Weapons relying solely on GPS guidance don't work well on moving targets



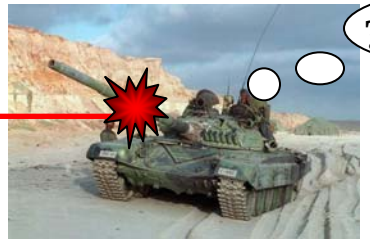
Bad Target Coordinates =

JDAM Very Precisely Misses Target!!!

Description of Problem

(Laser Guided Weapons)

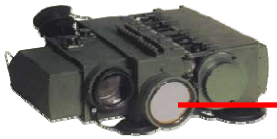
- Laser guided weapons can correct for poor target coordinates, but…
  - Timing of laser designation is critical
  - Currently, designation turn-on time is done via voice for air dropped weapons or by ad-hoc calculation by Designator Operator for artillery weapons
- Current fielded laser designators have limited lamp life, and require large, heavy batteries
- Laser designators are easily detected. Operator survivability is a major concern.



Is There a Way to Shorten Designation Time???

What If….

- What if the weapon could ***communicate*** with the designator operator?
  - The weapon would:
    - Request designation ***at the proper time***
    - Receive target coordinates, TLE statistics (covariance matrix)
    - Track the confidence of its own position based on GPS availability and inertial sensors throughout its flight.
    - Compute the designation time based on this data and communicate with the designator operator
  - The enemy will not have enough time to react!



Too Late!

Weapon Effectiveness *and* Designator Operator Survivability Are Both Significantly Improved!

Current Work

- NSWC Dahlgren and UNC Charlotte investigated a modified Kalman Filter that would reside on the weapon and call for designation at the proper time*
- Covariance Matrix for Target Location is loaded into weapon prior to launch
- Weapon communicates with designator operator or designator directly to request designation
- Ground Soldier still has control over designator operation
- Augments, but does not replace current CONOPS

*Barry G. Sherlock, Yogendra P. Kakad, and Bryan J. Freeman 2005. A Target Tracking Algorithm that Reduces Designation Time for Laser Guided Weapons, in proceedings for SPIE Defense and security symposium 5810-19 v1

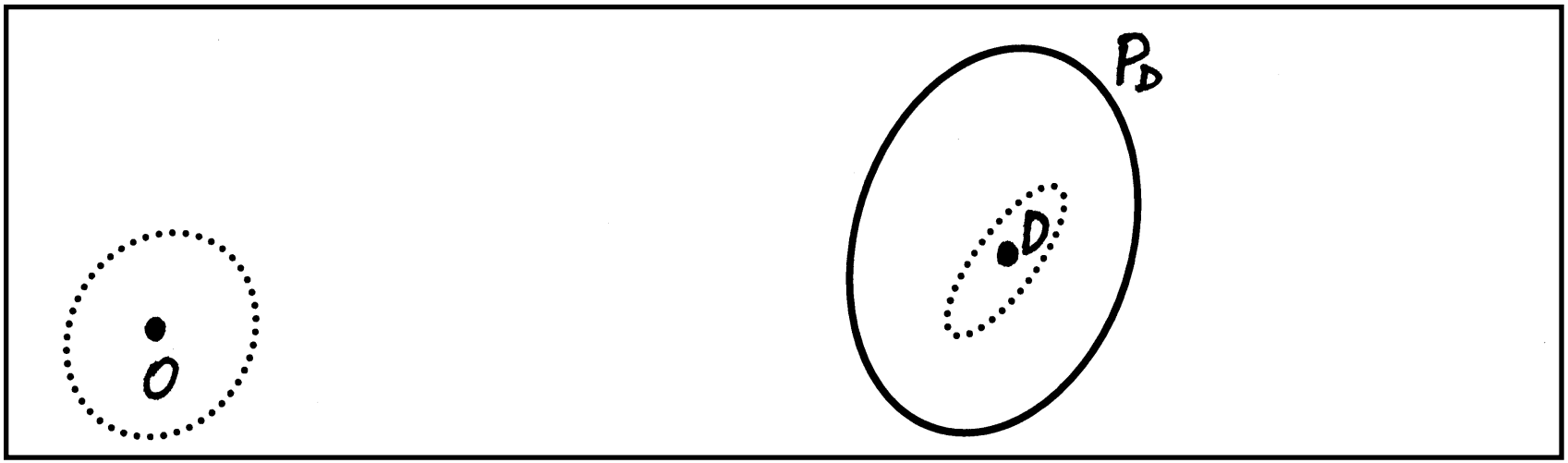
Target Tracking Algorithm

- In the Figure Below:
  - T and P_T are target position and covariance
  - W and P_W are the weapon position and covariance
  - P_T contains targeting errors, such as GPS (or estimate of error if map is used), azimuth, and range
  - P_W contains weapon position errors, including IMU drift and GPS errors

*Illustrations courtesy of Prof. Barry Sherlock, UNC Charlotte

Target Tracking Algorithm

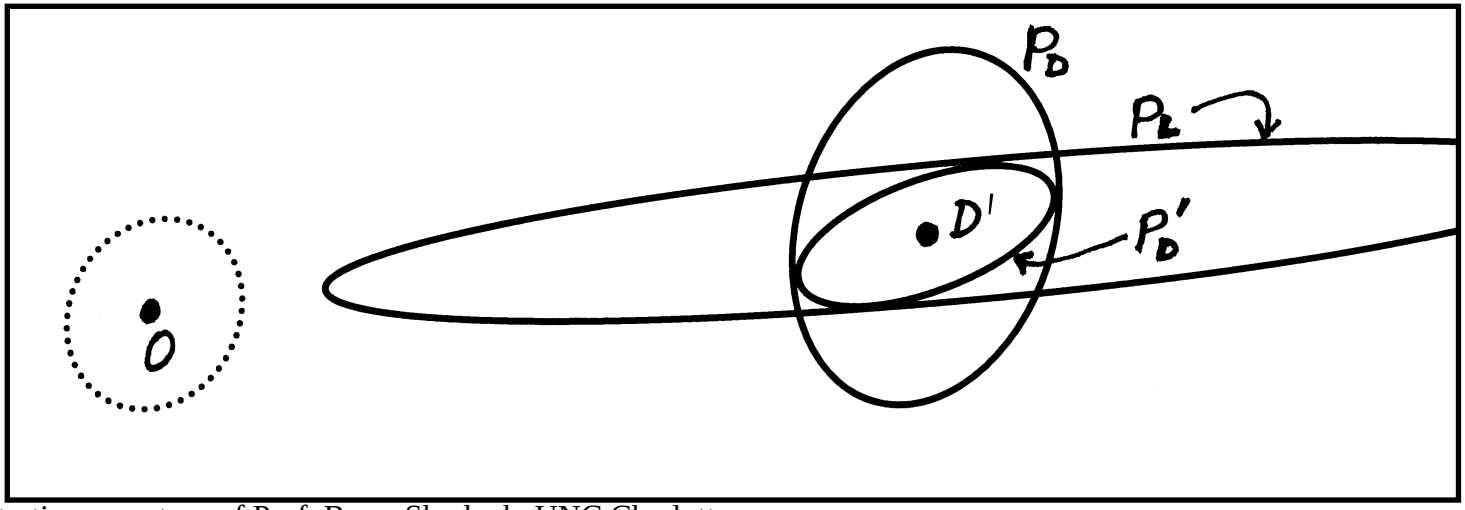
- Now, change to weapon body coordinates
  - Point *O* is now the target location and is the new origin, while point *D* is the weapon location
  - Covariance P_D is the combination of P_W and P_T ($P_D = P_W + P_T$)
  - Note that P_T does not change while P_W changes as the weapon flies
  - At some point in flight, the weapon determines that its uncertainty of its own position is near the limit of it's ability to maneuver to the target and requests a brief designation



*Illustrations courtesy of Prof. Barry Sherlock, UNC Charlotte

Target Tracking Algorithm

- The Laser Designator provides *only* bearing and elevation angles to the target, and provides *no* information on range
  - In the algorithm, the laser designator covariance P_L range component is set to an arbitrarily large value, such as 90% of the estimated weapon to target range
  - The new combined covarince matrix is represented graphically below by P'_D
  - The illustration below is *not* to scale. P'_D is smaller than shown
  - The **MATH!**
    - $\underline{D'} = P_D(P_L + P_D)^{-1}\underline{L} + P_L(P_L + P_D)^{-1}\underline{D}$
    - $P'_D = (P_D^{-1} + P_L^{-1})^{-1}$



*Illustrations courtesy of Prof. Barry Sherlock, UNC Charlotte

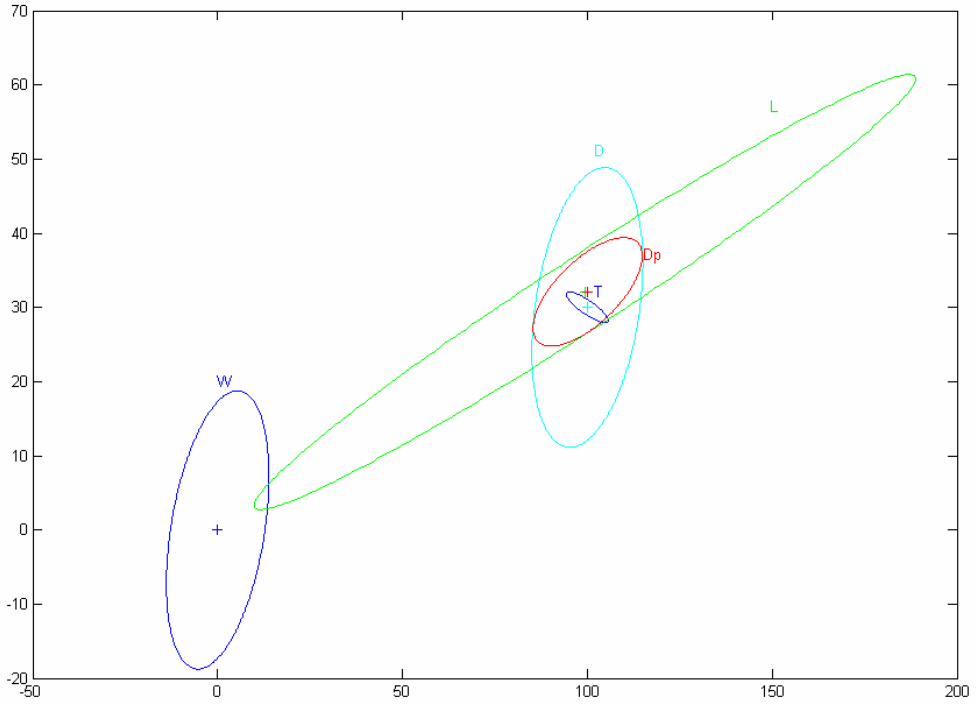
Target Tracking Algorithm

- Another way of looking at the improvement is to use the designator covariance information to improve the weapon position estimate while leaving the target position estimate alone
- The **MATH!**
  - $\underline{W'} = \underline{T} - \underline{D'}$
  - $P'_W = P'_D - P_T$

*Illustrations courtesy of Prof. Barry Sherlock, UNC Charlotte

2-D Matlab Simulation

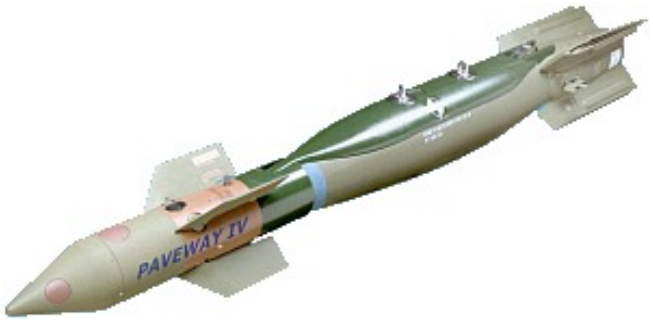
- W – Weapon Position Covariance
- T – Target Position Covariance
- D – Combination of W and T viewed over the target
- L – Laser Designator Covariance
- D_p – Combination of W, T, and D showing considerable improvement over D



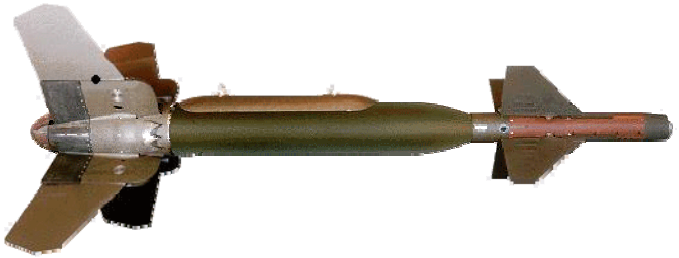
*Illustrations courtesy of Prof. Barry Sherlock, UNC Charlotte

Next Steps

- MARCORSYSCOM Fire Support Systems has funded study to investigate how to implement method in fielded and future systems in support of the future Joint Effects Targeting System (JETS)
- Paveway IV (a.k.a. ELGB) has the ability to have multiple target coordinates loaded on aircraft and for in-flight redirection
- Paveway IV and Paveway III both include a high quality IMU coupled with GPS. Both can track for 10 seconds if laser lock is lost
- Paveway IV is currently only a RAF effort, with fielding in 2007



Paveway IV



Paveway III

Conclusions

- We have developed a method to augment the navigation Kalman filter that exists in Paveway III and IV LGB's that
  - Allows for accurate targeting and engagement in a GPS denied environment
  - Reduces designation time
  - Allows for the weapon to account for target position uncertainties along with its own position uncertainty, thus optimizing designation time
  - Allows for the automation of laser designator operation

Questions?

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Referenced Paper on Laser Guidance:

Barry G. Sherlock, Yogendra P. Kakad, and Bryan J. Freeman 2005. A Target Tracking Algorithm that Reduces Designation Time for Laser Guided Weapons, in proceedings for SPIE Defense and security symposium 5810-19 v1

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