real time fire control solution for individual and crew-served direct firing infantry weapons - algorithm and implementation

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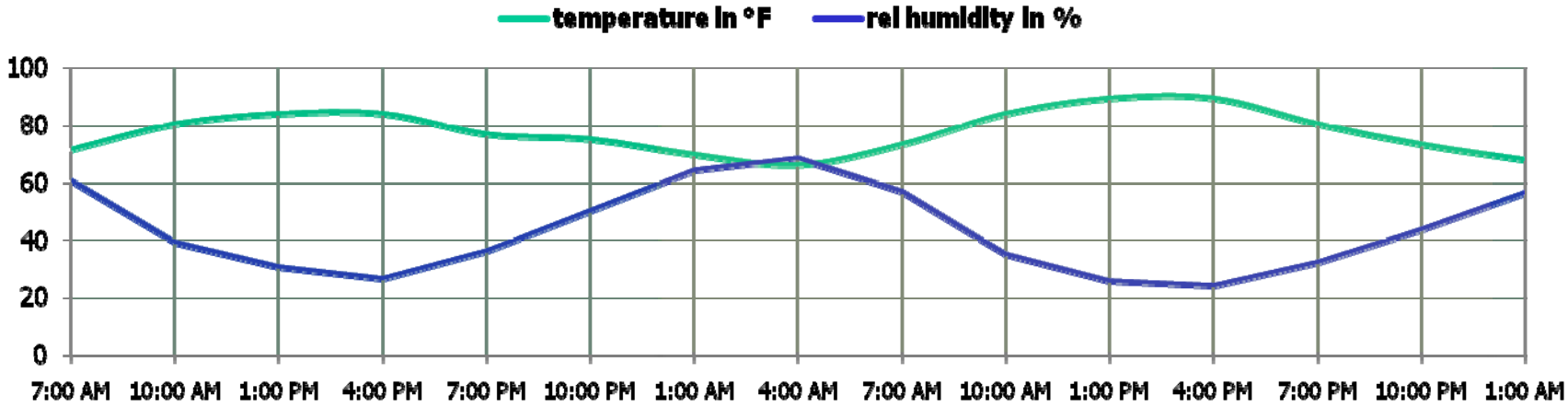
Mazár-e-Sharif

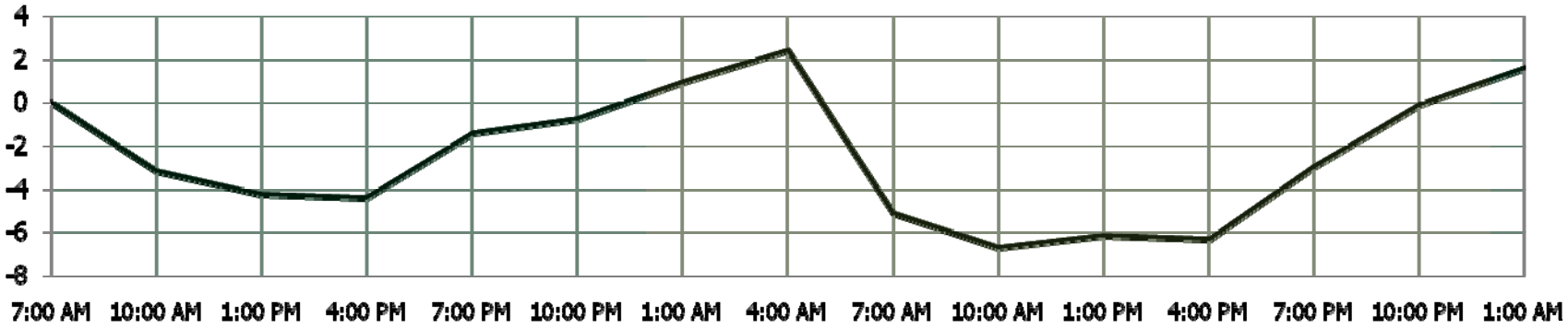
08 0730 D may 08

rH: 60% T: 71°F

target range: 1500m



click adjustments due to weather conditions



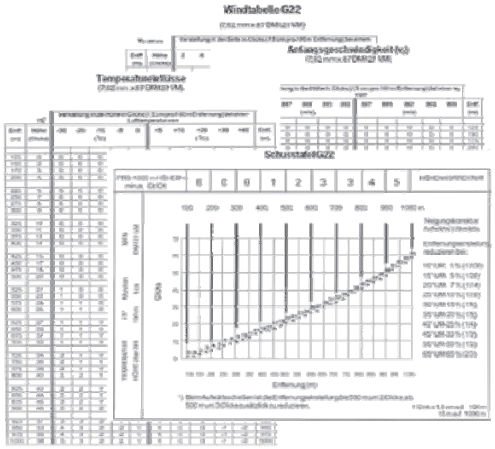
target range: 1500m

Mazár-e-Sharif

Agenda

1. Status quo
2. Requirements
3. Theoretical Approach
4. Algorithm
5. Testing and Accuracy
6. Performance
7. Implementation
8. Conclusions

Status Quo

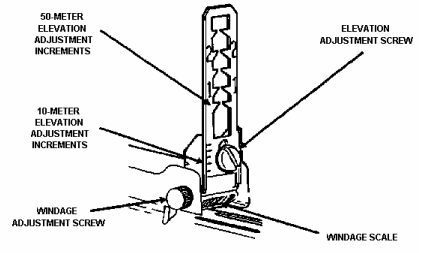


LRF

DMC

PDA

GPS



thermal sight

video sight

Requirements

requirement	fulfilled
range- and crosswind	
arbitrary angle of site	
muzzle velocity	
coriolis force	
magnus force	
multiple ammunitions	
height dependent air temperature	
height dependent air pressure	
user-defined targeting sights	
time fuze capability	

Approach

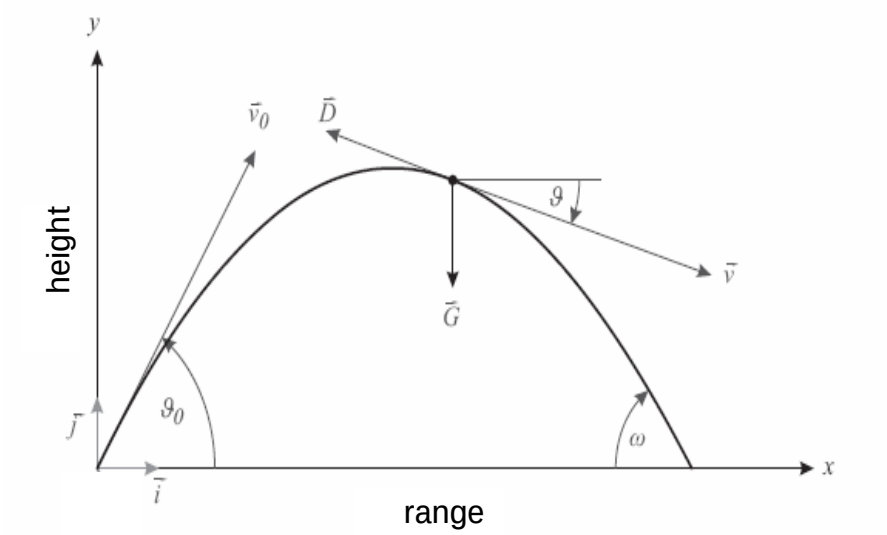
Point Mass Trajectory Model

only drag and gravity acting on projectile

adding flat fire assumptions

Adding generalized power drag law

analytically solvable set of differential equations of motion



$$
\begin{aligned}
\dot{x} &= v\,\cos(\vartheta), & x(t_0) &= 0;\\
\dot{y} &= v\,\sin(\vartheta), & y(t_0) &= 0;\\
\dot{v} &= -\frac{D}{m} - g\,\sin(\vartheta), & v(t_0) &= v_0;\\
\dot{\vartheta} &= -\frac{g}{v}\,\cos(\vartheta), & \vartheta(t_0) &= \vartheta_0.
\end{aligned}
$$

Approach

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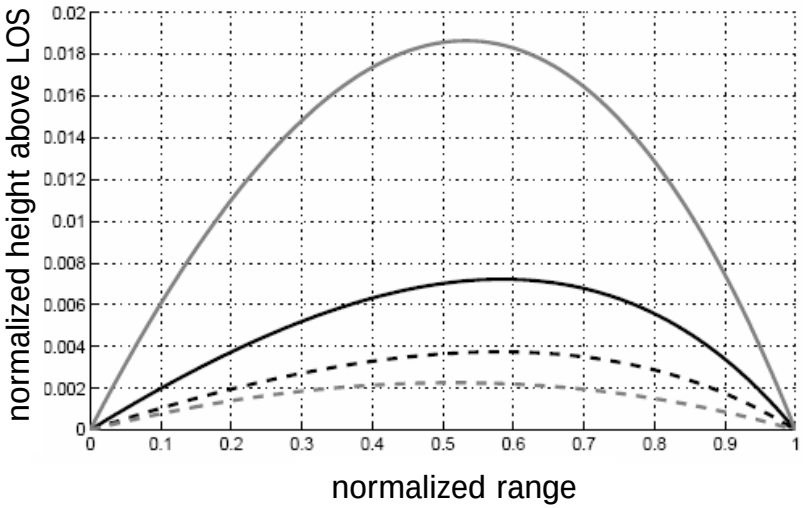

$$R := \frac{x_{max}}{y_{max}}.$$

$$\vartheta_0 < 5°$$

Approach

Point Mass Trajectory Model

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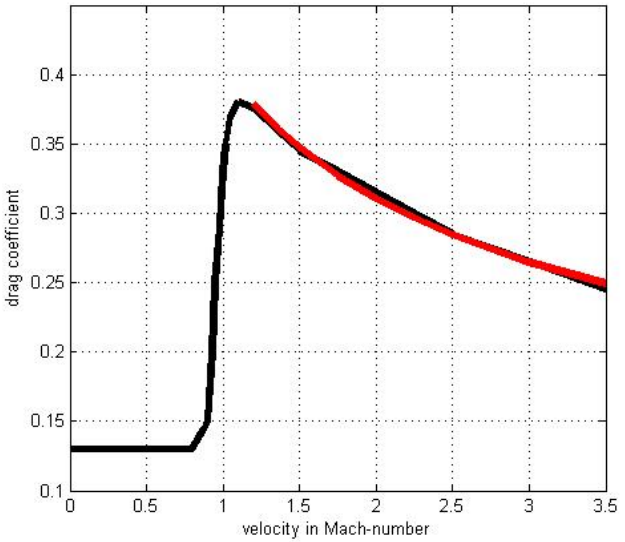
analytically solvable set of differential equations of motion



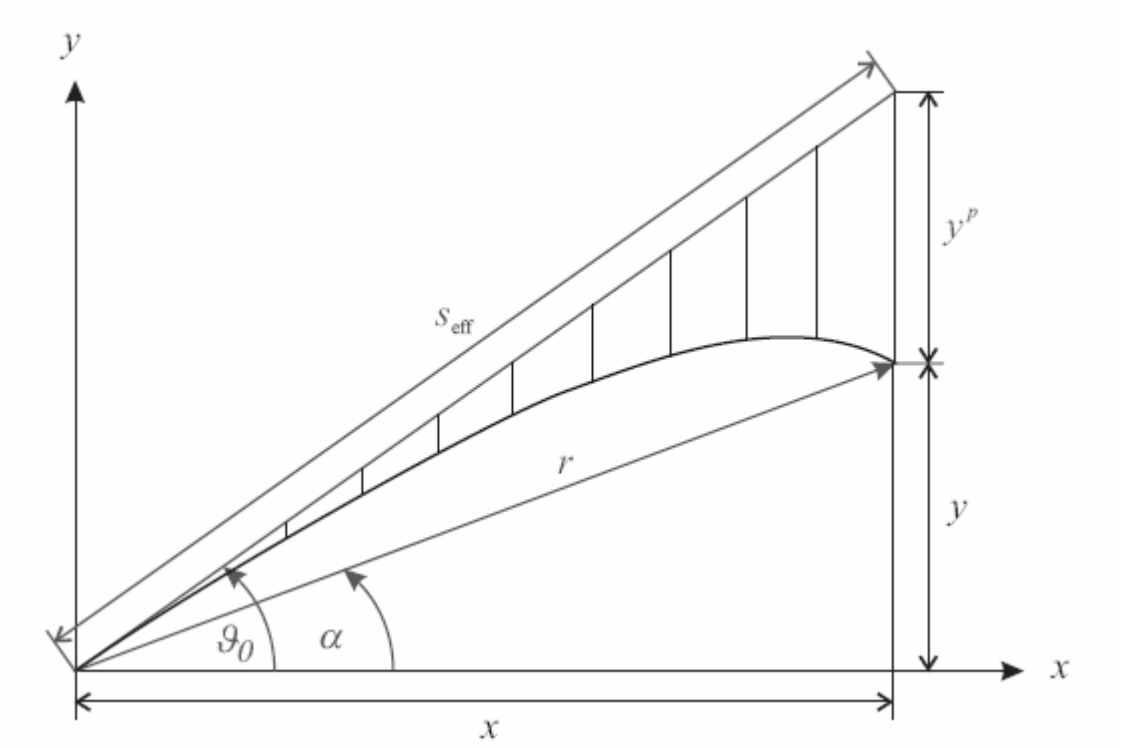
$$C_D := C_0 \, \mathrm{Ma}^{-n}$$

Algorithm

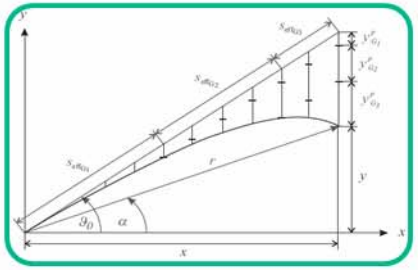
- ✓ super elevation
- ✓ striking velocity
- ✓ time of flight
- ✓ strinking energy

calculated using

- o Mach dependent analytical solutions
- o splitted solutions for slant range and gravity drop
- o gravity corrected projectile velocity

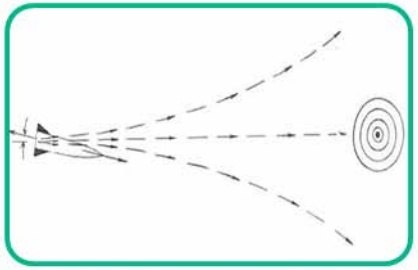


Algorithm



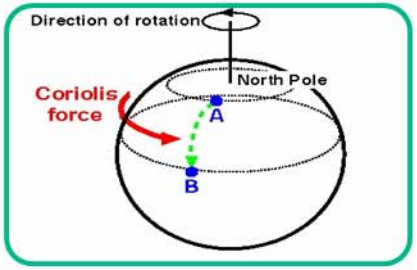
Multi Region Drag Fitting

- Extends range of validity



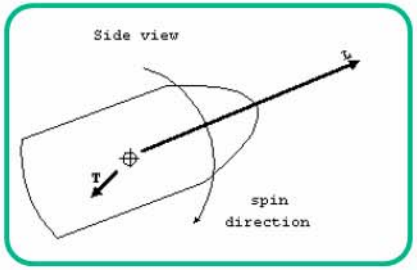
Range- and Crosswind

- Using perturbation mathematics



Coriolis Force

- Using McCoy's approximation



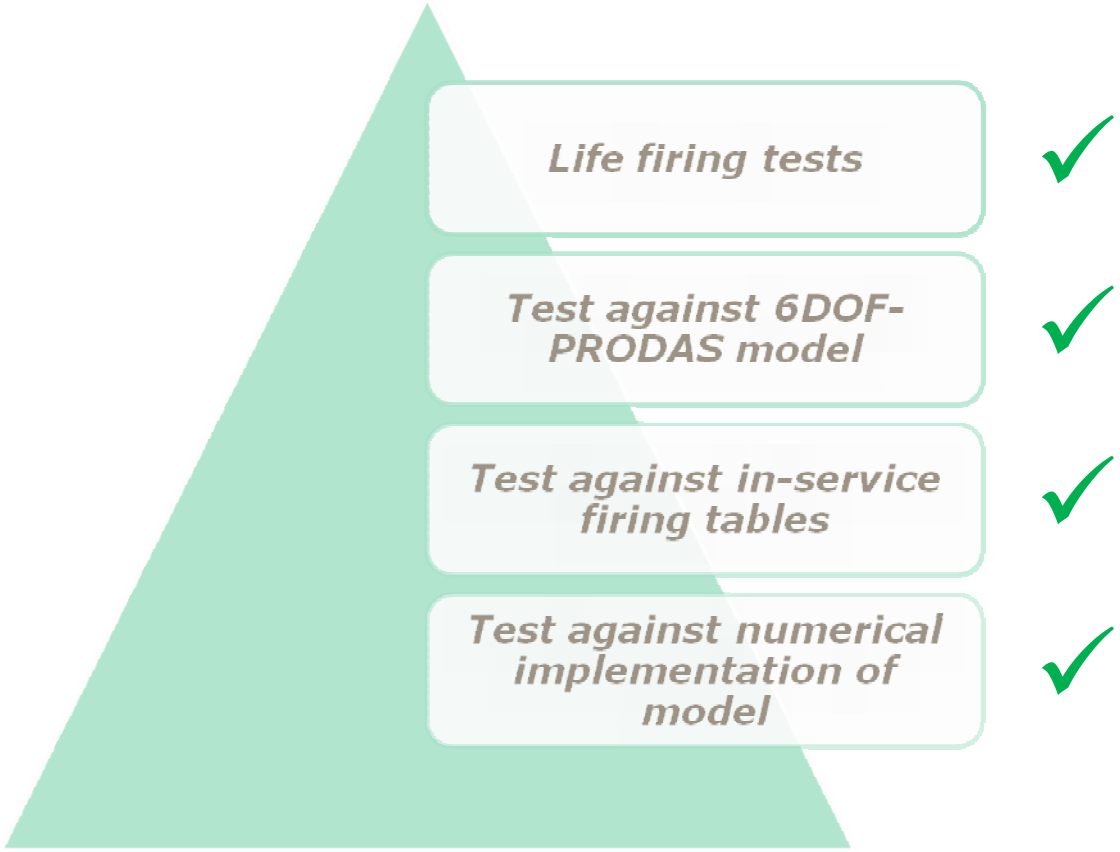
Spin Deflection

- Using NATO STANAG 4355 Appendix F approximation

Algorithm

requirement	fulfilled
range- and crosswind	✓
arbitrary angle of site	✓
muzzle velocity	✓
coriolis force	✓
magnus force	✓
multiple ammunitions	✓
height dependent air temperature	✓
height dependent air pressure	✓
user-defined targeting sights	✓
time fuze capability	✓

Testing and Accuracy

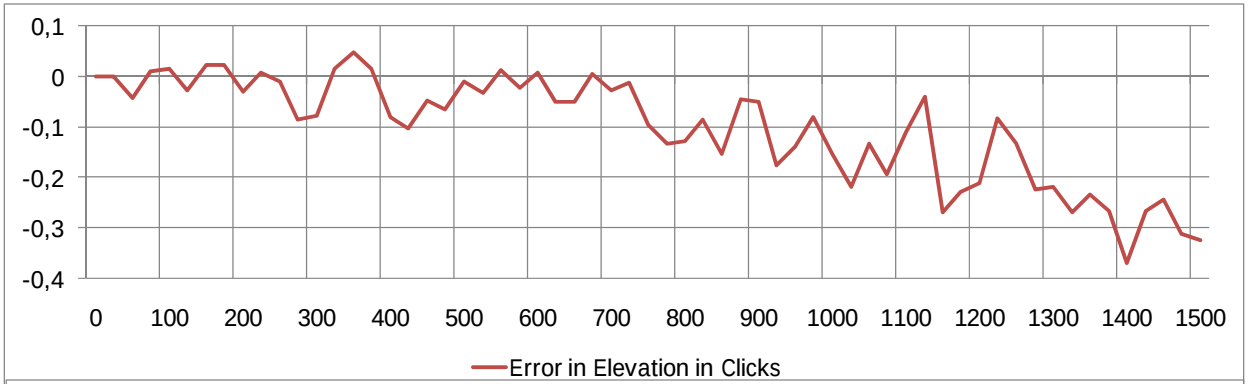


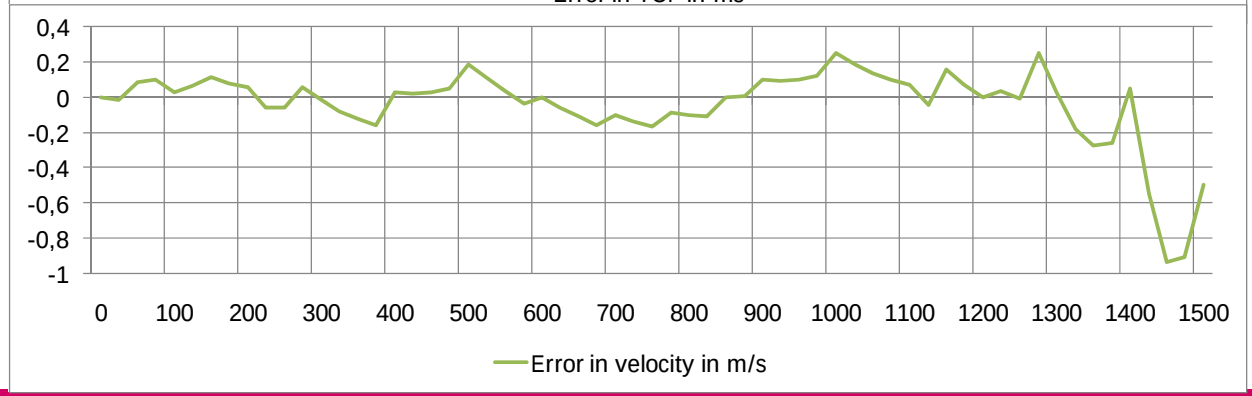
Accuracy

weapon:
M82A1

ammunition:
M8 .50BMG

range:
0 – 1500 m



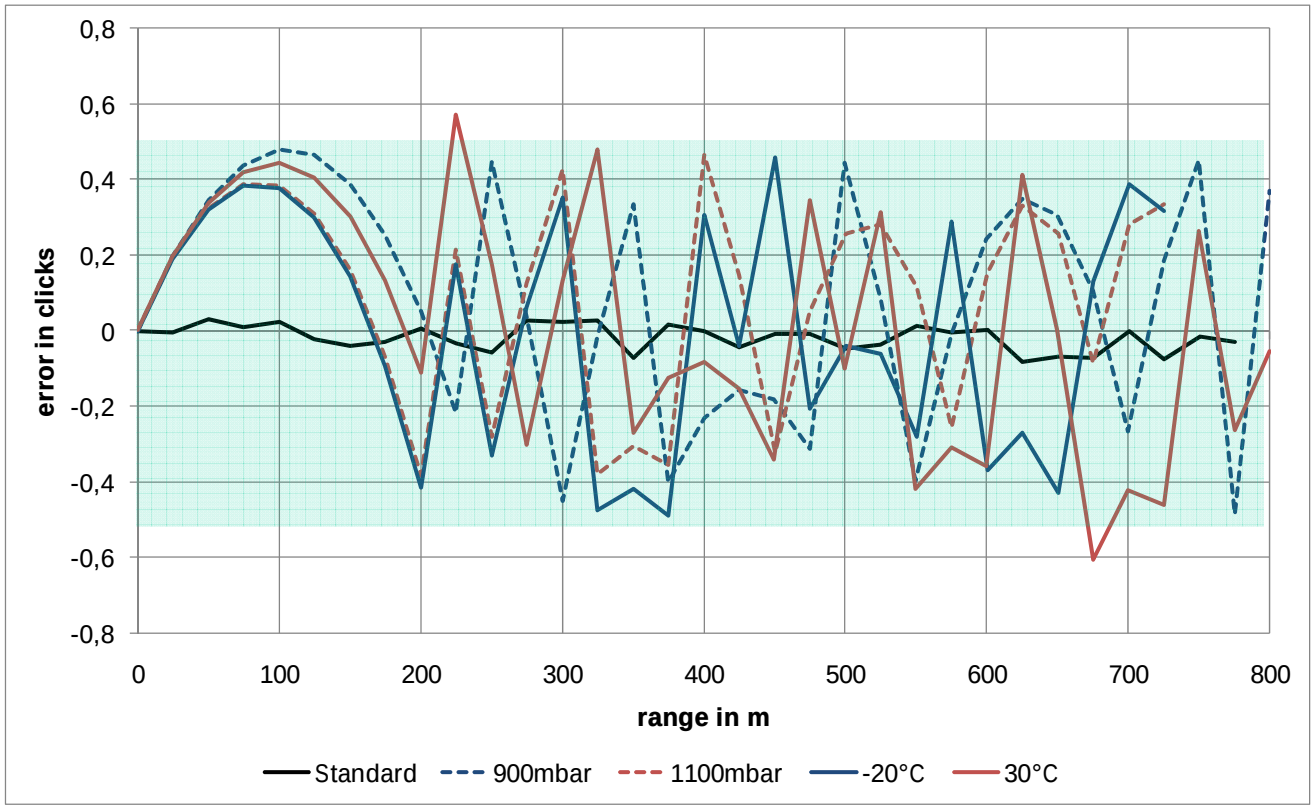


Met Variations

weapon:
HK G3

ammunition:
M80 .308

range:
0 – 800 m

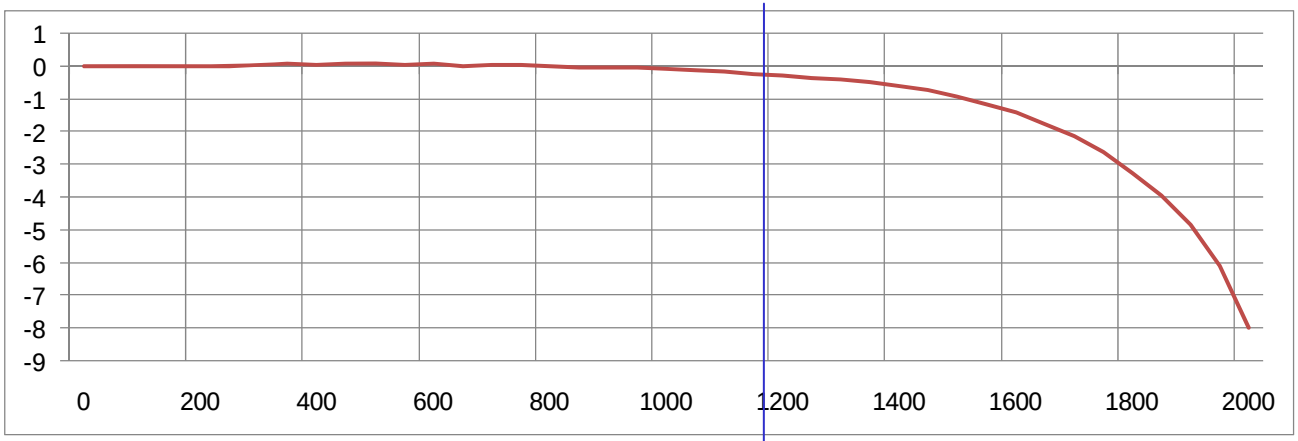


Model Limitations

weapon:
HK GMG

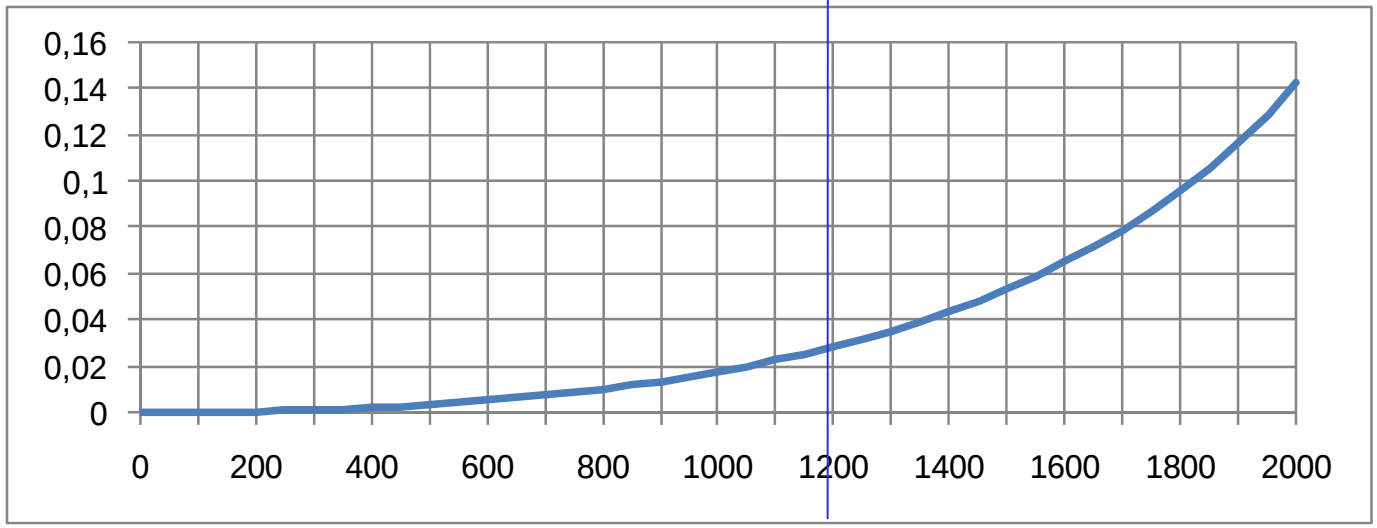
ammunition:
40mm

range:
0 – 2000 m

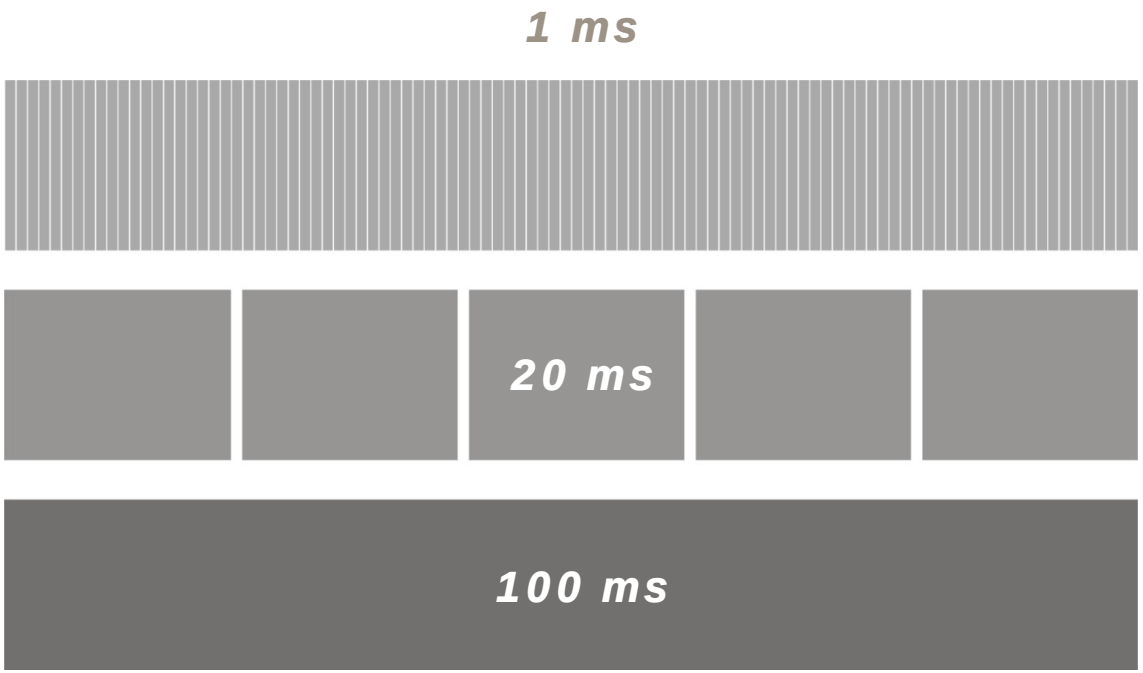


elevation error in mils

flattening R



algorithm usage in an automated fire control system



compute fire control solution

typically 0.1 to 1.2 ms
depending on options used

sensor readout

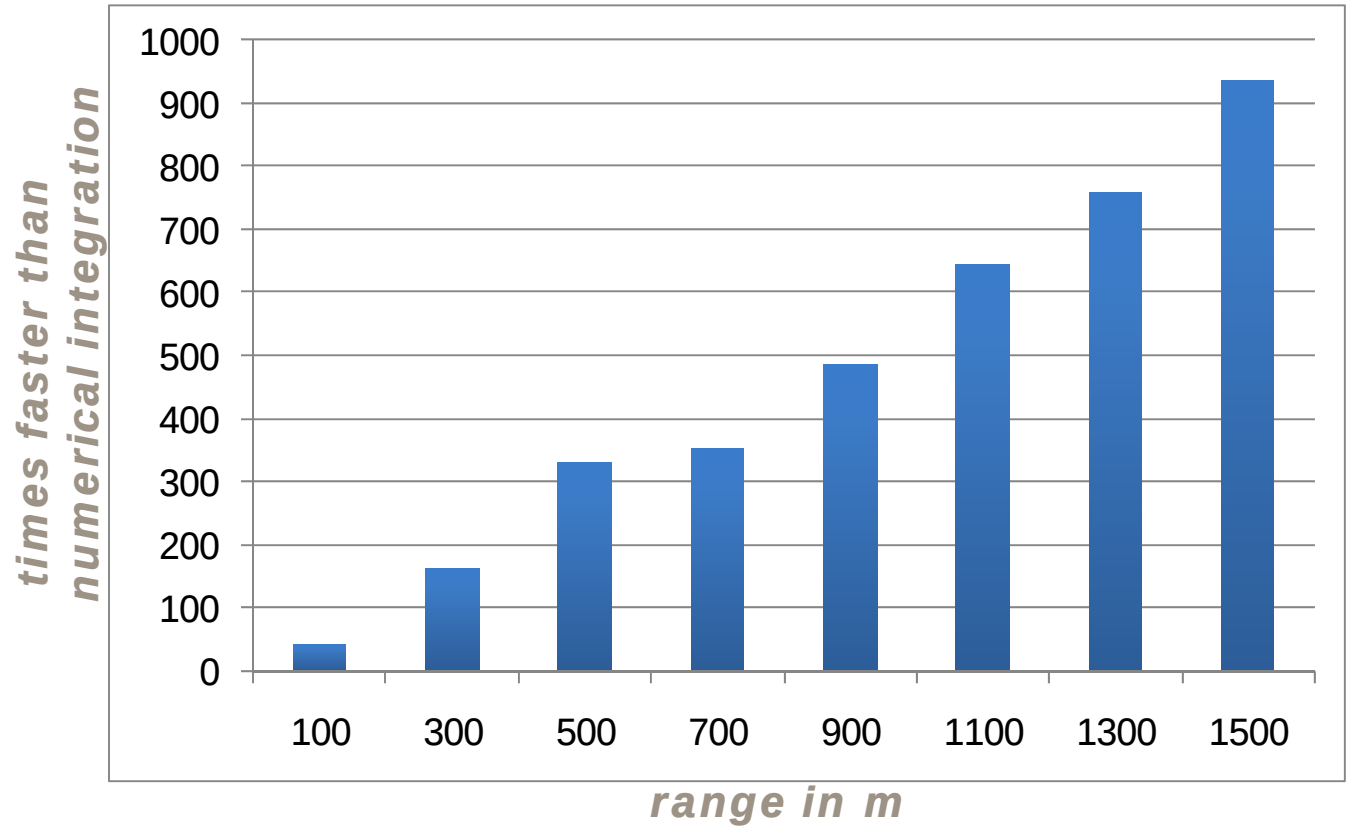
typically every 20 ms

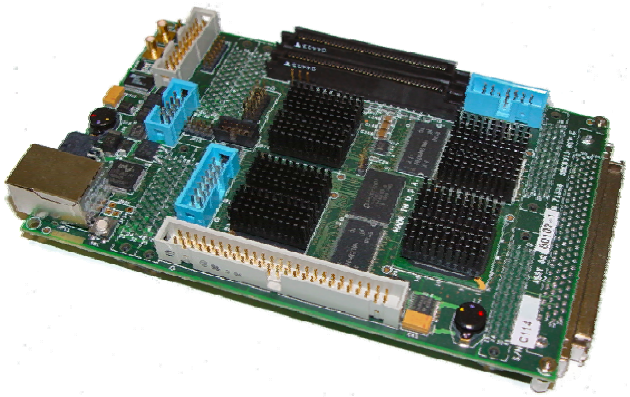
re-align weapon

typically 100 to 1000 ms

Performance

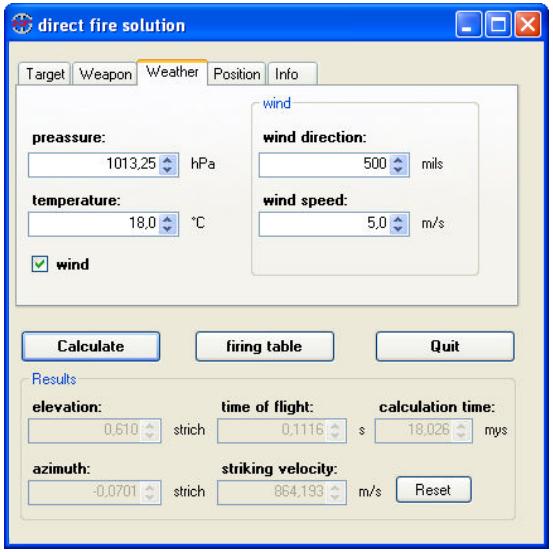
Comparing analytical solution with numerical RK4 integration for a .50BMG rifle:





DSP based stand alone fire control computer

Optimized MISRA-C source code compiled for TI DSP system



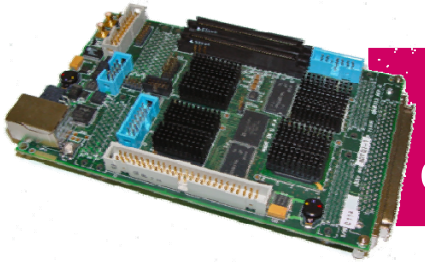
Windows demonstrator front end

C# source code compiled for MS Windows

Pocket PC implementation

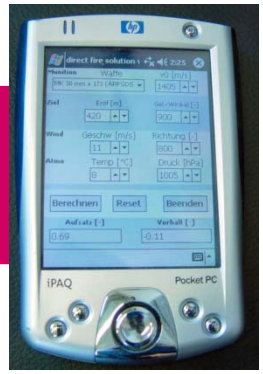
C# source code compiled for MS Pocket PC 2003

Implementations



using spare computational power

using spare computational power



Conclusions

An analytical solution for the differential equations of motion was found

- *thermodynamic state of the atmosphere was considered*
- *Multi region drag fitting*
- *uphill/downhill shooting*
- *wind / coriolis / spin deflection*

An optimized algorithm was developed

- *Optimized to minimized computation time*
- *Multi weapon / ammunition capabilities*
- *compact code size*
- *approved accuracy under nearly all conditions*

Sample implementations were introduced

- *handheld fire control for sniper teams*
- *in-sight automatic fire control for crew weapons*

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