# FLIGHT DISPERSION ANALYSIS OF A ROCKET

Nominal trajectory – Trajectory simulated with the design input
Differences between the real and predicted values due to

- manufacturing
- measurement
- atmospheric
- modeling errors

These lead to errors between the positions of a desired and a real impact point.

Estimation of these errors is very important.

Methods of estimation

- Root Mean Square Method
- Monte Carlo method
- Method of Co-variance matrix method

# Dispersion computation for a short range ballistic missile

## BOOST PHASE

Primary sources :–

Launcher dynamics – Ignition shock, acoustics, vibration

Launcher deflection,– inadequate structural rigidity

Launcher tip-off effect – finite length launcher – CG shift and pitching down – rate gyro measurement

Launcher setting errors – inclined launchers – Elevation and azimuth –

sensitive at higher elevations

Vertical launchers – verticality alignment, azimuth alignment

Rocket motor weight– propellant, structure – tolerances in the design, manufacturing, measurement

Rocket CG measurement inaccuracy and variation during the flight

Variation in rocket motor performance - temperature effect on

propellant – composition - ISP, burn rate

Guidance Navigation and control systems performance variation - ,

accelerometer and gyroscopes hardware specification and

mounting errors

software errors

control system functional response and valve operational delays

Thrust and fin misalignments – longitudinal axis, nozzle alignment, fin mounting errors, structural bending

Wind effects – Head / Tail winds and Cross winds – measurement accuracy, wind variability between the time of measurement and the time of launch

Aerodynamic coefficients estimation accuracy – theoretical / wind tunnel

## FLIGHT - REENTRY PHASE

Separation system / weapon delivery system performance characteristics

Effect of aerodynamic heating

Ballistic coefficient estimation W/ (Cd.A)

Reentry guidance and control errors

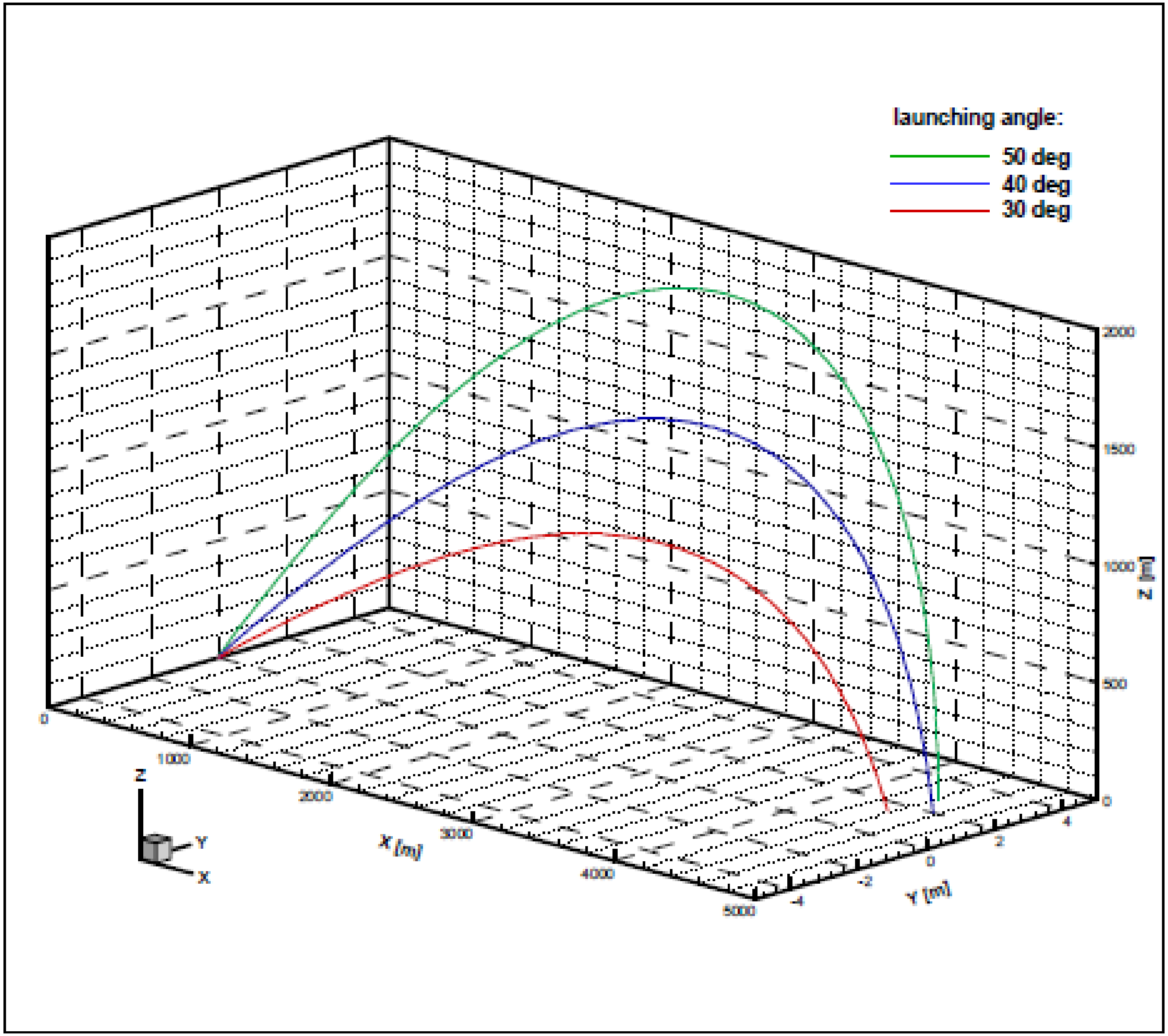


Fig. 3 Nominal trajectories for different launching angles

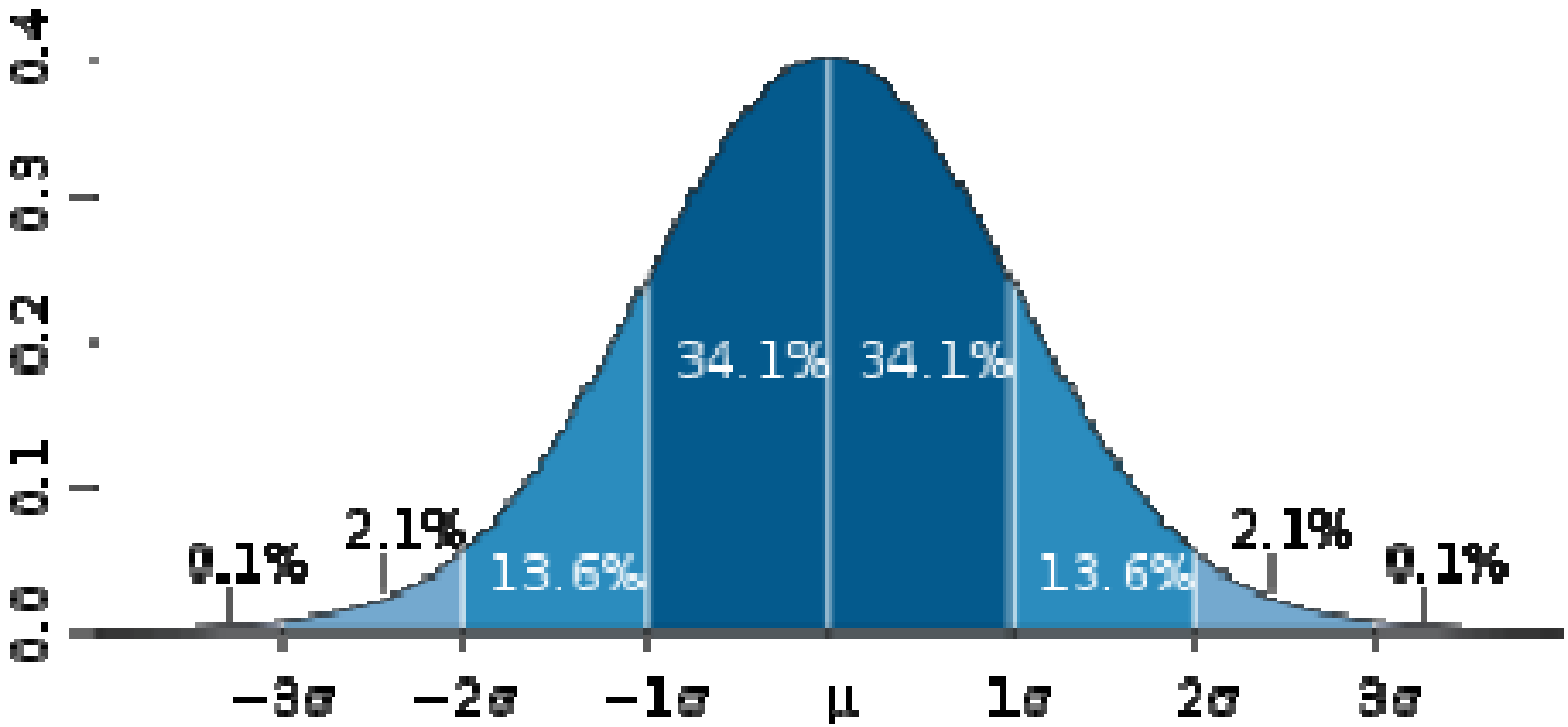


Fig. 1 The graph of Gaussian function

# Root Mean Square Method

1. Generate nominal input data
2. Generate permissible variation for each parameter - Range of magnitudes of uncertainties are defined based measurements, observations, individual error analysis, past data base, manufacturing, tools, instruments, procedures etc
3. Simulate the rocket trajectory with nominal data – DRn , CRn
4. Simulate the rocket trajectory perturbing one data at time – replace the nominal data with off-nominal input data
5. Calculate the impact point deviation – $\delta$ DR and $\delta$ CR
6. Square the deviations- square of ($\delta$ DR and $\delta$ CR)
7. Add the deviations $\sum$square of $\delta$ DR, $\sum$ square of $\delta$ CR
8. Take square root of sum of squares of $\delta$ DR and $\delta$ CR

This procedure removes smaller dispersion parameters.
Gives slightly higher dispersion

# Monte Carlo method of dispersion

Simulate the rocket trajectory with nominal data – DRn , CRn

Each input parameter is selected randomly in the defined ranges and used in the simulation - Random number generator software.

Few thousands of simulations are made

Calculate the impact point deviation – $\delta$ DR and $\delta$ CR

Statistical estimate of the dispersion is made.

Takes more computer time – few thousands of simulation

Realistic estimate

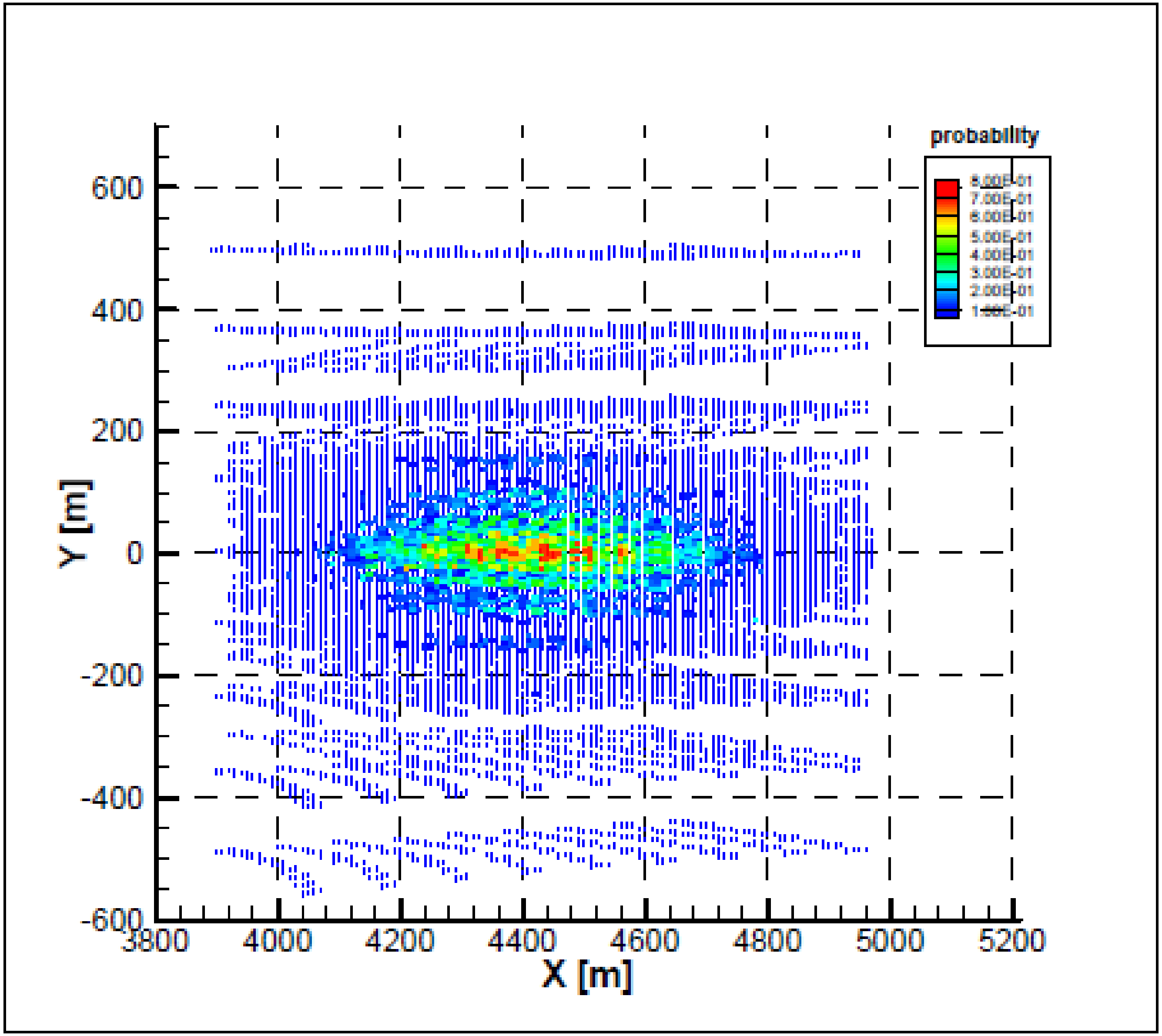


Fig. 8 The area of possible impact point using the first model

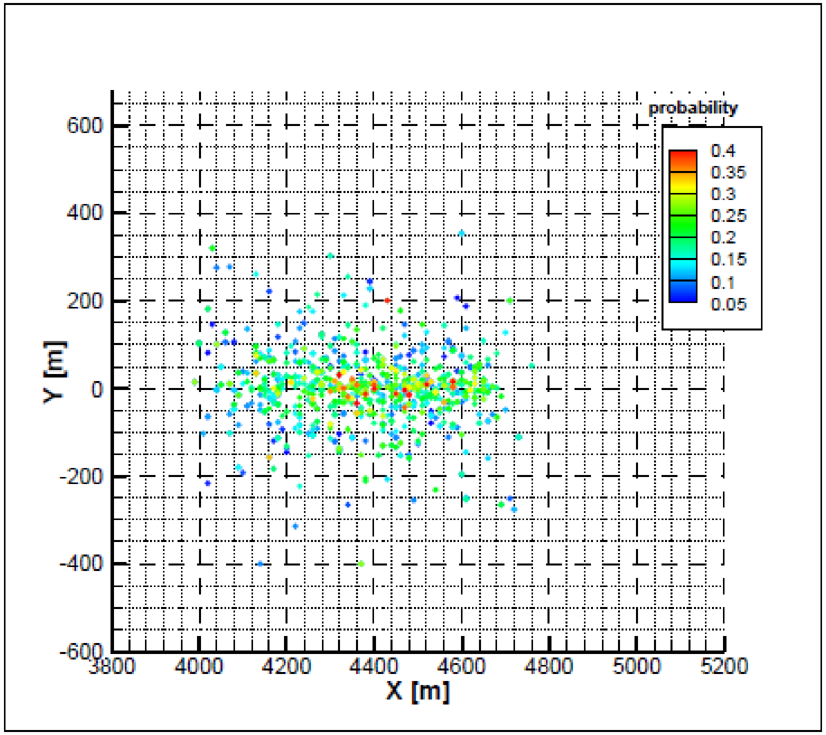


Fig. 9 The area of possible impact point using the Monte Carlo method for 1000 iterations

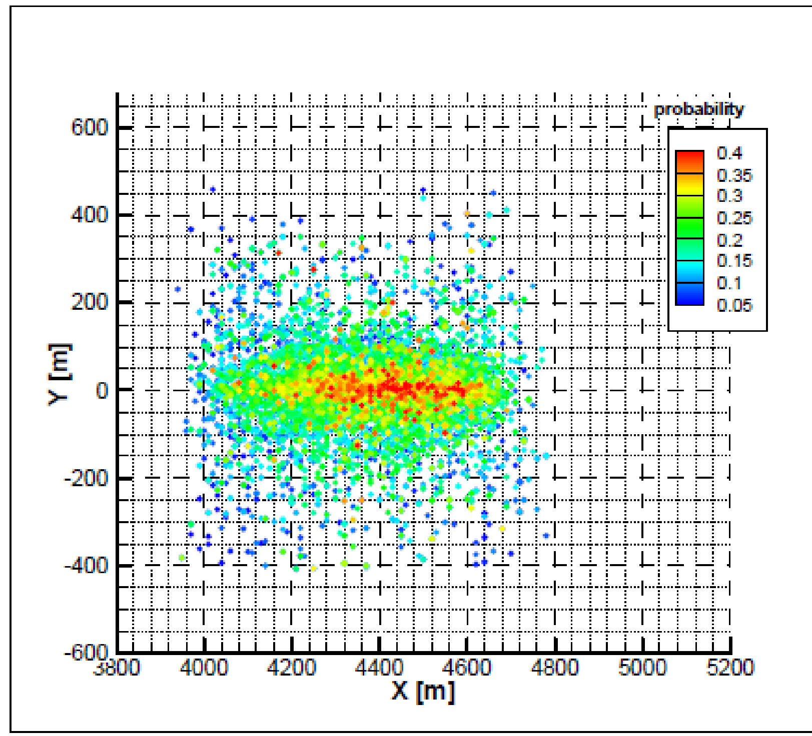


Fig. 10 The area of possible impact point using the Monte Carlo method for 10000 iterations