How PortOSim is used for L-0

- Day of launch the Operational Safety Risk Analyst (OSRA) will run the PortOSim tool which pulls from the latest GFS data and mission specific parameters (Float time, payload weight, balloon type, etc.)
- The tool will run 15,000 trajectories and produce an associated risk for the impact of each simulation.
  - The output is broken down into Nominal Flights, Ascent Failures, and Float Failures. This helps to show what the risk driver is.
- All impacts are then averaged together to gather the total Ec for the mission.
- This value along with plotted nominal trajectory are then presented as L-0 slides during the weather brief.

Example L-0

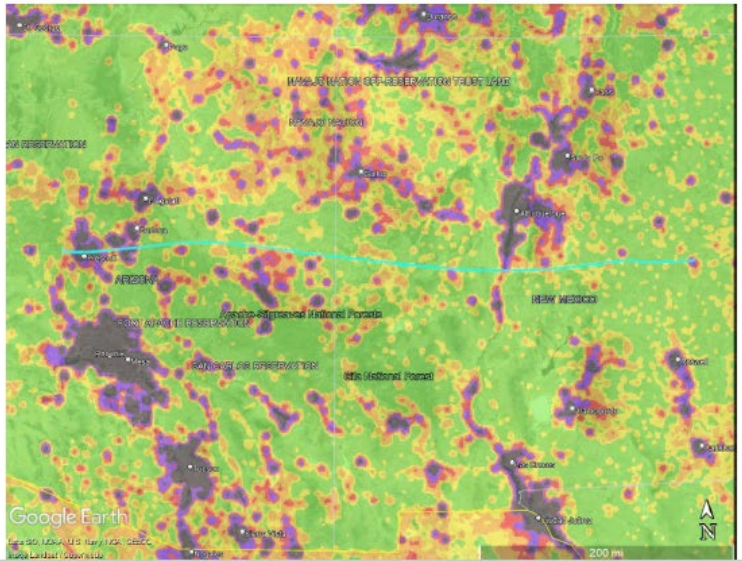
Trajectory Prediction
L-1 Day forecast valid for 20 Aug 2024 13Z Launch

Risk Summary	Launch E_C Risk ($x10^{-6}$)
Total	7

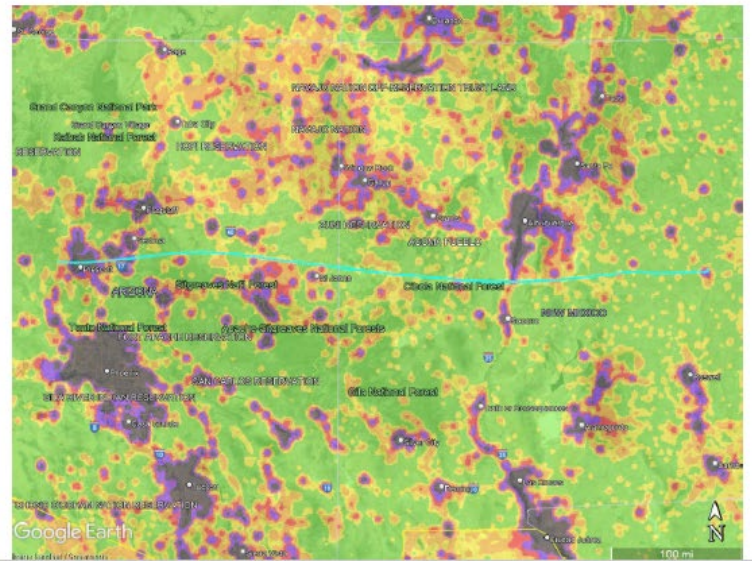
Mission: Salter Test Flight
Balloon: 11 MCF ZPB

Note: Nominal flight completed 12.2 hours after launch

Balloon Risk Map

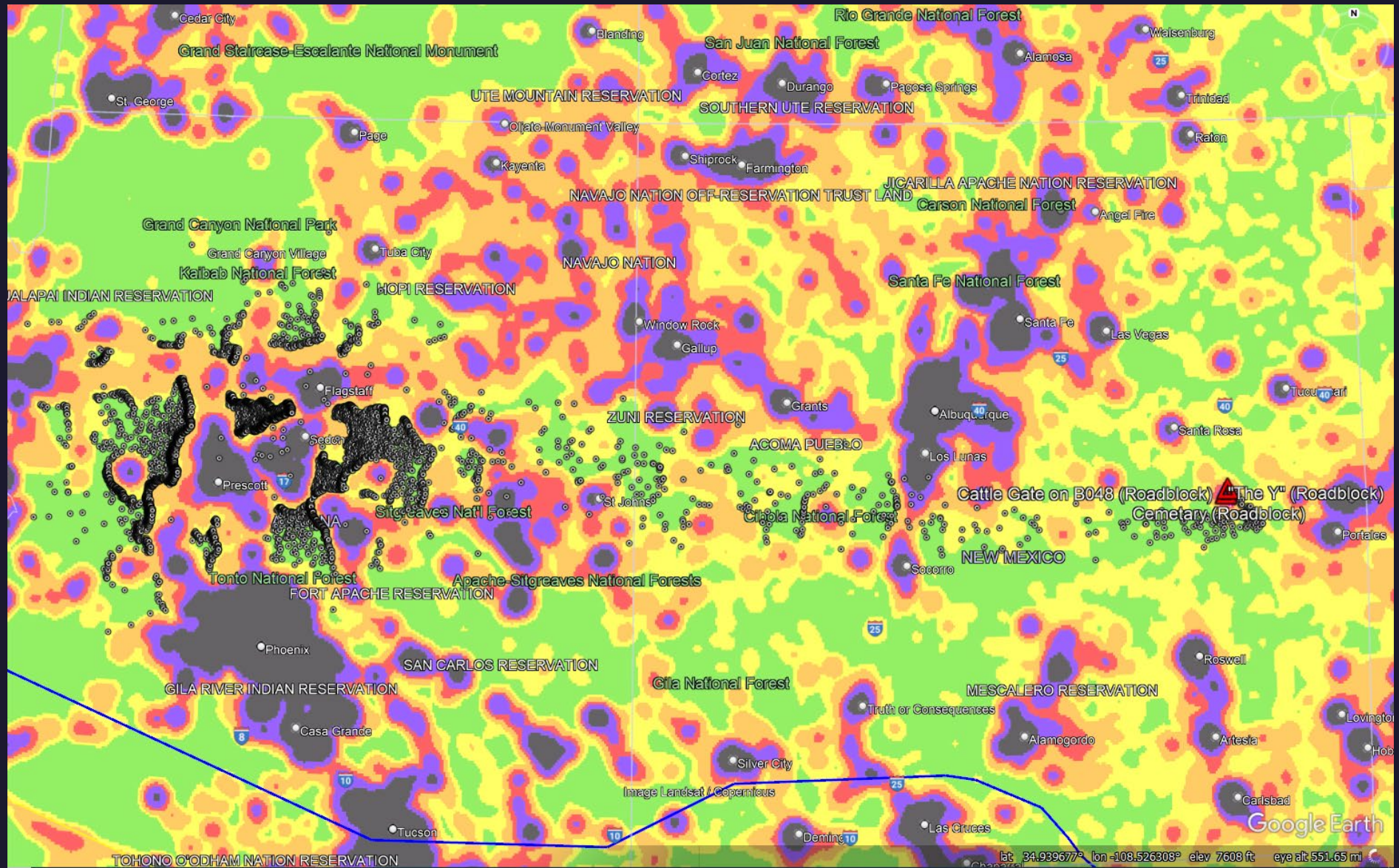


Payload Risk Map



Monte Carlo Points

- The tool also provides the Lat Long of each impact point used for determining Ec.
- These can be plotted to give a better idea of the risk drivers.



Balloon Risk Analysis Tool

An Overview by:

Jim Lanzi (WFF-598)

Presented by:

Joe Joyce (WFF-392)

Agenda

Analysis Flow

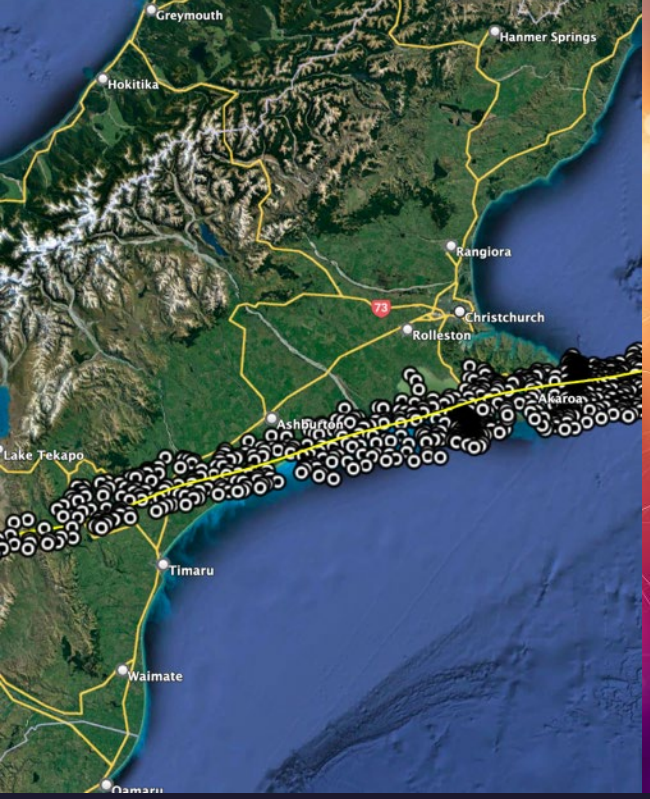
The Mission Model

Balloon Trajectory Modeling

Failure Modeling

Operator Response Modeling

Risk Calculation




Introduction

The balloon risk analysis framework was reworked in 2022 to incorporate realistic models of balloon flight, failures rates, and operator response. The tool-suite has been successfully utilized in several campaigns since. It is maintained by 390 and 598.

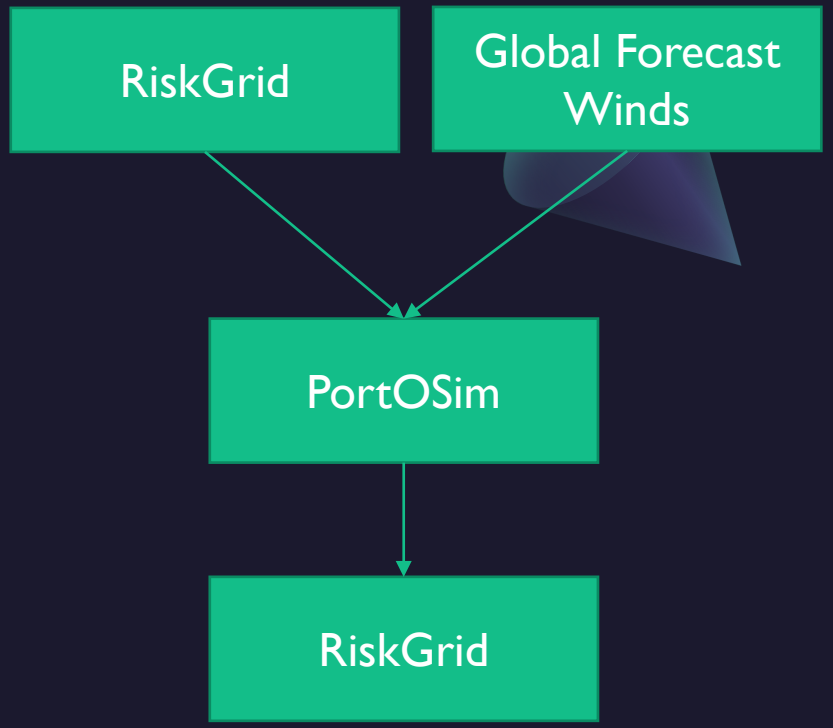
Analysis Flow

What are the elements of the safety risk analysis tool suite? How do they fit together? How are they related to the heritage analysis tools?

Tools in the Toolbox

THE SUITE

- RiskGrid – Computes E[C] for gondola and balloon impacts over analysis grid. Data used during operations for population avoidance at terminate.
- GFS Wind Set Download Scripts
- PortOSim – Performs Monte Carlo simulation of nominal and failure mode flight profiles through forecast wind profile using CSBF terminate ConOps
- RiskGrid – Used to compute risk at end-of-sim terminate
- Wrap Up Scripts for collecting nominal and Monte Carlo perturbed model results



Mission Scenario Model

- Balloon trajectory modeled using SINBAD mass and thermal balance equations + 3dof propagator (PortOSim)
- Transition from balloon buoyancy/drag dynamics to balloon/payload descent dynamics governed by Terminate flag
- Terminate flag triggered by
  - CSBF Operator model

    - OR -

  - Failure Model

Balloon Trajectory Modeling

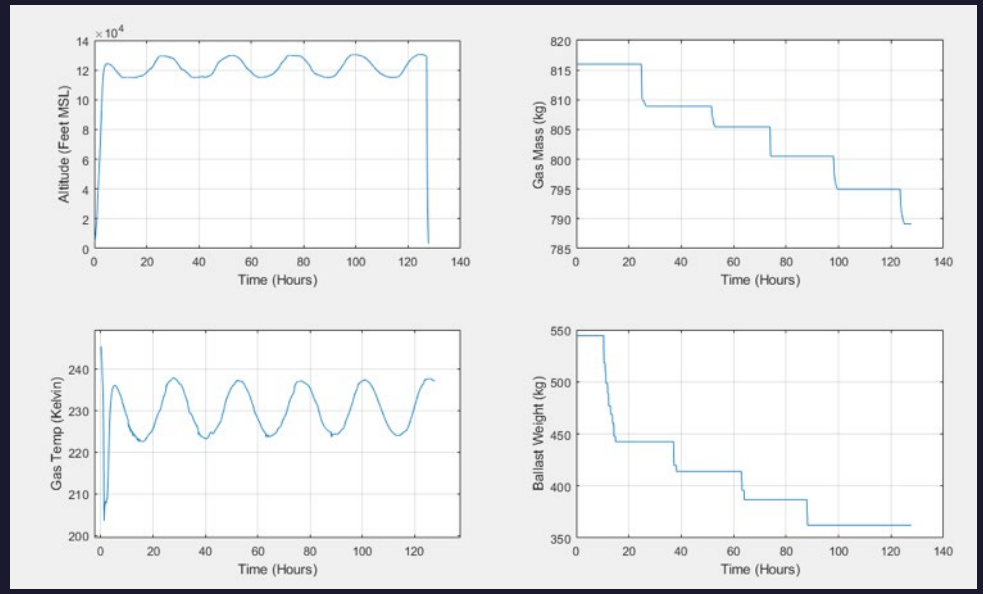
How do you know where the balloon is going to go?

PortOSim

- PortOSim is a multipurpose modeling and simulation tool
  - Developed and maintained by Code 598
  - Used primarily for missile, satellite, drone and multi-body dynamics sims
- PortOSim is written in C++ and makes use of its object-oriented approach to model multiple “simulation objects” in parallel
- PortOSim has its roots in the Range Safety application and has built in parameter randomization, failure event modeling and scripting that make it ideal for applying to the balloon risk assessment problem

PortOSim Balloon Modeling

- Balloon SINBAD ascent and thermal balance model ported from FORTRAN to PortOSim (C++) as part of BRAT effort in 2022
  - Additional horizontal translation degrees of freedom added to the model
  - Made use of already existing solar and atmosphere models built into PortOSim
  - Add facility for atmosphere model to ingest raw GFS GRIB files
- PortOSim trajectories generally agree with CSBF climbout and float models, with variations stemming from known modeling differences



Balloon Trajectory Dispersion

- The dynamic sim (SINBAD) approach was selected because of the built in facility for varying parameters that affect the flight trajectory
- Key Dispersed Parameters include:
  - Wind forecast error varied using the GRAM algorithm for time/space correlated variation
  - Balloon radiation parameters: albedo, black-ball temperature varied via a Gaussian distribution about CSBF predicts
  - Helium fill mass is varied using a uniform distribution -1% - 0.
  - Balloon and descent body drag coefficients varied via Gaussian distribution
- Experience has shown that altitude dispersion from radiation parameter variation produces the widest geographic dispersion from the balloon floating in a different wind layer than expected

Robert told us this would be the case.

Failure Modeling

In which we address the observations:

Balloons do rarely fall from the sky without warning.

Extending the planned mission duration does not reduce the risk to overflown populations.

PortOSim Failure Event Modeling

Without considerations of the physics of leaks, structural failures, or other snakes in the woodpile the failure sequence adopted in the model proceeds as follows:

- A failure initiating event occurs at a random point in time during the flight
  - Failure event trigger is assessed at each simulation clock tick using a Failure Rate Per Hour that varies with flight phase
- There follows a random time interval during which a controlled descent is possible
  - ”Coast Time” after failure event assessed using Weibull distribution using a Mean Time To Terminate that varies with flight phase
- After this “coast time” has elapsed, the balloon will self terminate

Unless the operator gets it first.

Operator Response Modeling

The CSBF flight operators have a role in mitigating the risk during nominal and failure mode scenarios.

PortOSim Operator Modeling

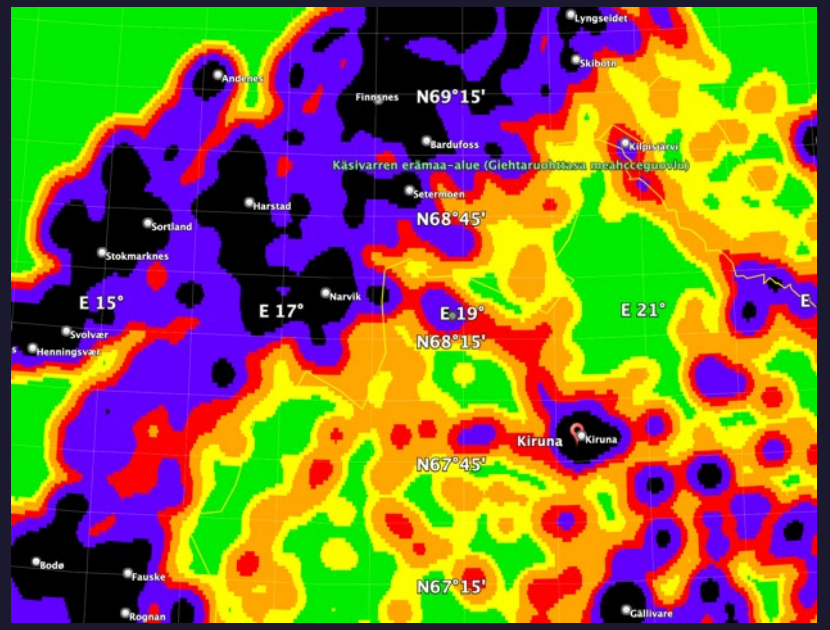
- Balloon Operator Model was developed as part of the 2022/BRAT effort
- During a scenario, operator model is "awakened" under one of following conditions:
  - Time at float has exceeded planned flight time for mission profile
  - Post Failure Event Reaction Timer times out (operator reaction time also drawn from Weibull distribution)
- Once alerted, the operator object uses balloon/payload descent vectors and RiskGrid matrices to determine when/where to terminate the flight
  - Flight terminated by operator model at first opportunity that risk is below a programmed threshold
- Each scenario presents a race condition between an Operator Termination and a Balloon Self Termination

Risk Calculation

What do we do with all this data?

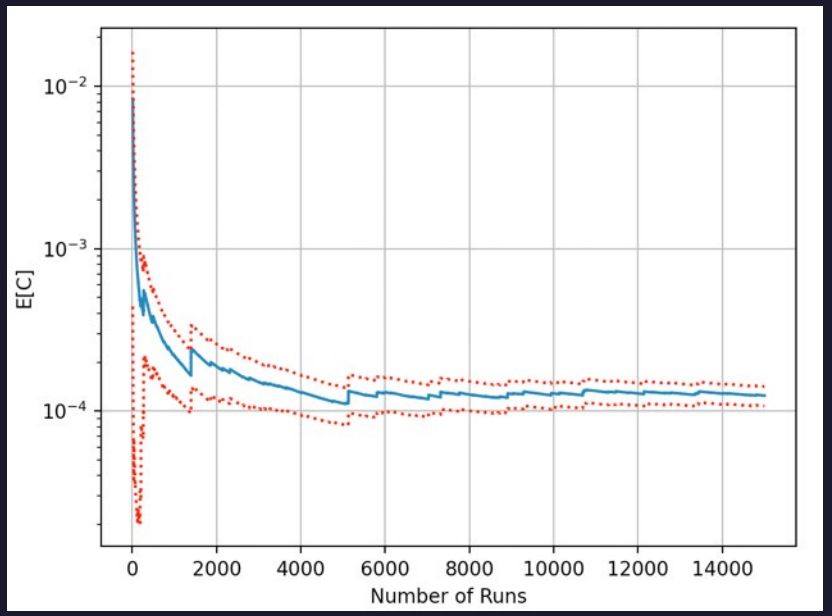
Scenario Risk Assessment

- Mission scenario model produces a pair of impacts (balloon + payload on chute)
- Monte Carlo repetition produces thousands of pairs of impact coordinates
- Whether from failure or simulated operator, impacts correspond to a targeting of two coordinates per run
- RiskGrid is the heritage tool utilized to compute expectation of casualty given the targeting of a coordinate
- Risk Analysis Approach utilizes RiskGrid results to "look up" the single scenario risk associated with the terminate state



Mission Risk Assessment

- Mission Scenario produces a terminate risk for each simulation run
- Monte Carlo repetition produces thousands of risk assessments
- We are interested in the ”Expected” risk – this is taken as the average over all scenarios run
- As the scenarios accumulate, an error bar is computed based on an estimated 90% confidence interval on the E[C] value
  - Error Bar ~ z * Risk Std Dev / sqrt(n)
- Typically require >5000 sims to converge. Will stop when result is obvious.



The way to get started is to quit talking and begin doing.

- Walt Disney