Using Simulation to Define and allocate probabilistic Requirements

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Introduction

- General thesis
  - Integration of model-based system engineering with simulation in 3D synthetic environments is a cost effective way to design and analyze systems
- This is illustrated by
  - analyzing the feasibility of a proposed design to add terrain following and obstacle avoidance to an existing air vehicle
- Objective
  - Improve requirements by adding bounds to requirements based on analysis

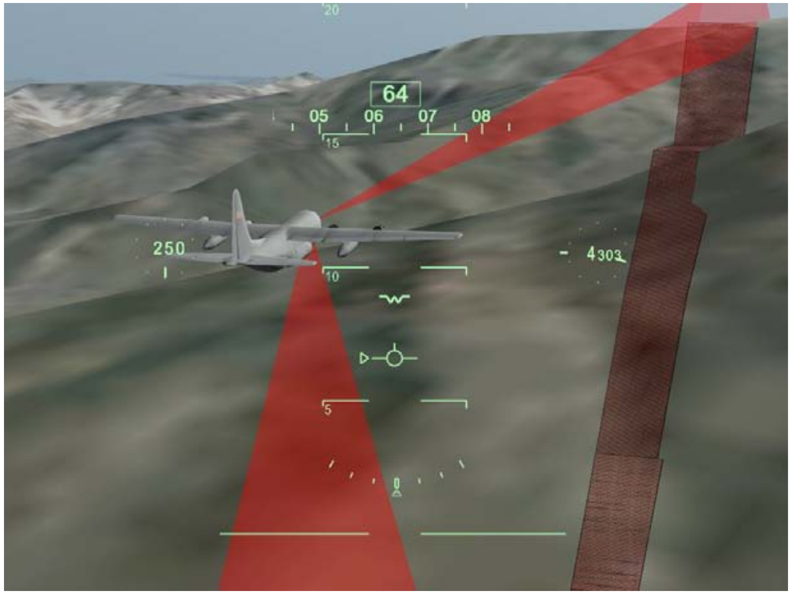
Engineering Application Example

- Problem
  - Determine if the proposed design solution will meet customer needs

- Work to be done
  - Refine requirements to make them bounded and precise
  - Determine critical environmental issues
  - Prototype design sufficiently to verify feasibility
  - Validate refined requirement with customer

Initial Requirement For Design Upgrade

- Initial requirement
  - avoid terrain and obstacles while flying low over mountainous terrain to avoid detection



- Proposed design
  - specific radar integrated into the avionics system

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Approach: Configure 3D Synthetic Environment

- Integrated radar data with avionics
- Performance model of aircraft
  - Climb rate
  - Velocity
- Sensor models
  - Detection distance
  - Sweep pattern
- Environment
  - Mountains
  - Obstacles
  - Weather

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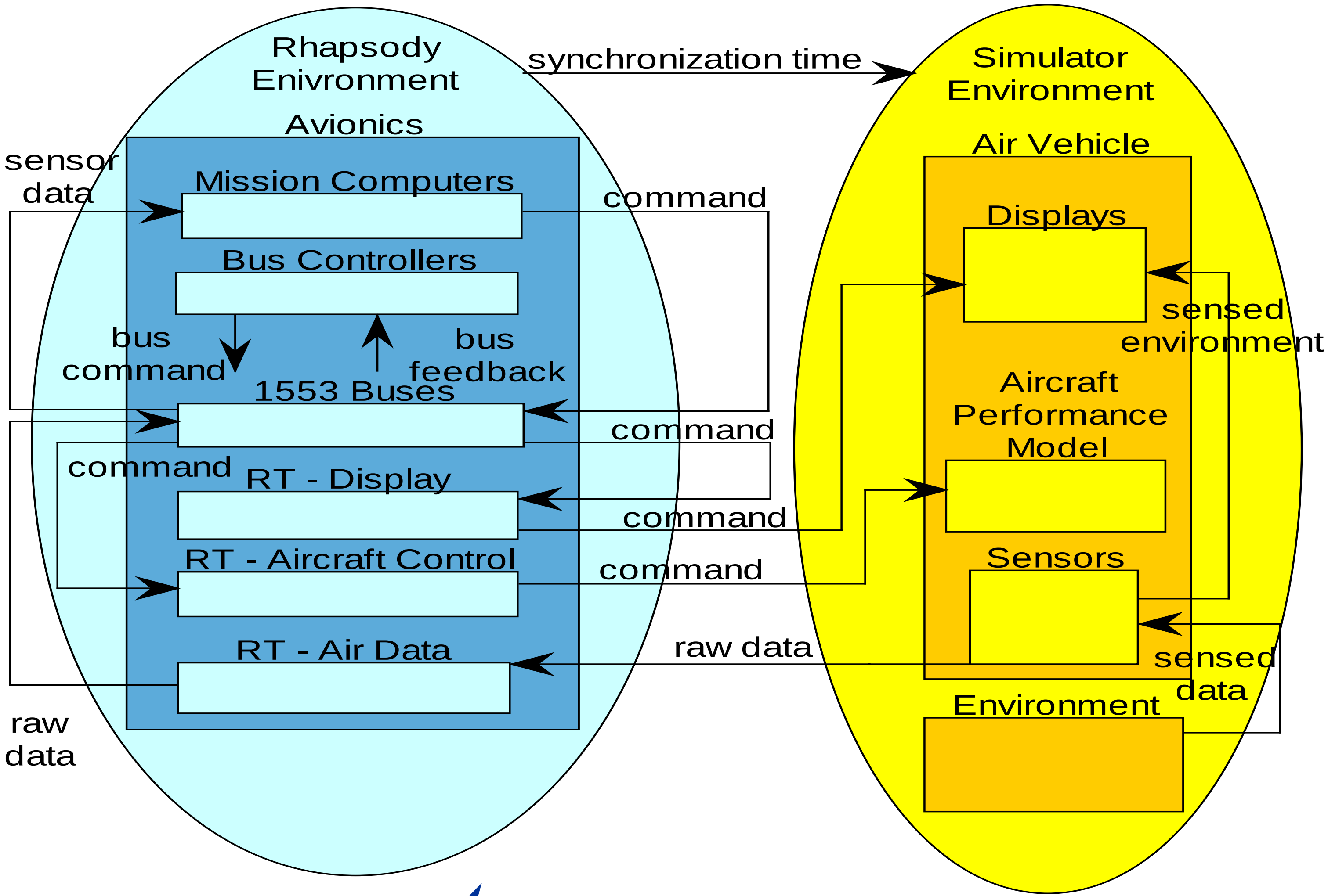
Approach: Integrated Executable Avionics Model With Simulation



Approach: Model System and Environment

- Simulation developed to model the characteristics of the system and environment
- Run simulation multiple times varying all of the inputs
  - Collect results for statistical analysis

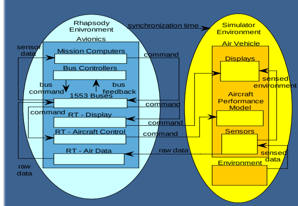
System Attributes

- Aircraft speed
- Aircraft climb rates
- Radar power
- Radar scan rates
- Radar sweep pattern

Environmental Conditions

- Obstacle Height
- Obstacle Location

Simulation

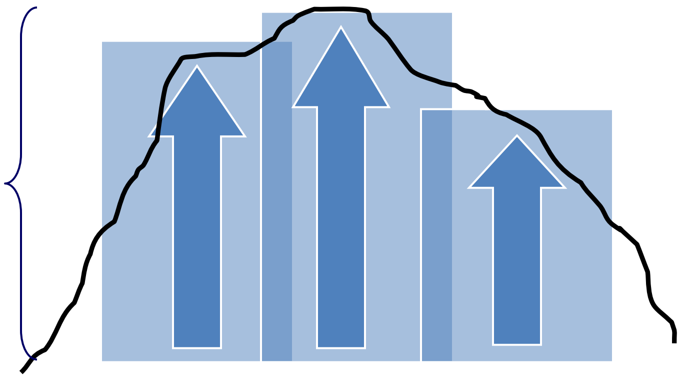


Simulation Results

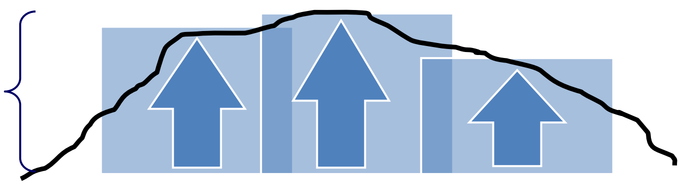
Scenarios – Terrain Variation

- Obstacle at height of max elevation range
- Obstacle at half height of max elevation range
- Plateau at max elevation range
  - Represents Full sweep

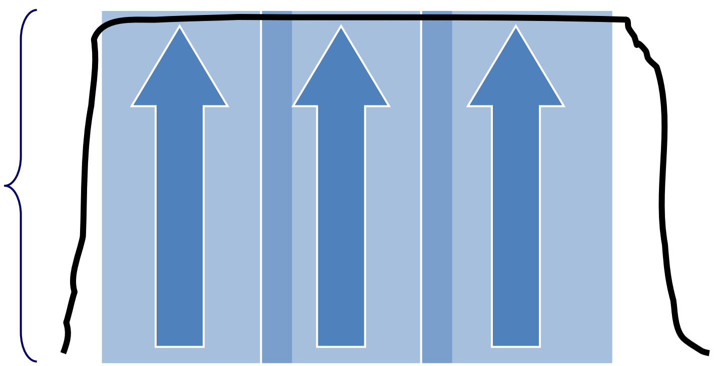
40 deg



20 deg

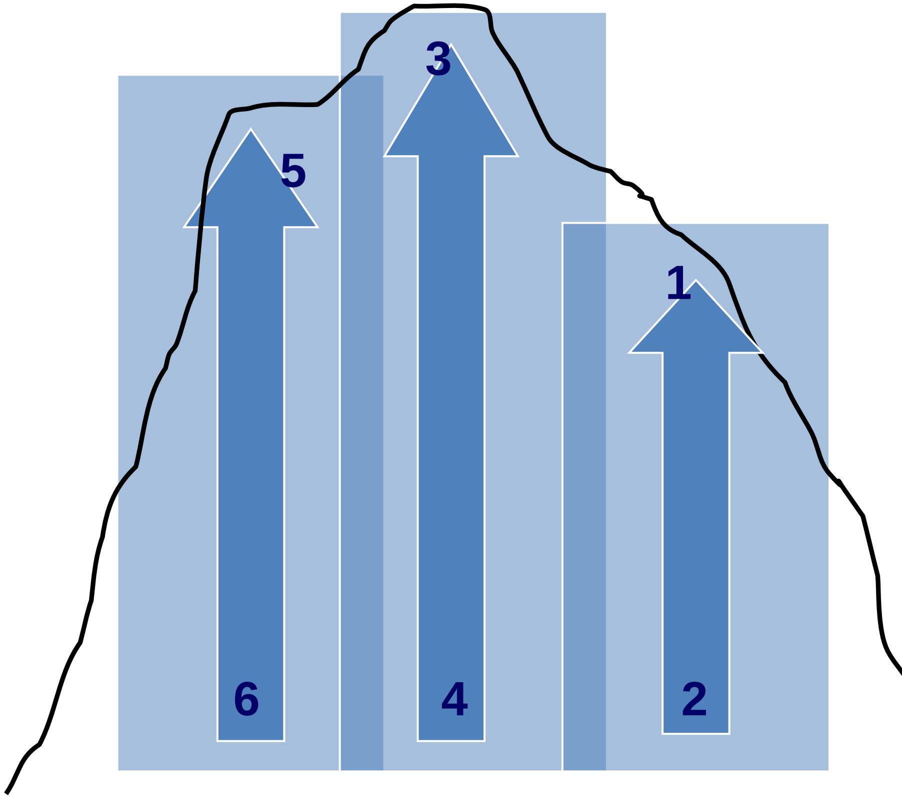


40 deg



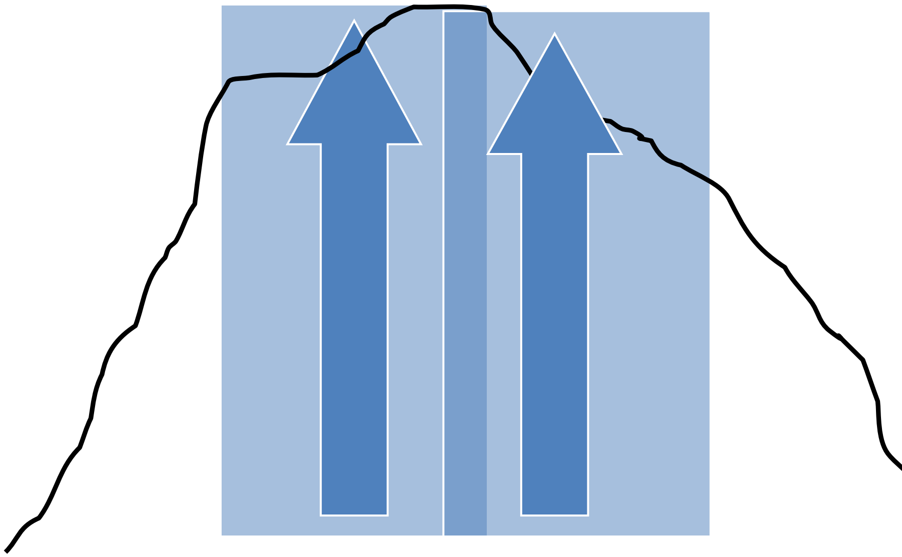
Scenarios - Scan Position Variation

- Top of the right bar
- Bottom of the right bar
- Top of middle bar
- Bottom of middle bar
- Top of left bar
- Bottom of left bar

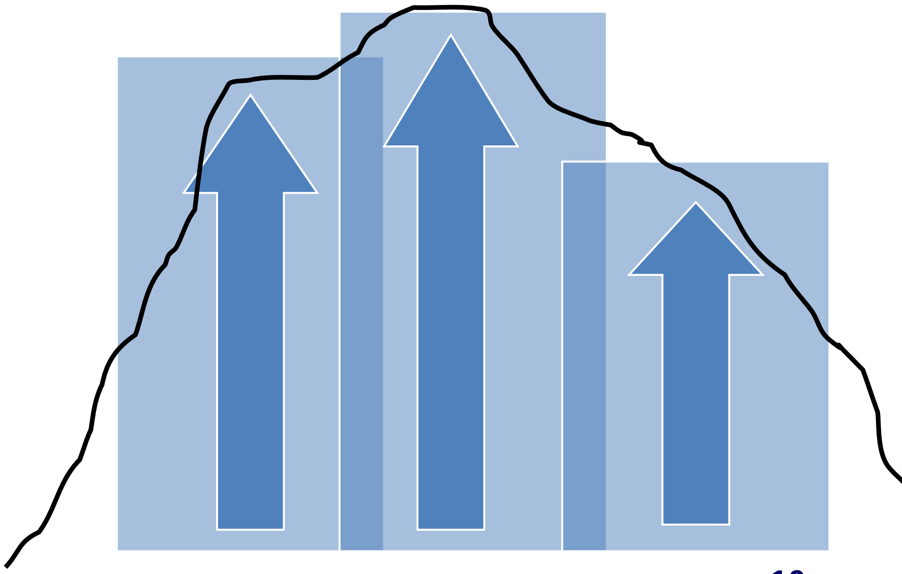


Scenarios - Scan Bars

- 2 scan bars
  - Faster



- 3 scan bars
  - More detail



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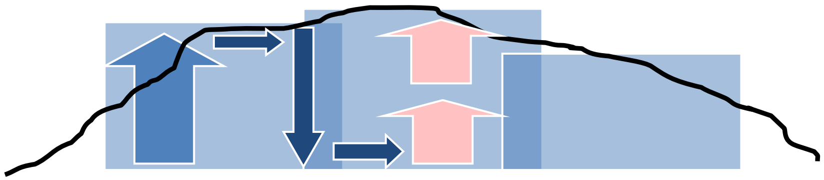
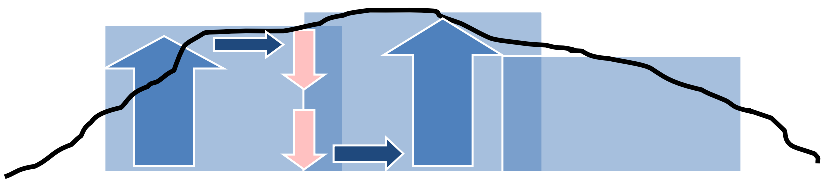
Scenario – Scan Rate Variation

- Normal rates

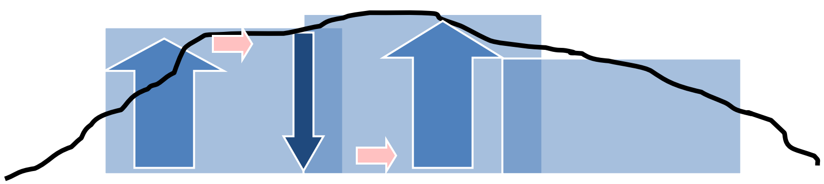
- Double up rate



- Double down rate



- Half turnaround



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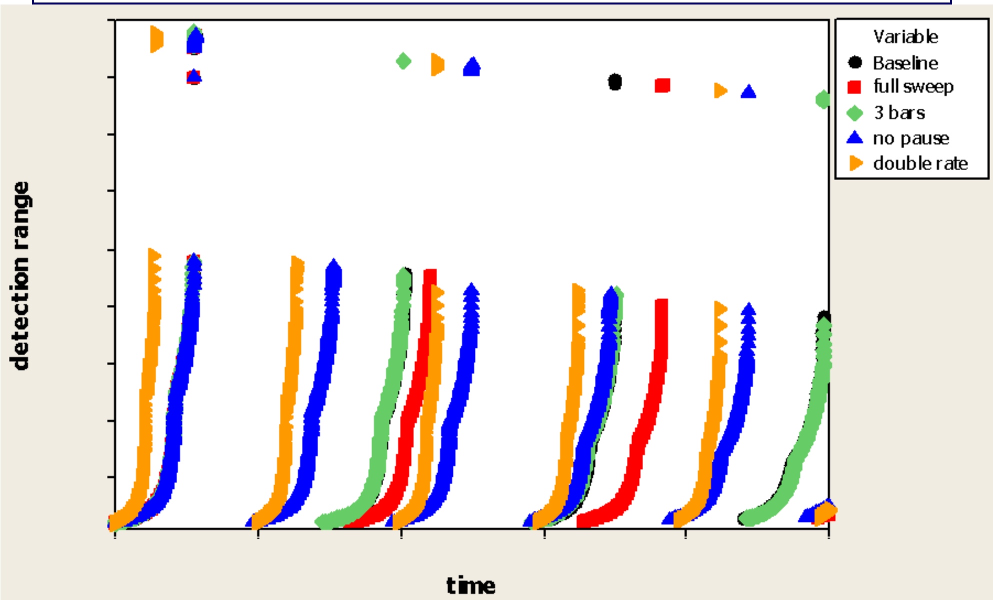
Data Collection From Simulations

- Velocity held constant
- 2 bars, normal pattern, normal rates
- 3 bars, normal pattern, normal rates
- 2 bars, normal pattern, double rates
- 2 bars, full pattern, normal rates
- 2 bars, no pauses for the sensor to turn around, normal rates

Detection Distance versus time for 5 runs



- Orange (Double scan rate) and Blue (Faster turnaround time) runs lead the others
- Red line (Full sweep) is slowest
- No difference between Black (baseline) and Green (more scan bars)

Simulation Results

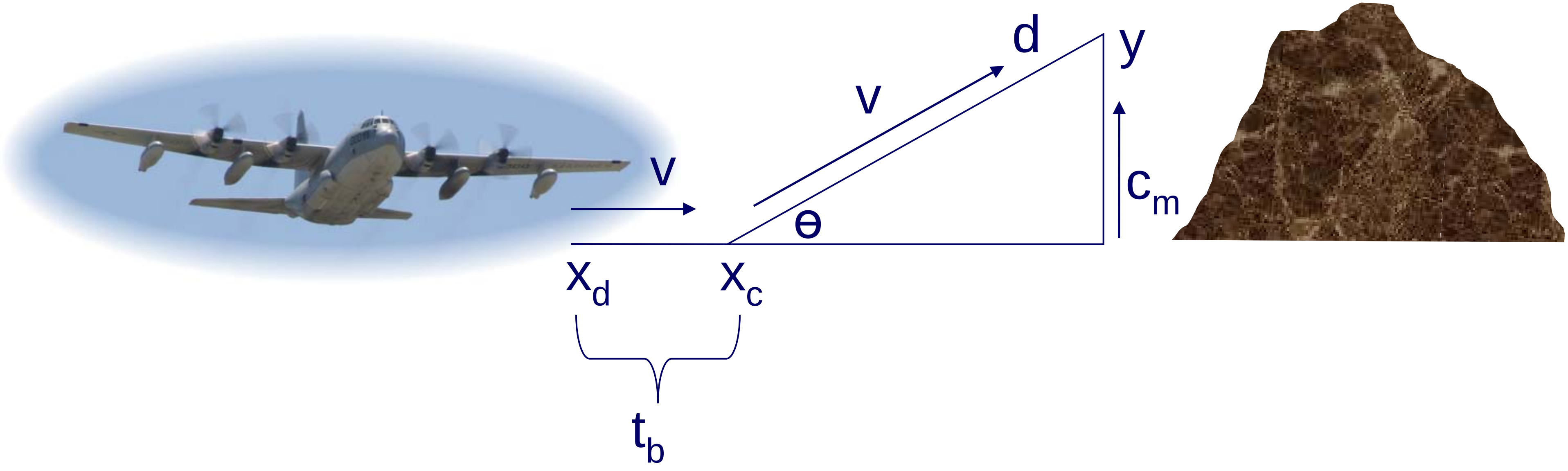
- Running the simulation
  - Showed what impacts the detection distance which in turn impacts the time budget
  - Showed the behavior of detection distance
  - Can put results and observation together to refine allocated detection requirements
    - Flight path impacted by
      - Airspeed
      - Climb rate
      - Detection distance
      - Obstacle height
      - Sweep pattern

Requirement

- Closer to a bounded requirement
- Aircraft shall compute a safe flight path within TBD seconds of detecting obstacles of TBD milliradians in size while flying level at an airspeed between TBD and TBD knots with an ability to climb at the rate of at least 2000 feet per minute.

Analysis of Parameter Relationships

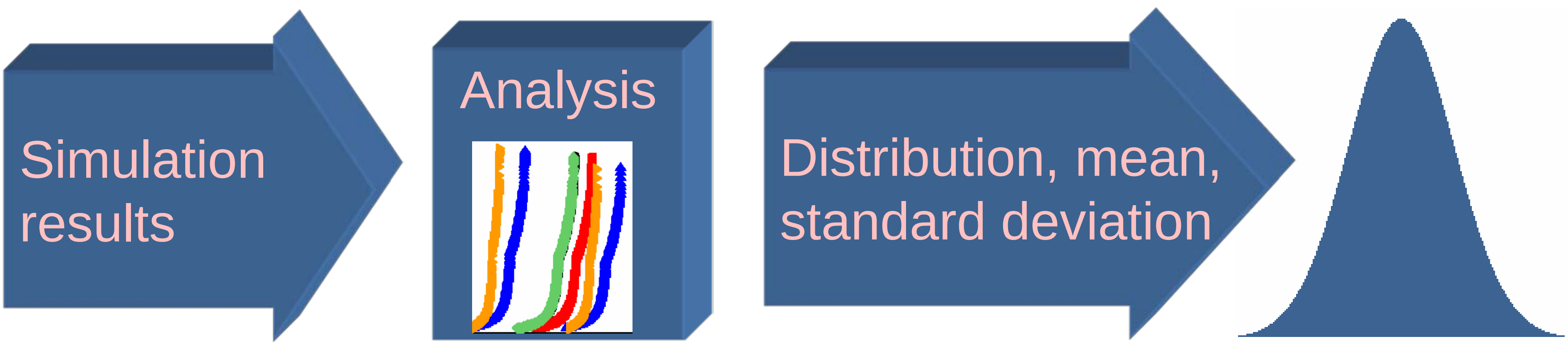
- Use physics to form equation with parameters that impact the time budget for safe flight computations



Analysis of Inputs

- Analyze each of the inputs to determine their distribution, mean and standard deviations.

- E.g. Run simulations on the input detection distance



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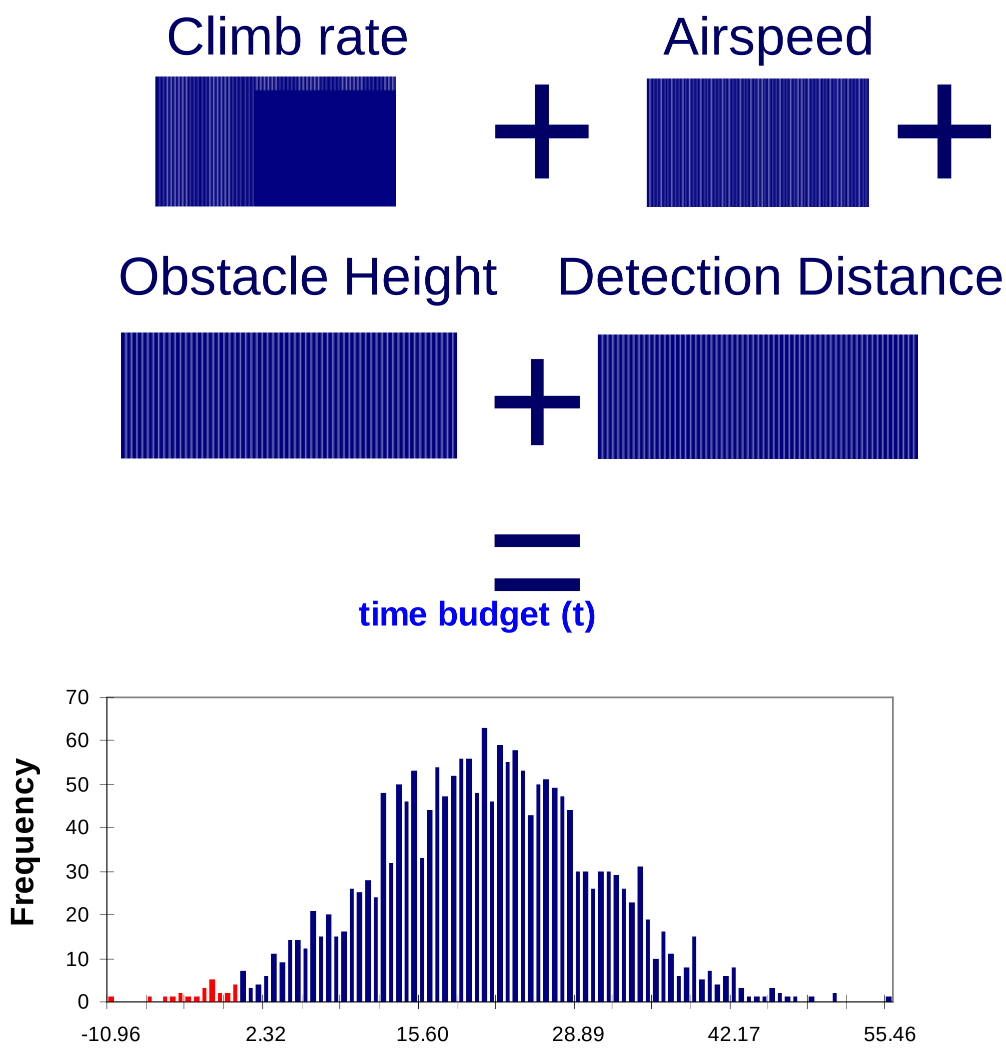
Sensitivity Analysis To Determine Probability of Non Compliance

- Run a sensitivity analysis to determine the probability of compliance



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Refined Requirement

- From: Avoid terrain and obstacles while flying low over mountainous terrain.

- To: Aircraft shall compute a safe flight path 99.98% of the time within 0.11 seconds of detecting obstacles of 0.5 milliradians in size while flying level at an airspeed between 200 and 280 knots with an ability to climb at the rate of at least 2000 feet per minute.

Conclusion

- Simulations help clarify environmental impacts
- Physics and geometry used to determine model
- Simulation with statistical analysis used to determine distribution and mean
- Sensitivity analysis to determine PNC