Probabilistic Technology (PT) Application for High Reliability Fuze

Lee Luong

US Army ARDEC, RDAR-MEF-F

(973) 724-5687

lee.luong@us.army.mil

May 16, 2012

Distribution Statement A. Approved for public release; distribution is unlimited.

Outline

Distribution Statement A. Approved for public release; distribution is unlimited.

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

RDECOM

Project Objective

- **Develop a Probabilistic Technology (PT) Process/Method that can be used *to evaluate, predict, and improve reliability of any fuze architecture even with limited data.***
- **Part of the Joint Fuze Technology Program (JFTP) is focused on ARMY Fuze applications. Lessons learned will benefit other high reliability DOD Fuze programs.**

Distribution Statement A. Approved for public release; distribution is unlimited.

High Reliability Fuze Overview

PERFORMANCE GOAL:
<1% UNEXPLODED ORDNANCE (UXO)

Fuze Design Approach:

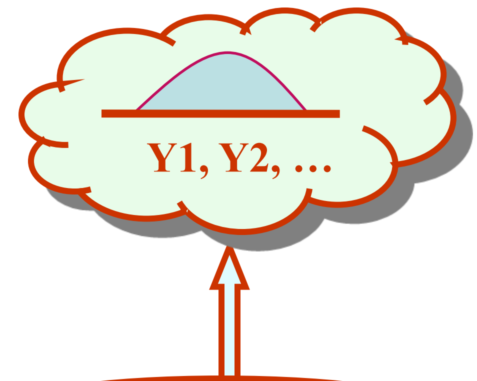
- **Redundant control electronics**
- **Redundant power sources**
- **Redundant Safe & Arm (S&A’s) devices**
- **Multiple Detonation Function Modes**
- **Leverage previous and current fuze programs**

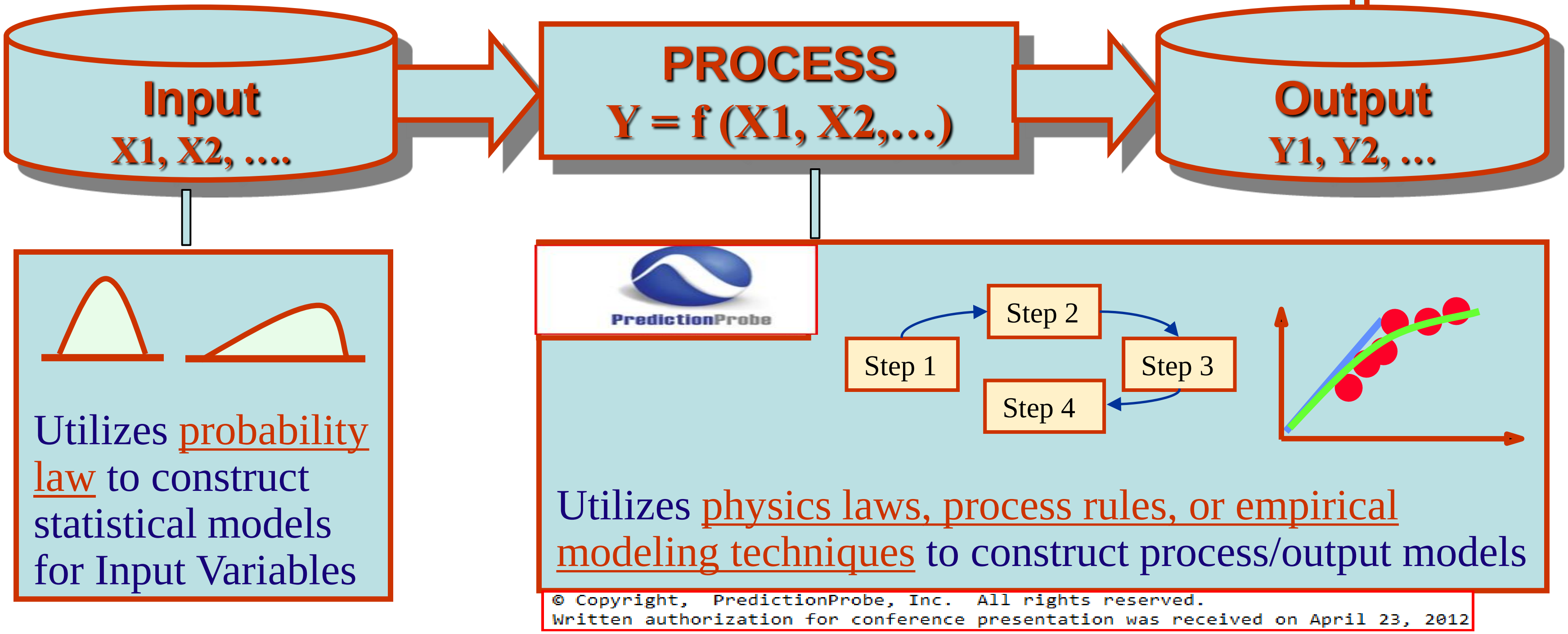
Distribution Statement A. Approved for public release; distribution is unlimited.

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Probabilistic Technology Overview

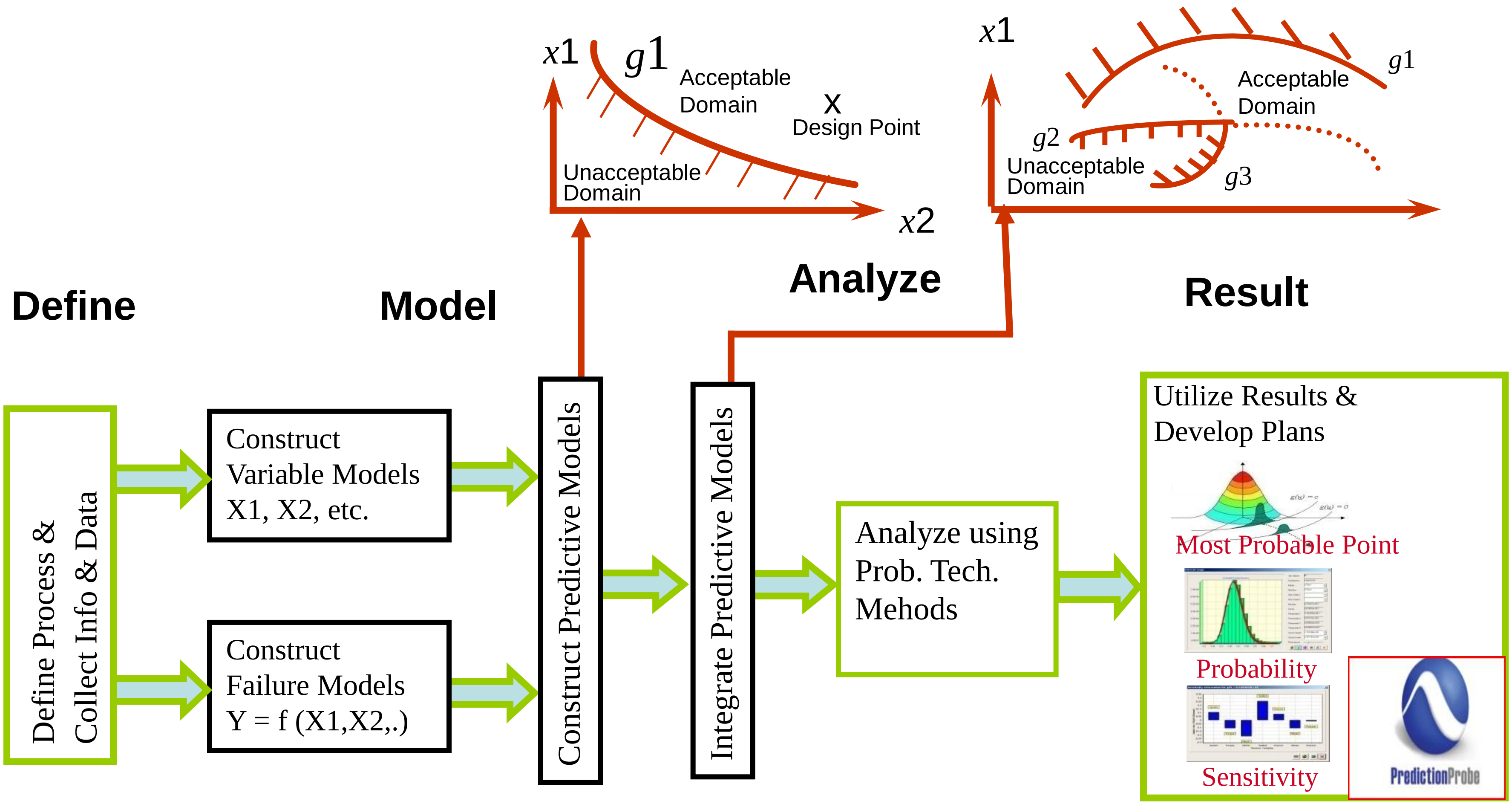
- Probabilistic Technology is a set of advanced predictive methods that allow for realistic predictions by integrating uncertainties into process models and evaluating the effects.
- PredictionProbe, Inc. Unipass PT software used. (Others available)





Distribution Statement A. Approved for public release; distribution is unlimited.

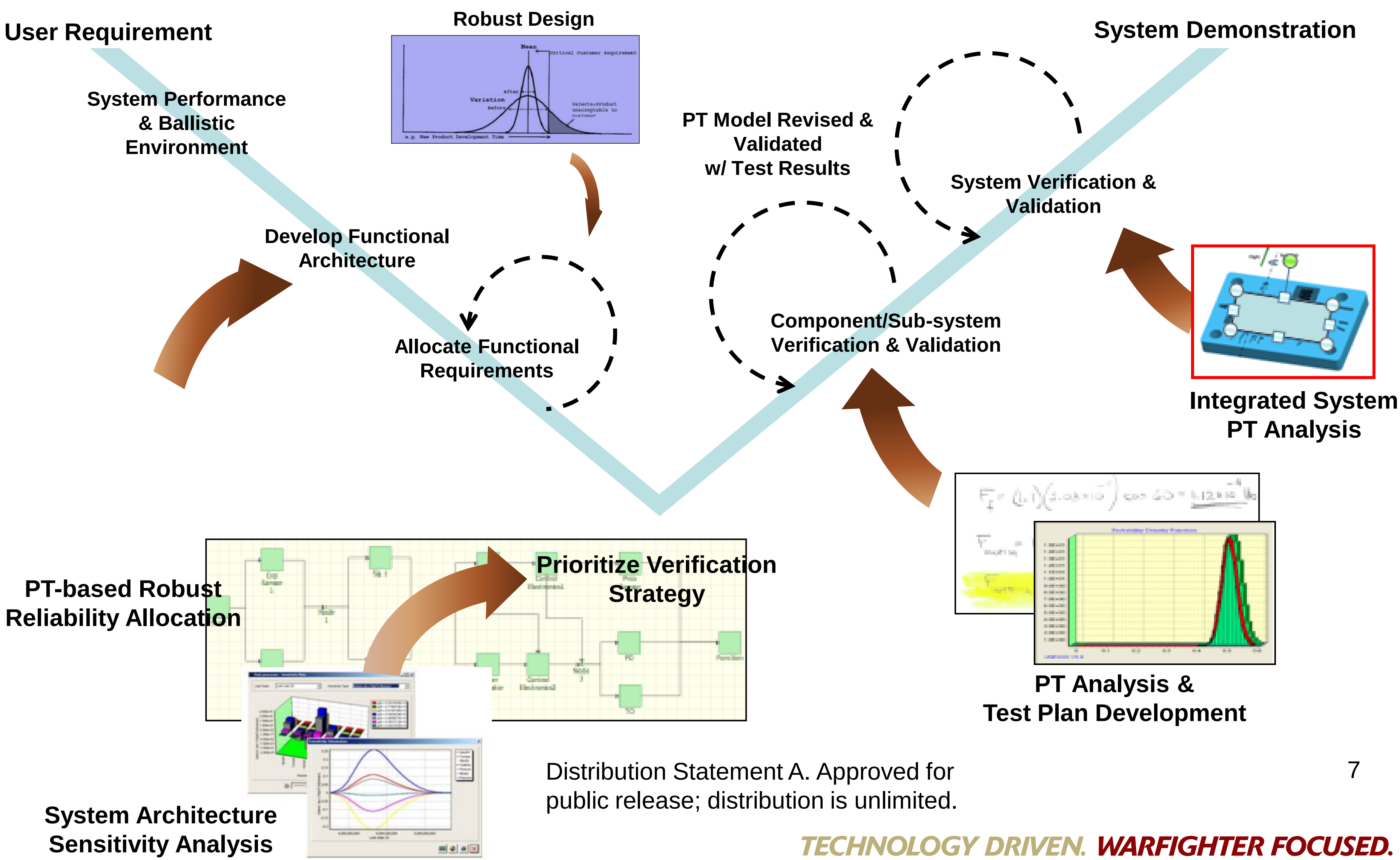
Probabilistic Technology Overview



© Copyright, PredictionProbe, Inc. All rights reserved.
Written authorization for conference presentation was received on April 23, 2012

Distribution Statement A. Approved for public release; distribution is unlimited.

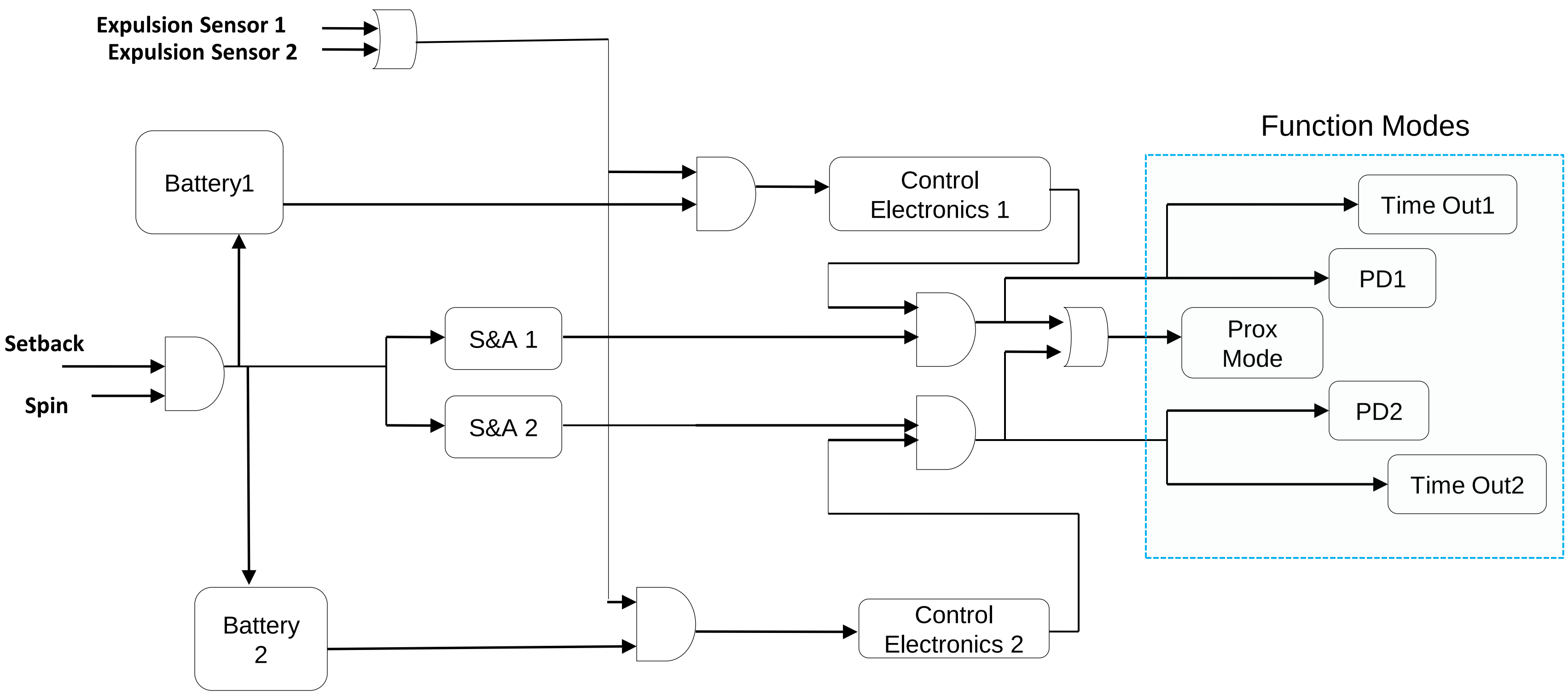
PT Approach Roadmap



Distribution Statement A. Approved for public release; distribution is unlimited.

RDECOM
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Fuze Logic Architecture

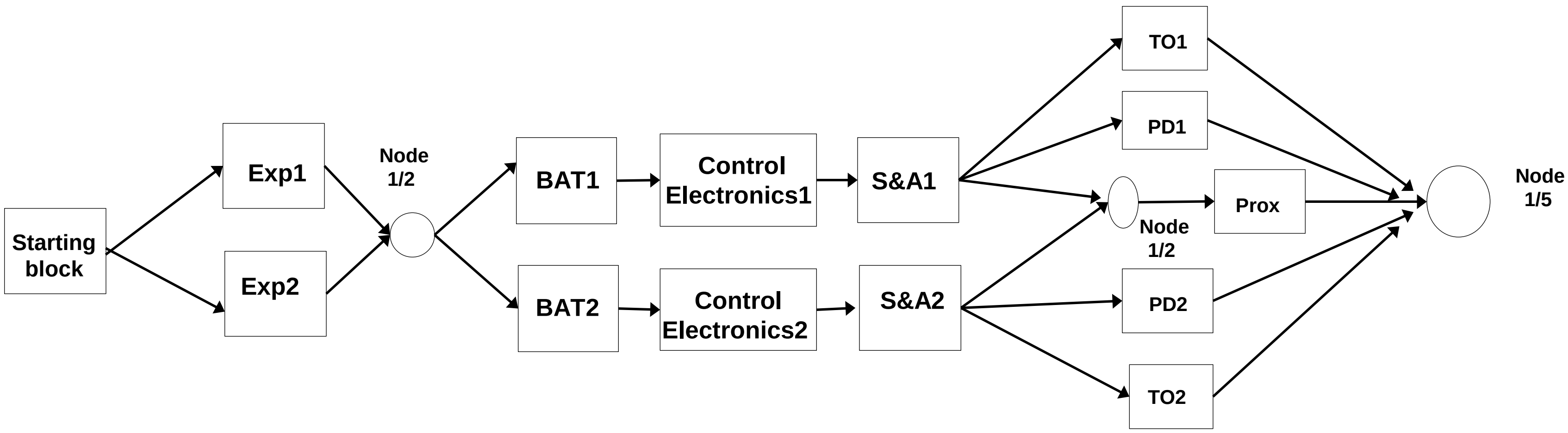


This represents the baseline design architecture

Note: PD1 = Point Detonation 1
PD2 = Point Detonation 2

Distribution Statement A. Approved for public release; distribution is unlimited.

Fuze Reliability Analysis



Note: TO1 = Timeout 1
TO2 = Timeout 2

Distribution Statement A. Approved for public release; distribution is unlimited.

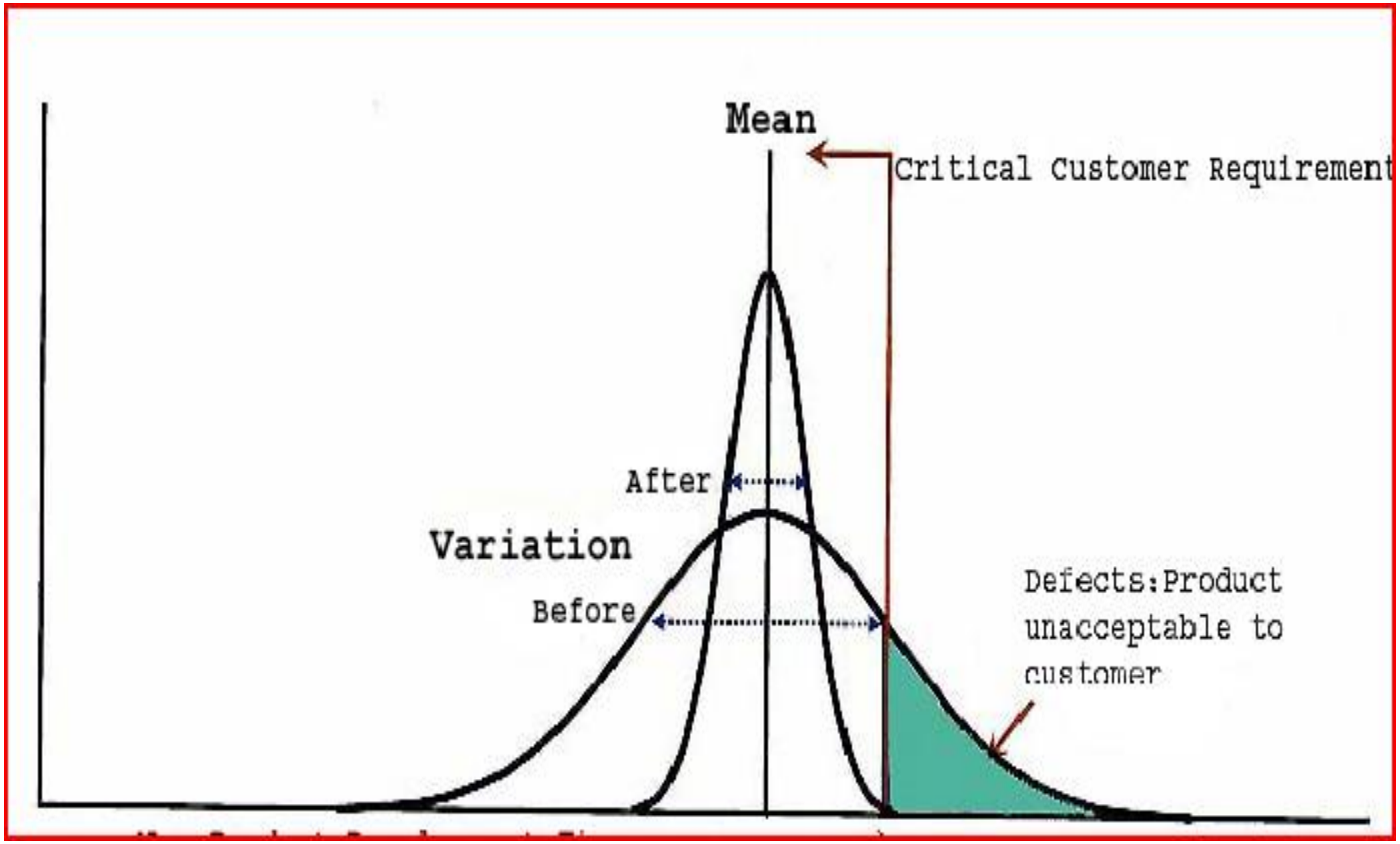
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Robust Design

- **Model**
  - **Construct Variable Models**
  - **Construct Failure Models**
- **Input**
  - **Component Reliability Allocation Range**
- **Output**
  - **Component Reliability Allocation**
  - **Identify robust point which enables the design to achieve minimal deviation of response**

Distribution Statement A. Approved for public release; distribution is unlimited.

Robust Design



Distribution Statement A. Approved for public release; distribution is unlimited.

RDECOM

Constraints for Robust Allocation
-Baseline Approach

Design Variable Name	Input Description	Lower Bound	Upper Bound
ES1_range	Range of Mean Reliability of Expulsion Sensor 1	0.85	0.97
ES2_range	Range of Mean Reliability of Expulsion Sensor 2	0.85	0.97
SA1_range	Range of Mean Reliability of S&A 1	0.99	0.999
SA2_range	Range of Mean Reliability of S&A 2	0.85	0.92
Bat1_range	Range of Mean Reliability of Battery 1	0.9	0.992
Bat2_range	Range of Mean Reliability of Battery 2	0.9	0.992
ContE1_range	Range of Mean Reliability of Control Electronics 1	0.9	0.995
ContE2 _range	Range of Mean Reliability of Control Electronics 2	0.9	0.995
PS_range	Range of Mean Reliability of Prox Sensor mode	0.85	0.97
PD_range	Range of Mean Reliability of Point Detonation mode	0.85	0.92
TO_range	Range of Mean Reliability of Time Out mode	0.4	0.5

Fuze System Reliability Allocation = 0.9901

Distribution Statement A. Approved for public release; distribution is unlimited.

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Robust Design Point

– Baseline Approach

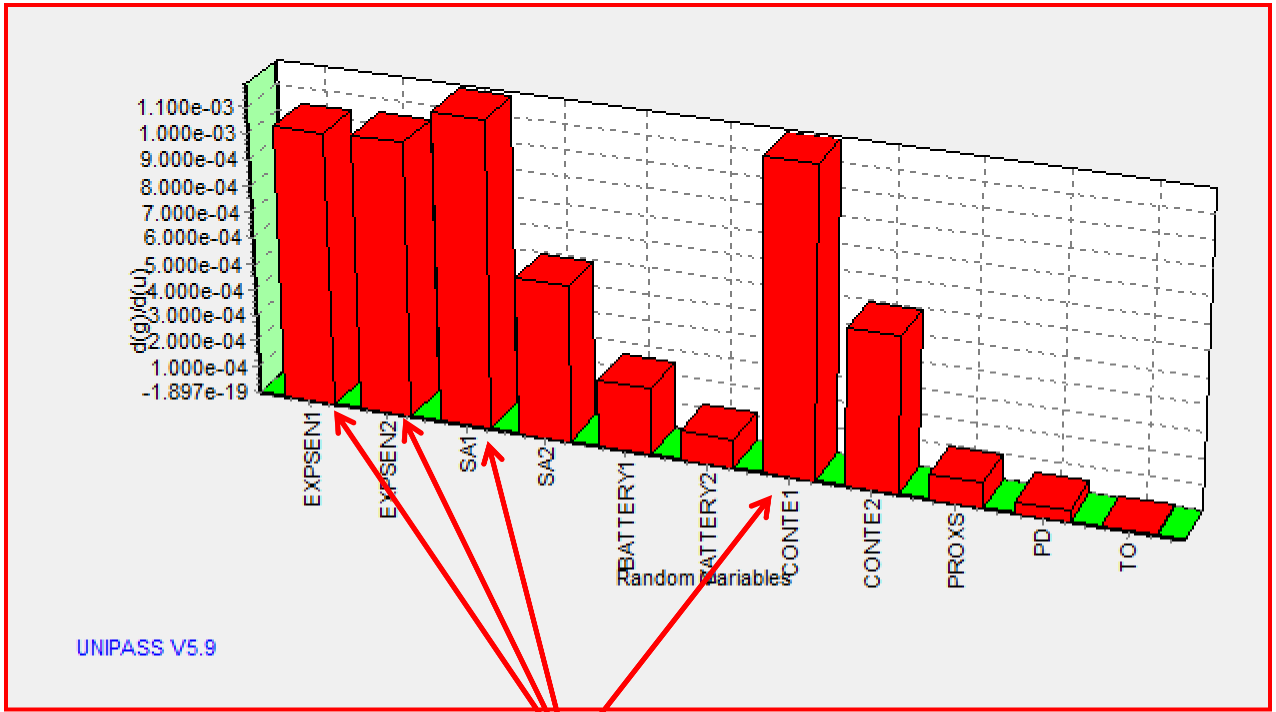
Variable Name	Output Description	Robust Mean Reliability
ExpSen1	Expulsion Sensor 1	0.92397
ExpSen2	Expulsion Sensor 2	0.92420
SA1	S&A 1	0.99899
SA2	S&A 2	0.91999
Bat1	Battery 1	0.98111
Bat2	Battery 2	0.98312
ContE1	Control Electronics 1	0.95874
ContE2	Control Electronics 2	0.99499
ProxS	Proximity Sensor	0.96954
PD	Point Detonation (PD)	0.91559
TO	Time out (TO)	0.49891

Distribution Statement A. Approved for public release; distribution is unlimited.

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Subsystem Sensitivity
– Baseline Approach

Fuze System Reliability Allocation = 0.9901



Four components that have greatest effect on the Fuze reliability (sensitivity)

Distribution Statement A. Approved for public release; distribution is unlimited.

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Alternate Approach 1: Same as the Baseline except that both S&A's are identical.

Constraints for Robust Allocation

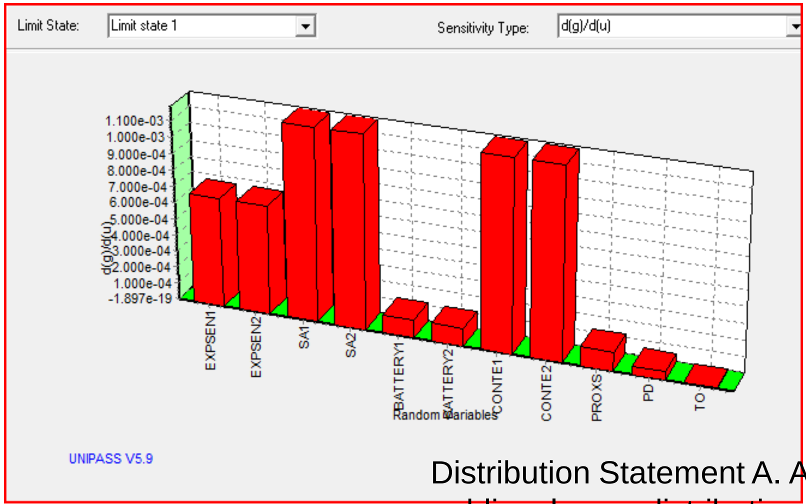
Design Variable Name	Input Description	Lower Bound	Upper Bound
ES1_range	Range of Mean Reliability of Expulsion Sensor 1	0.85	0.97
ES2_range	Range of Mean Reliability of Expulsion Sensor 2	0.85	0.97
SA1_range	Range of Mean Reliability of S&A 1	0.85	0.92
SA2_range	Range of Mean Reliability of S&A 2	0.85	0.92
Bat1_range	Range of Mean Reliability of Battery 1	0.9	0.992
Bat2_range	Range of Mean Reliability of Battery 2	0.9	0.992
CONE1_range	Range of Mean Reliability of Control Electronics 1	0.9	0.995
CONE2_range	Range of Mean Reliability of Control Electronics 2	0.9	0.995
PS_range	Range of Mean Reliability of Prox Sensor mode	0.85	0.97
PD_range	Range of Mean Reliability of Point Detonation mode	0.85	0.92
TO_range	Range of Mean Reliability of Time Out mode (i.e. control electronics survive impact)	0.4	0.5

Fuze System Reliability Allocation = 0.9901

SA1 reliability range input changed

Robust Design Point (Output)

Variable Name	Description	Robust Mean Reliability
ExpSen1	Expulsion Sensor 1	0.95121
ExpSen2	Expulsion Sensor 2	0.95123
SA1	S&A 1	0.92000
SA2	S&A 2	0.92000
Bat1	Battery 1	0.99198
Bat2	Battery 2	0.99200
ContE1	Control Electronics 1	0.99500
ContE2	Control Electronics 2	0.99500
ProxS	Proximity Sensor	0.96995
PD	Point Detonation (PD)	0.91997
TO	Time out (TO)	0.49304



Observation

Architecture: Use 2 S&A 2's instead of S&A1 and S&A2.

Output:
Critical components are operating at the upper-end reliability range.

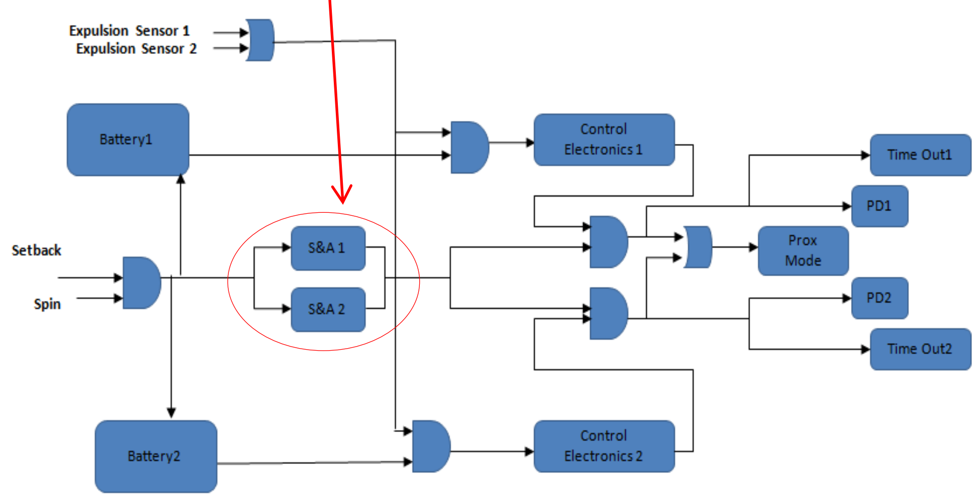
Distribution Statement A. Approved for public release; distribution is unlimited.

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

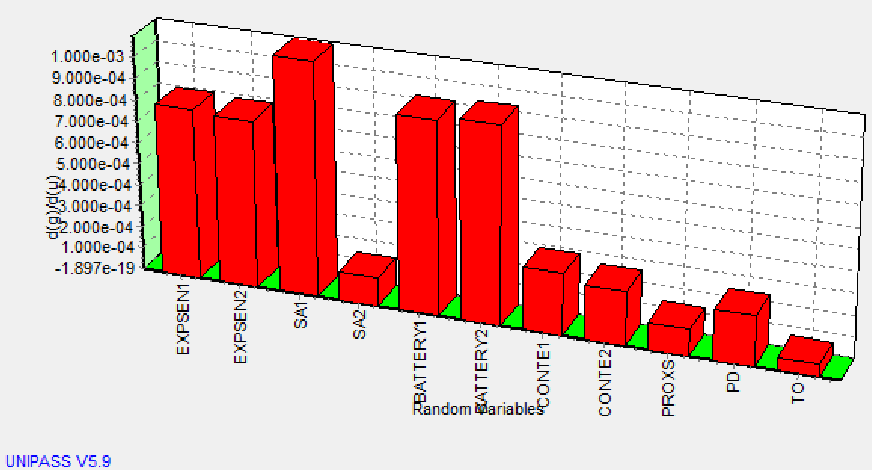
Alternate Approach 2 : Same as the Baseline except S&A's Redundant Architecture Change

Robust Design Point (Output)

Architecture change -- crossover initiation architecture



Variable Name	Description	Robust Mean Reliability
ExpSen1	Expulsion Sensor 1	0.94291
ExpSen2	Expulsion Sensor 2	0.94242
SA1	S&A 1	0.99007
SA2	S&A 2	0.92000
Bat1	Battery 1	0.93268
Bat2	Battery 2	0.93414
ContE1	Control Electronics 1	0.99474
ContE2	Control Electronics 2	0.99233
ProxS	Proximity Sensor	0.85055
PD	Point Detonation (PD)	0.85038
TO	Time out (TO)	0.40000



Observation

Architecture: Improve robustness, both S&A's could be functioned by either path of Control Electronics.

Output:

Reliability mean of the most critical component lower.

Distribution Statement A. Approved for public release; distribution is unlimited.

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Fuze Sub-assembly Verification & Validation

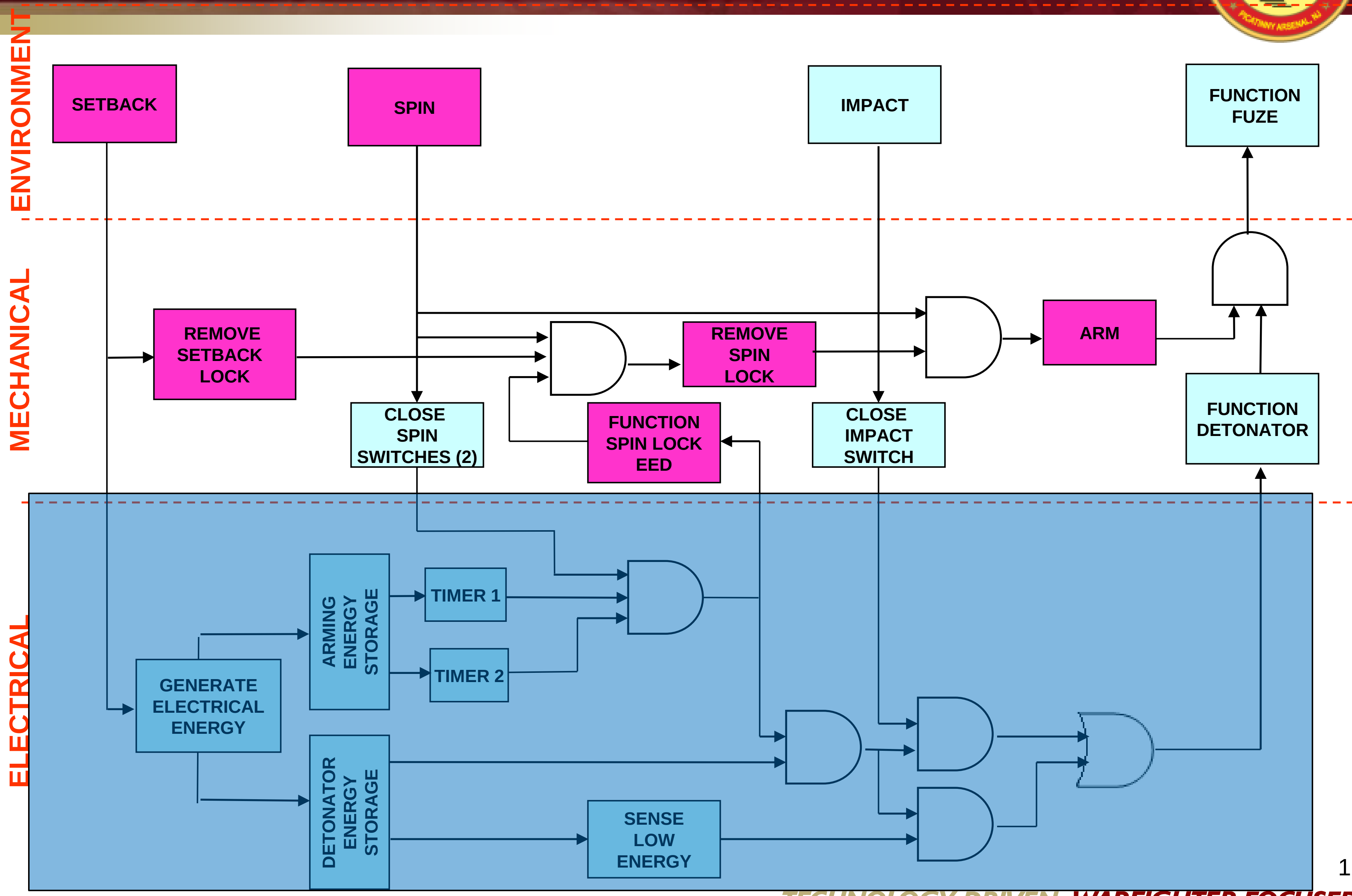
- Control Electronics - Continued effort
  - ➢ Reduce part count trade studies
  - ➢ Component trade studies
  - ➢ Architecture trade studies

- MEMS S&A (S&A2) - Command Arm S&A (in progress)
  - ➢ Setback lock Analysis --- The result of PT simulation has indicated that the removal of setback lock under gun launch is very reliable.
  - ➢ Spin lock Analysis
    - Slider Assembly Analysis --- The result of PT simulation has indicated that the slider moves (due to spin environment) to align the explosive train is very reliable.
    - Remove the Spinlock --- Estimated to have .995 reliability by the time the item is qualified.

Distribution Statement A. Approved for public release; distribution is unlimited.

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

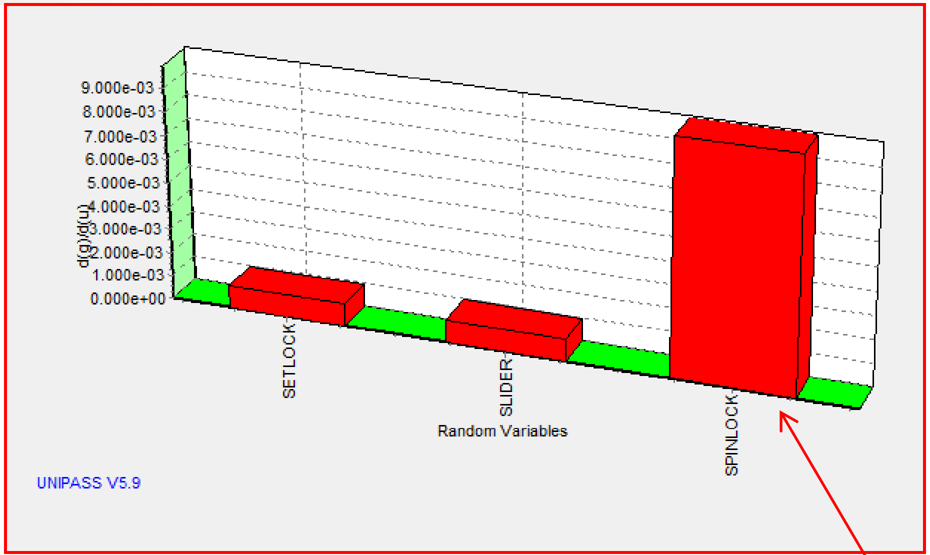
MEMS Fuze Block Diagram

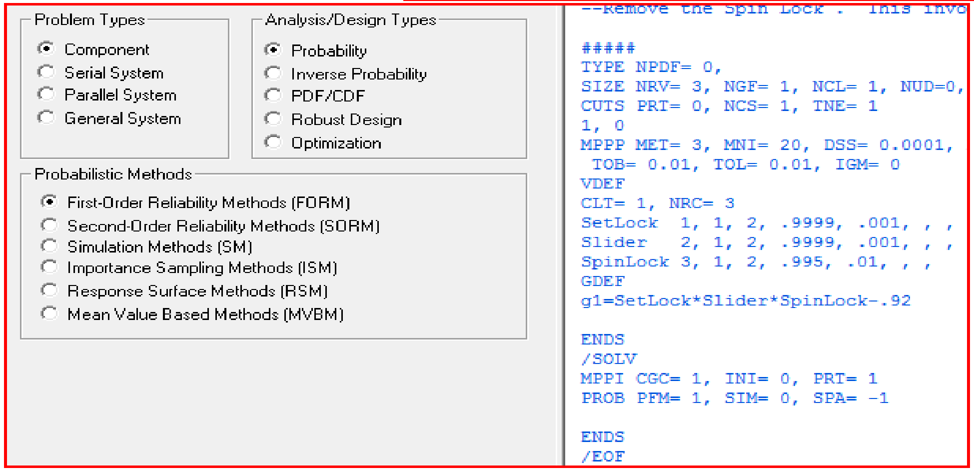


TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Distribution Statement A. Approved for public release; distribution is unlimited.

MEMS S&A Sensitivity





Most critical function

Distribution Statement A. Approved for public release; distribution is unlimited.

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Summary

Why Use Probabilistic Technology?

- **PT can be used to evaluate and predict fuze reliability even with limited data.**
- **PT can be used for Design or Analysis, and could be applied throughout all phases of the project.**
- **PT is physics based process that systematically evaluates the impact of uncertainties.**
- **The output of the PT process provides 3 key metrics to quantitatively evaluate design performance**
    - **Probability Information**
    - **Sensitivity**
    - **Most Probable Point**

Distribution Statement A. Approved for public release; distribution is unlimited.