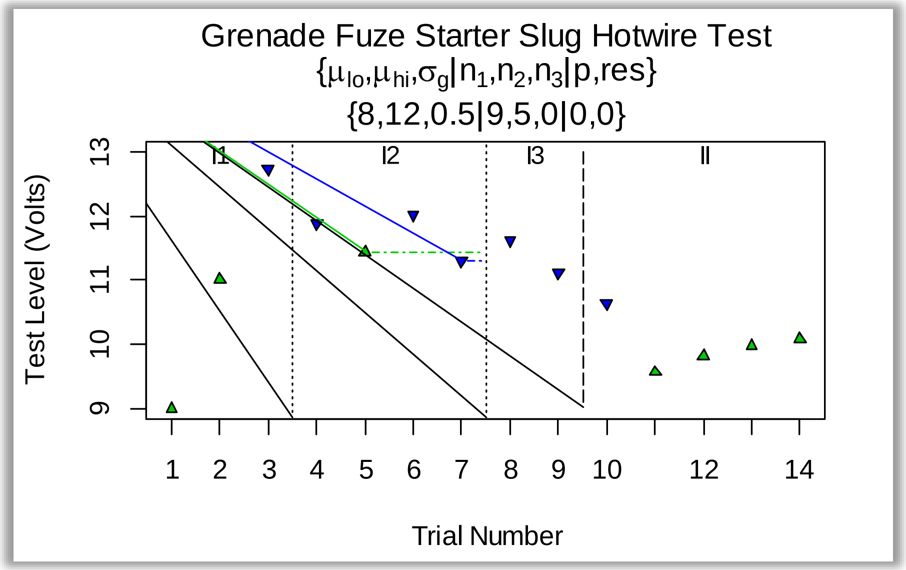
US ARMY RDECOM

M201A1 Grenade Fuze Starter Slug Hotwire Sensitivity Test



Test Objective:

- Determine all-fire and no-fire thresholds from a precise model for P[initiation] vs Voltage
- Results will feed into future testing at an ammunition depot to validate test results in varying conditions (noise factors)
- Use results to develop Lot Acceptance Test procedure for Starter Slugs
- Test constraints – logistical difficulties associated with fully sequential test approach

DOE Approach:

- 3podm adaptive sensitivity test algorithm (Wu, in publication) Phase I, with a few additional sequential points in Phase II
- Binary Logistic Regression used to analyze this data and develop a Bayesian D-optimal experiment with points split evenly between 2 levels
- Binary Logistic Regression used to model sensitivity data

Results:

- Developed precise sensitivity model by targeting location of points optimally in design space - maximized information
- Minimized logistical burden of large-sample sequential test, maximizing test efficiency and test flexibility

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Hotwire Sequential Test Strategy: Part 1 – 3podm Ph I&II

```
>source("3podMxxx.R")
> z=w
> w=ntripod(8,12,.5)
```

This program executes the 3podm sensitivity test procedure as described in:
1. Wu, C. F. J, and Tian, Y. (2014), Three-phase optimal design of sensitivity experiments Journal of Statistical Planning and Inference 149, 1-15
2. Wang, D. P., Tian, Y. B., and Wu, C. F. J. (2015), Comprehensive comparisons of major procedures for sensitivity testing, (Preprint)

Questions about the code or implementation of the procedure may be directed to:
Paul Roediger, UTRS, Inc. <paul.a.roediger.ctr@mail.mil>, and
Douglas Ray, US Army ARDEC, Picatinny Arsenal <douglas.m.ray.civ@mail.mil>

Enter title (without quotes): Grenade Fuze Starter Slug Hotwire Test
Enter units (without quotes): Volts

1. Test at X ~ 9. Enter X & R: 9 0
2. Test at X ~ 11. Enter X & R: 11 0
3. Test at X ~ 12.75. Enter X & R: 12.75 1
4. Test at X ~ 11.875. Enter X & R: 11.88 1
5. Test at X ~ 11.44. Enter X & R: 11.44 0
6. Test at X ~ 12.03. Enter X & R: 12.03 1
7. Test at X ~ 11.29. Enter X & R: 11.30 1
8. Test at X ~ 11.62. Enter X & R: 11.62 1
9. Test at X ~ 11.12. Enter X & R: 11.12 1

Phase I complete, (Mu, Sig) = (11.16113, 0.41151).
Enter Phase II (D-Optimal) size n2: 5

10. Test at X ~ 10.63111. Enter X & R: 10.64 1
11. Test at X ~ 9.55813. Enter X & R: 9.56 0
12. Test at X ~ 9.80468. Enter X & R: 9.81 0
13. Test at X ~ 9.96771. Enter X & R: 9.97 0
14. Test at X ~ 10.08861. Enter X & R: 10.09 0

3podm:

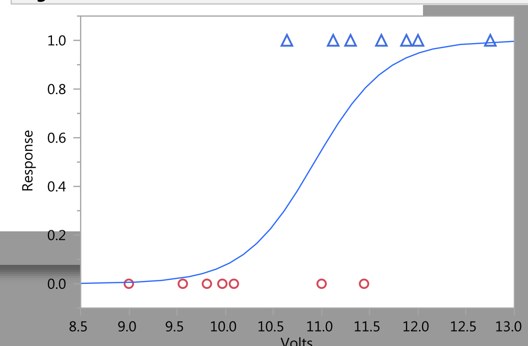
Ph I: 9 shots – *binary search/overlap*

Ph II: 5 Shots – *balance and characterize*

Generalized Linear Model Fit

Response: Response
Distribution: Binomial
Link: Logit
Estimation Method: Maximum Likelihood
Observations (or Sum Wgts) = 14

Regression Plot



Whole Model Test

Model	-LogLikelihood	L-R ChiSquare	DF	Prob>ChiSq
Difference	4.83997964	9.6800	1	0.0019 *
Full	4.86408089			
Reduced	9.70406053			

Goodness Of Fit Statistic	ChiSquare	DF	Prob>ChiSq
Pearson	8.8806	12	0.7131
Deviance	9.7282	12	0.6398

AICc
14.8191

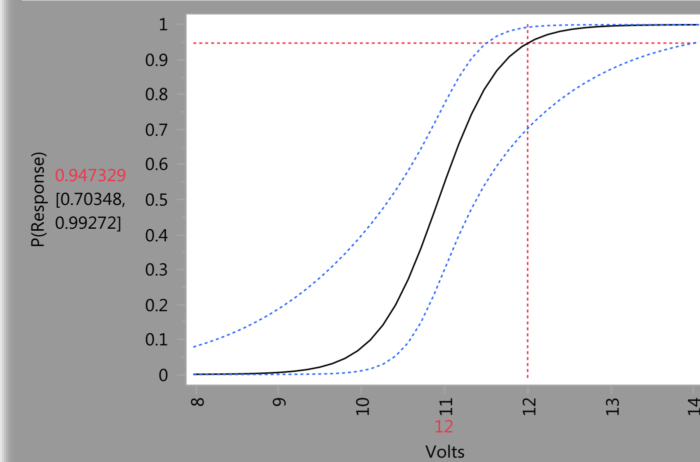
Effect Tests

Source	DF	L-R ChiSquare	Prob>ChiSq
Volts	1	9.6799593	0.0019 *

Parameter Estimates

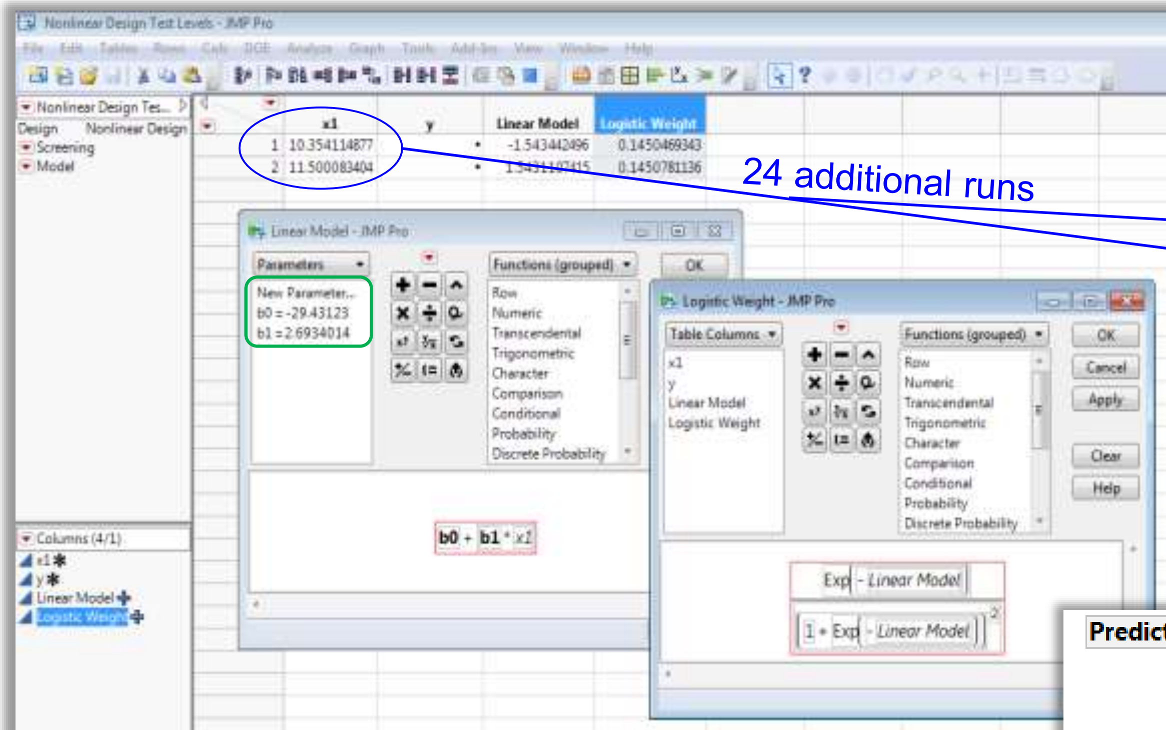
Term	Estimate	Std Error	L-R ChiSquare	Prob>ChiSq	Lower CL	Upper CL
Intercept	-29.43123	15.25016	9.6146014	0.0019 *	-55.25121	-13.9808
Volts	2.6934014	1.3820949	9.6799593	0.0019 *	1.2869091	5.0238558

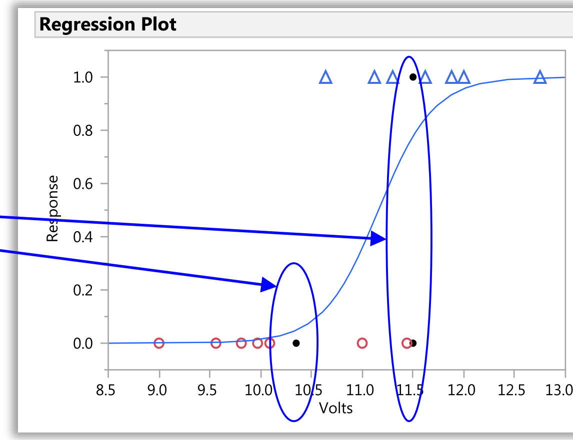
Prediction Profiler

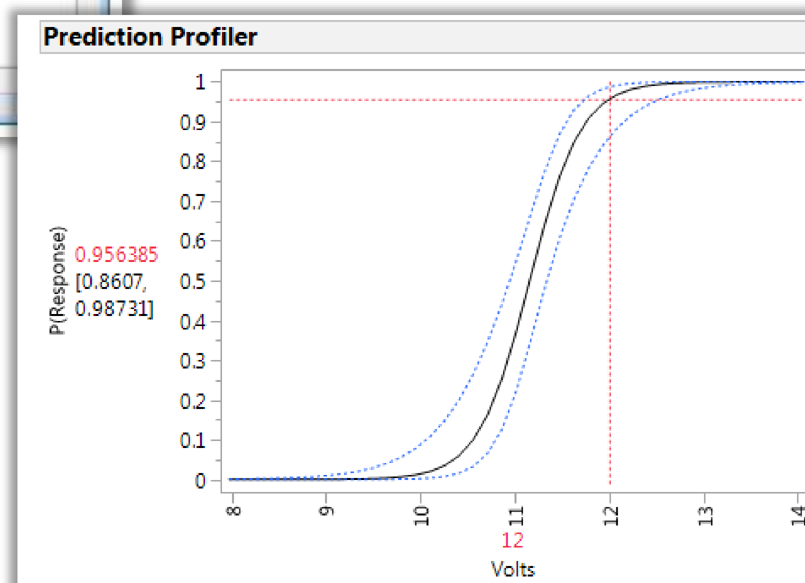


- **Resources:**
  - **'*R*' 3podm program**

Hotwire Sequential Test Strategy: Part 2 – Bayesian D-optimal Design

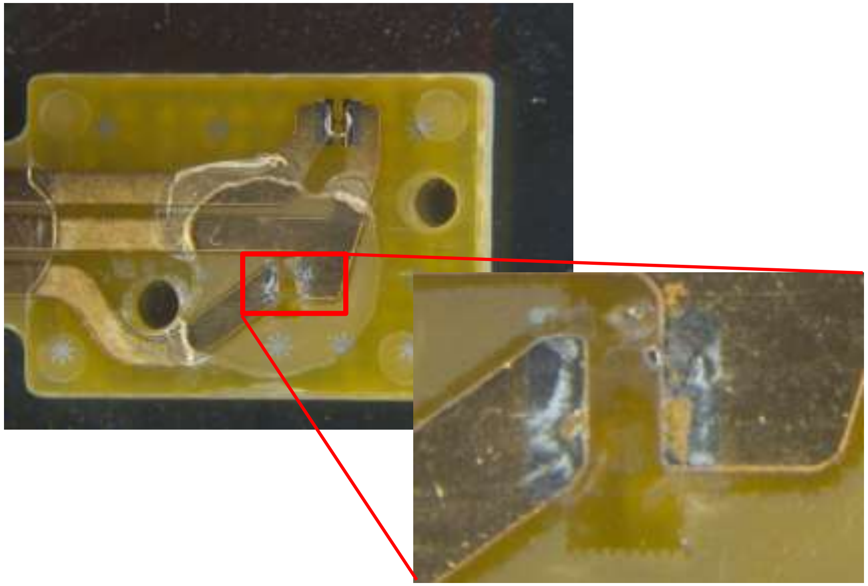






- **Resources:**
  - **JMP Nonlinear Design Platform**
  - ***Fast Computation of Designs Robust to Parameter Uncertainty for Nonlinear Settings*, C. Gotwalt, B. Jones, D. Steinberg, Technometrics 2009**
  - ***Generalized Linear Models 2nd ed*, 2010, R. Myers, D. Montgomery, G. Vining, T. Robinson, Chapter 8**

MEMS Fuze Bridgewire Design Down-select



Test Objective:

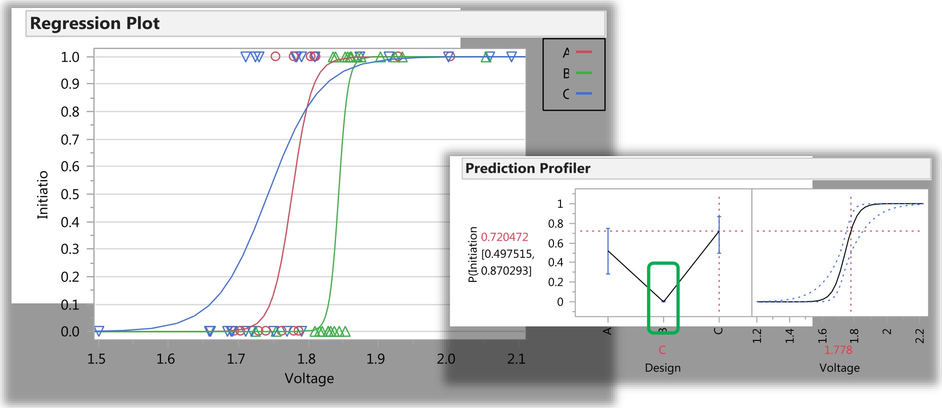
- To characterize initiation reliability of several candidate bridgewire designs across a range of input voltages
- To downselect optimal performing bridgewire configuration to exceed fuze reliability and safety standards

DOE Approach:

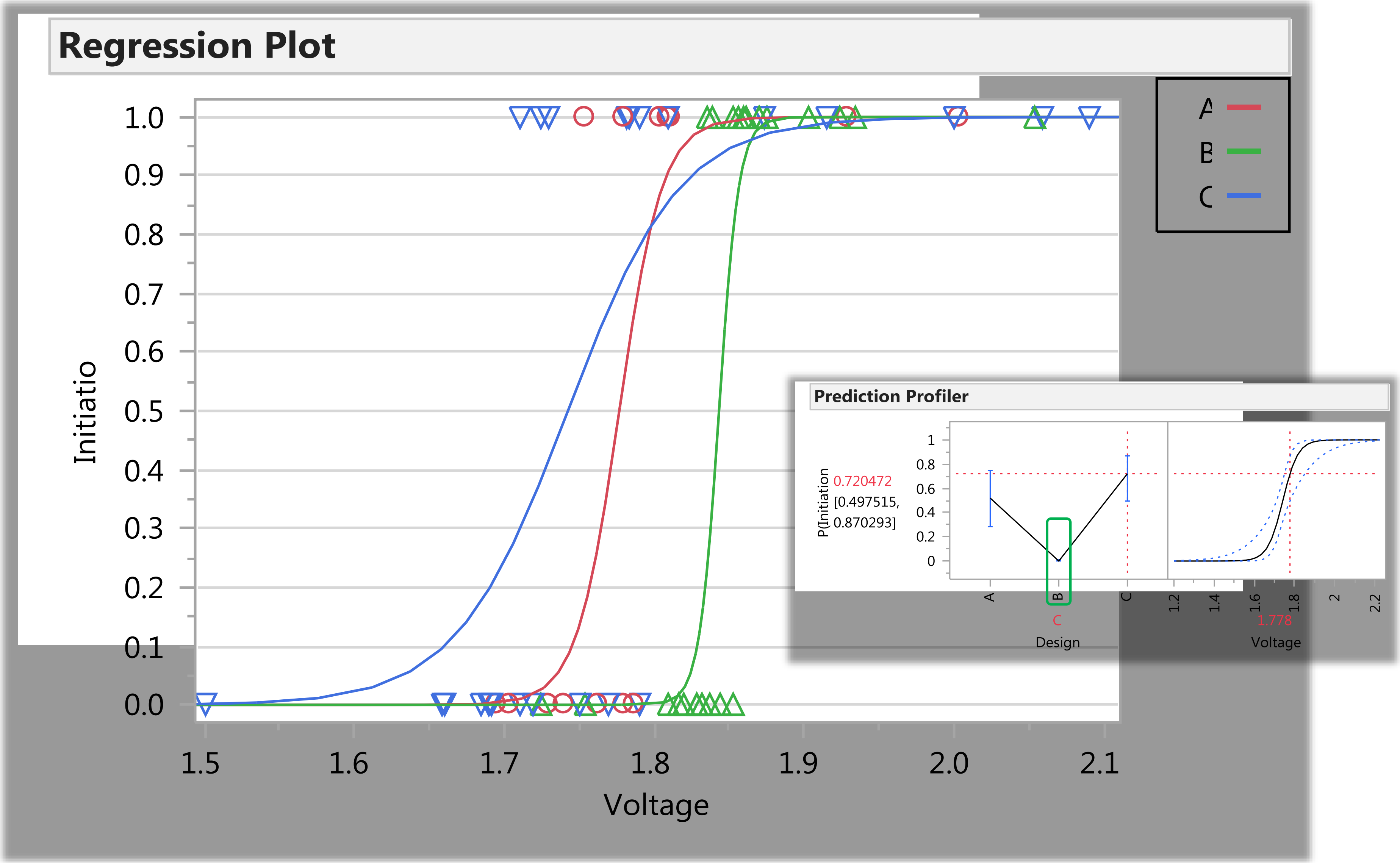
- 3pod adaptive sensitivity test algorithm (Wu, Tian 2014) used to maximize information obtained in testing with limited hardware for each design
- Binary Logistic Regression used to analyze the sensitivity and determine accurate 90% CI's for initiation reliability

Results:

- Identified and characterized best performing design while minimizing test quantities



Sensitivity Test & Analysis: Design Comparison



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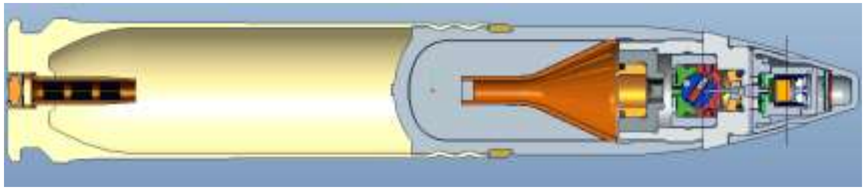
30mm Proximity Fuze Root Cause Analysis Sensitivity Test



Test Objective:

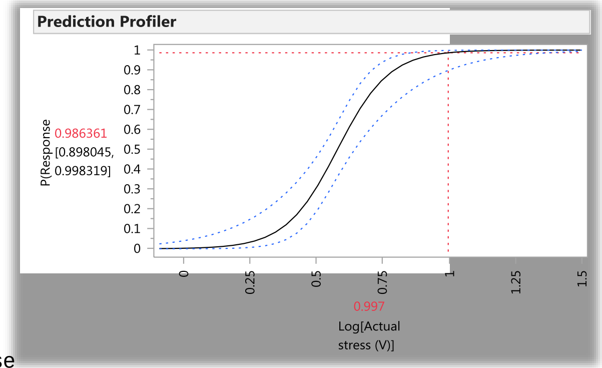
- To characterize initiation reliability of the 30mm fuze proximity sensor across a range of input voltages
- To optimize air-burst capability and reliability

DOE Approach:

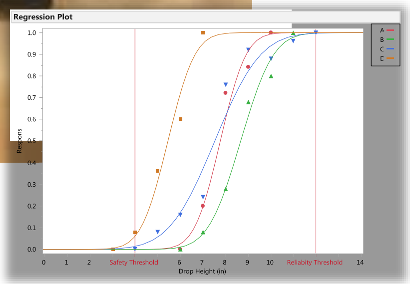
- 3pod adaptive sensitivity test algorithm (Wu, Tian 2014) used to maximize information obtained in testing with limited hardware for each design
- Binary Logistic Regression with log transformed voltage used to analyze the sensitivity and determine accurate 90% CI's for initiation reliability

Results:

- Characterized fuze prox sensor sensitivity, while reducing sample size by 60%, saving hardware and test time



5.56mm M1037 Ammo ‘Green’ Primer Design Optimization



Test Objective:

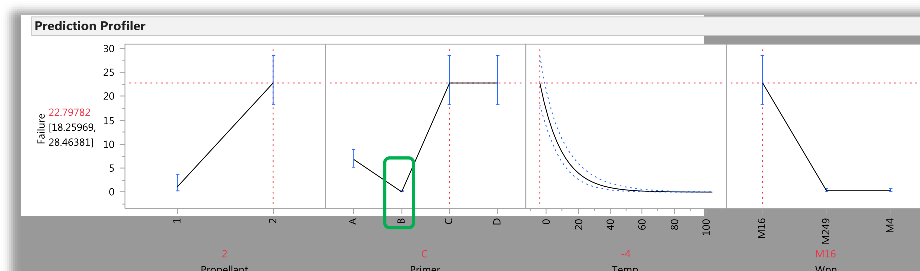
- To eliminate exposure of warfighter to lead styphnate in close-quarters training
- To downselect optimal performing primer configuration
- To ensure robustness in a variety of weapons, temperatures and usage conditions

DOE Approach:

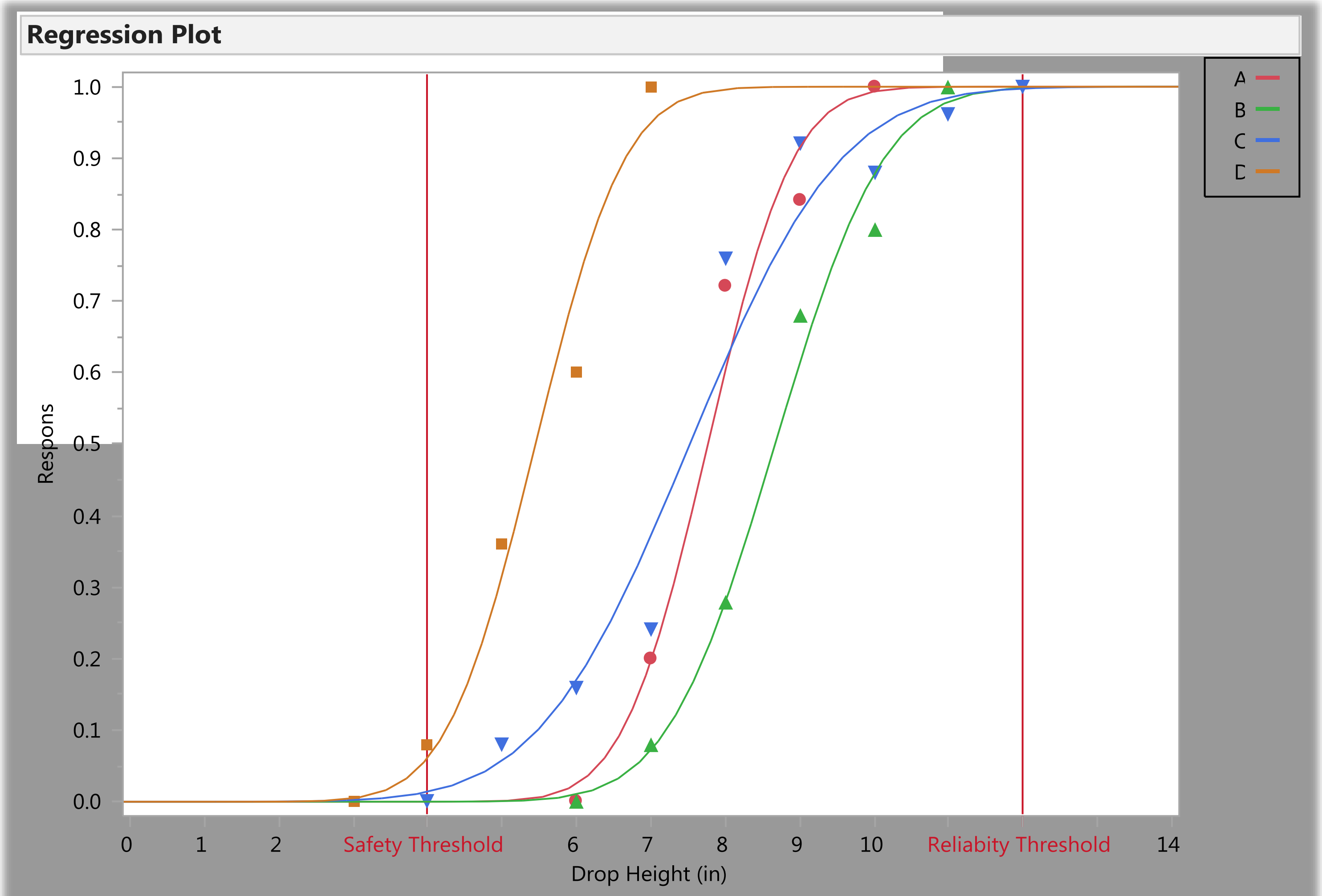
- In 3 separate experiments, used full factorial approach:
  - Analyzed F&C test using GLM - Negative Binomial Regression
  - Analyzed primer sensitivity using GLM - Probit Regression
  - Analyzed EPVAT (Pressure and Velocity) and Dispersion data using Loglinear Variance

Results:

- For F&C 1 primer configuration stood out as best
- For other tests, primers configurations performed similarly

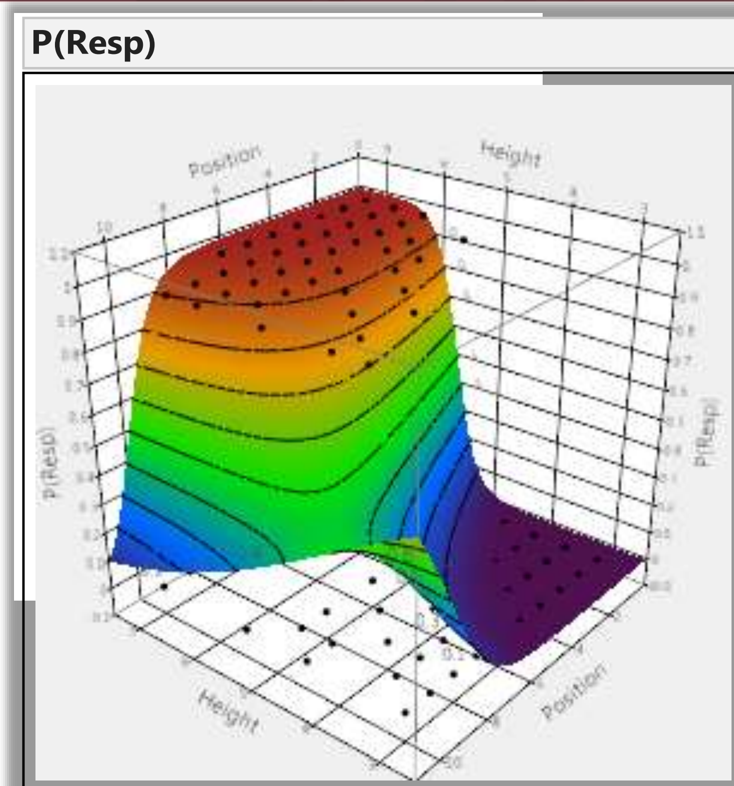


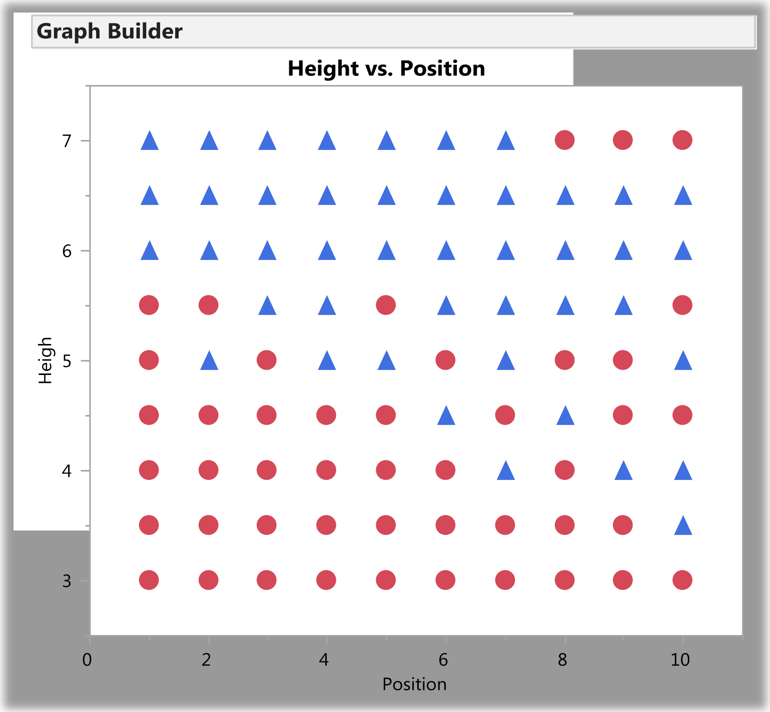
Sensitivity Test & Analysis: Design Down-selection

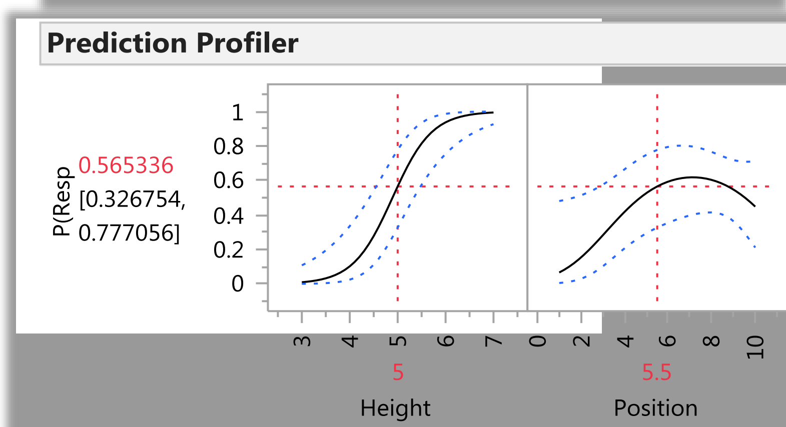


Towed Artillery Primer Exploratory Study

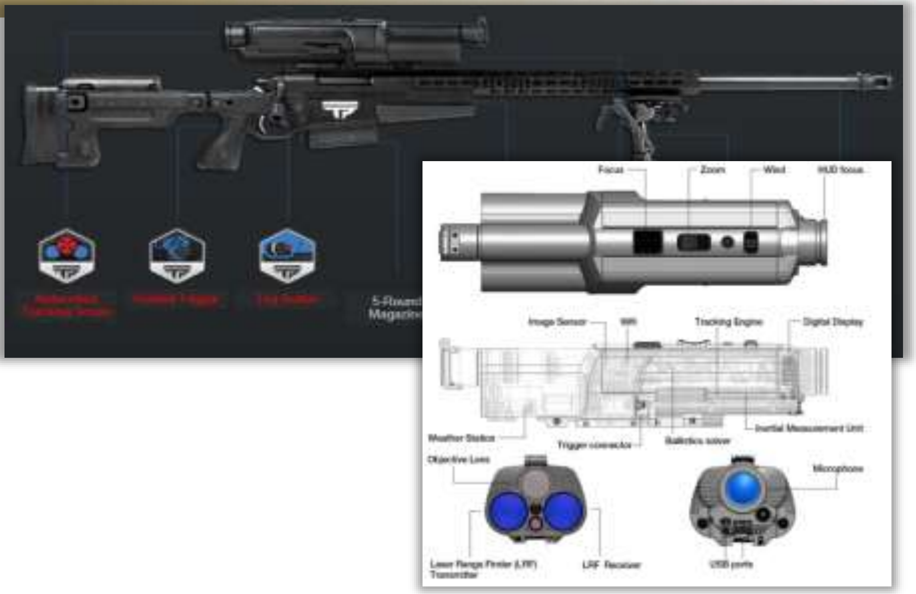
- Towed Artillery Primer shock loading
- Multifactor exploratory sensitivity testing
- Factor-covering array approach







Precision Guided Firearms (PGF) User Performance Test



Objective:

- Characterize impact and operational suitability of integrating a precision fire control package to a sniper rifle
- Determine if integration improves hit probability, and how
- Improve analysis results over previous systems analysts estimates by using statistically sound methodology

Approach:

- Generalized Linear Models approach used with Log-transformed range vs. P[Hit]
- Re-categorized sniper teams into proficiency levels from untrained shooters to trained special-operations snipers

Effect Tests

Source	DF	L-R ChiSquare	Prob>ChiSq
Sniper Proficiency	2	25.977093	<.0001 *
Type_sight	2	44.532558	<.0001 *
Lane_Num	2	10.245571	0.0060 *
Log[Actual Range]	1	221.07464	<.0001 *
Type_sight*Log[Actual Range	2	25.535636	<.0001 *

Results:

- Discovered key interactions between type of sight and both target range, and user proficiency
- Integration of PGF was found to improve P[Hit]