ROBUST OPTIMIZATION AND SELECTION FOR UNDERSEA WARHEAD DESIGN

CECD — CENTER FOR ENERGETIC CONCEPTS DEVELOPMENT

UNIVERSITY OF MARYLAND 1856

NAVSEA INDIAN HEAD — Surface Warfare Center Division

S. Gunawan, K. Maddulapalli, Ph.D. Students - S. Azarm, Professor, A. Boyars (NSWC-IH), Engineer

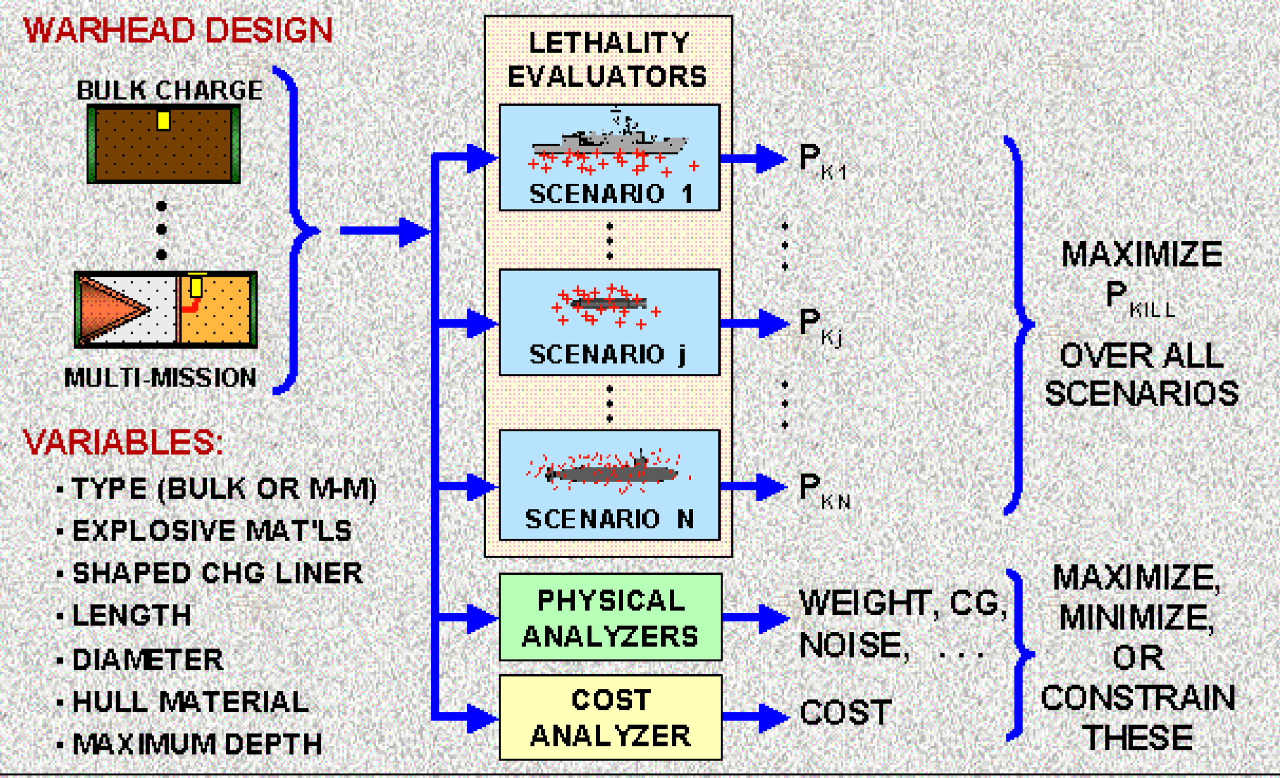
Overview

- **OBJECTIVE:** TO GET THE "BEST" DESIGN THAT CAN ABSORB VARIABILITY IN UNCONTROLLABLE PARAMETERS
- WE HAVE ADOPTED A TWO-STEP APPROACH ("FRAMEWORK")
  - OPTIMIZATION -- OBTAINING ROBUST PARETO DESIGN SOLUTIONS WHICH MAXIMIZE PROBABILITY OF KILL, P_K, IN ALL SCENARIOS WHILE ACCOUNTING FOR VARIABILITY
  - SELECTION -- FINDING "ROBUST PREFERRED DESIGN(S)"
    - PRESUMES 'DECISION MAKER' HAS AN UNEXPRESSED "VALUE FUNCTION" WITH VARIABILITY

HERE, OUR FOCUS IS ON UNDERSEA WARHEAD DESIGN (CONCEPT-LEVEL), BUT OUR METHODS ARE GENERAL.

1

Undersea Warhead Design



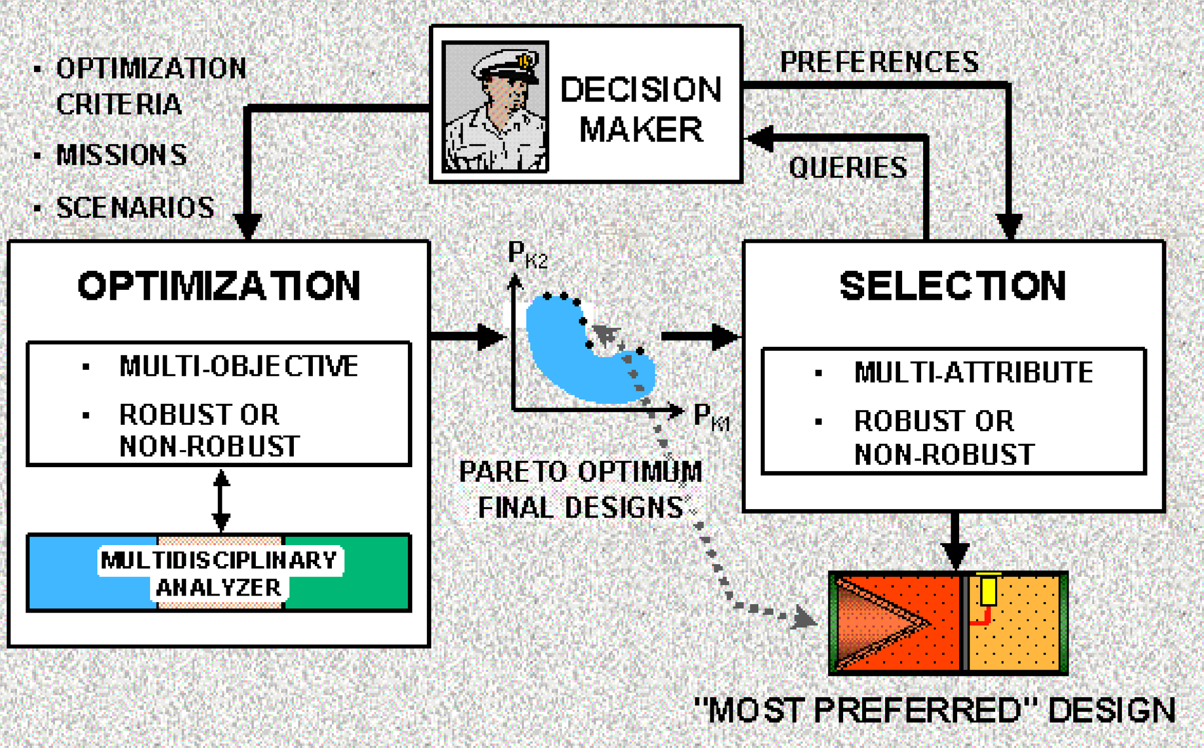
2

Current Investigations

- ROBUST OPTIMIZATION
  - VARIABILITY COMES FROM UNCERTAINTY IN EVALUATION OF OBJECTIVES (WE FOCUS ON P_K's)
  - UNCERTAINTY GROWS FOR PROJECTIONS OF FUTURE CAPABILITIES OR THREATS
- ROBUST SELECTION
  - VARIABILITY COMES FROM:
    - INCOMPLETE INFORMATION AVAILABLE TO DECISION MAKER
    - DECISION MAKER'S INHERENT UNCERTAINTY

3

Framework



4

Robust Optimization

OPTIMIZATION PROBLEM WITH ROBUSTNESS CONSTRAINT

$$\begin{aligned} &\underset{x}{\text{minimize}} \quad \boldsymbol{f}(\mathbf{x},\mathbf{p}) = [f_1,\ldots,f_M] \\ &\text{subject to}: g_j(\mathbf{x},\mathbf{p}) \le 0 \;,\; j = 1,\ldots,J \\ &\text{subject to}: \eta_0 - \left(\frac{\overline{R}(\Delta\mathbf{p}^*)}{\overline{R}_E^0}\right) \le 0 \end{aligned}$$

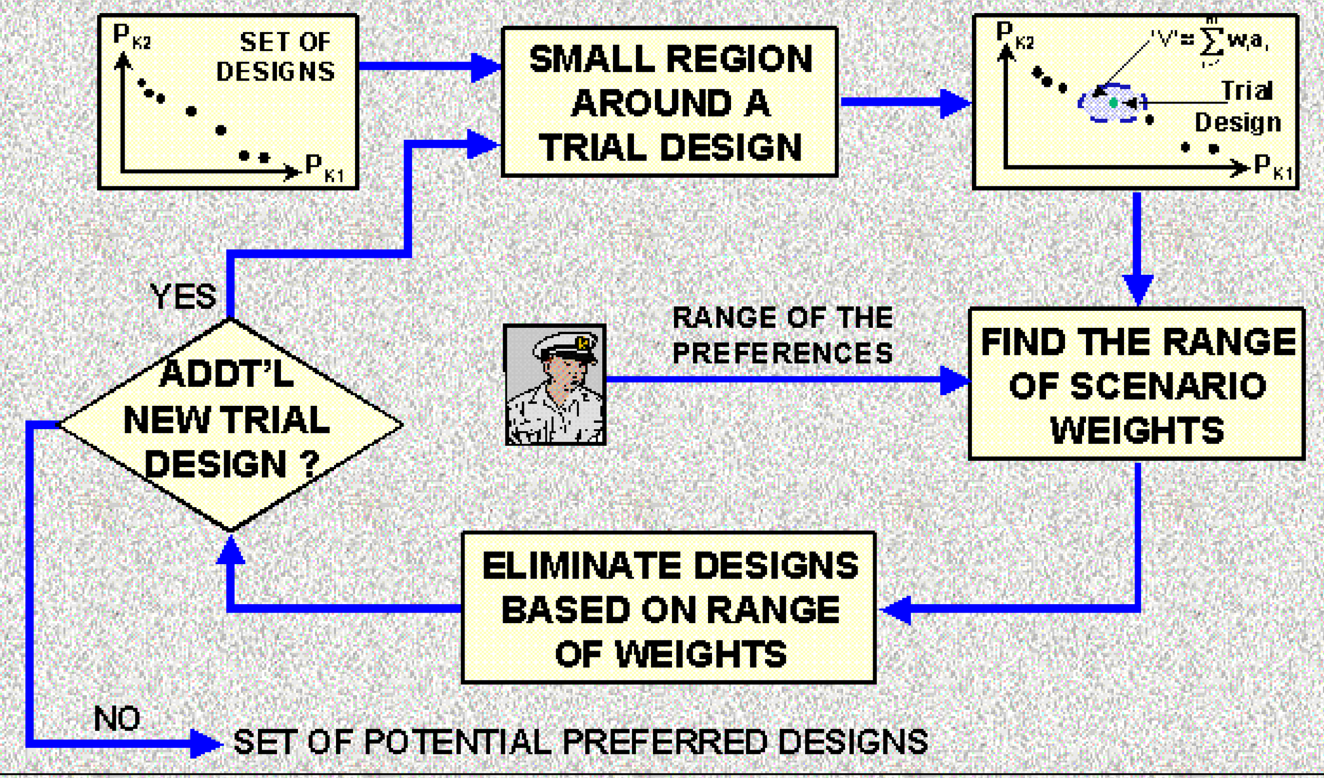
x^* ↓ ↑ $\Delta\mathbf{p}^*$

CALCULATING ROBUSTNESS CONSTRAINT

$$\begin{aligned} &\underset{\Delta\mathbf{p}}{\text{minimize}} \quad \overline{R}(\Delta\mathbf{p}) = \left[\sum_{i=1}^{P}\left(\frac{\Delta p_i}{\Delta p_i^0}\right)^2\right]^{\frac{1}{2}} \\ &\text{subject to}: \frac{\sum_{i=1}^{M}(\Delta f_i^0)^2}{\sum_{i=1}^{M}\left[f_i(\mathbf{x}^*,\mathbf{p}+\Delta\mathbf{p}) - f_i(\mathbf{x}^*,\mathbf{p})\right]^2} - 1 = 0 \end{aligned}$$

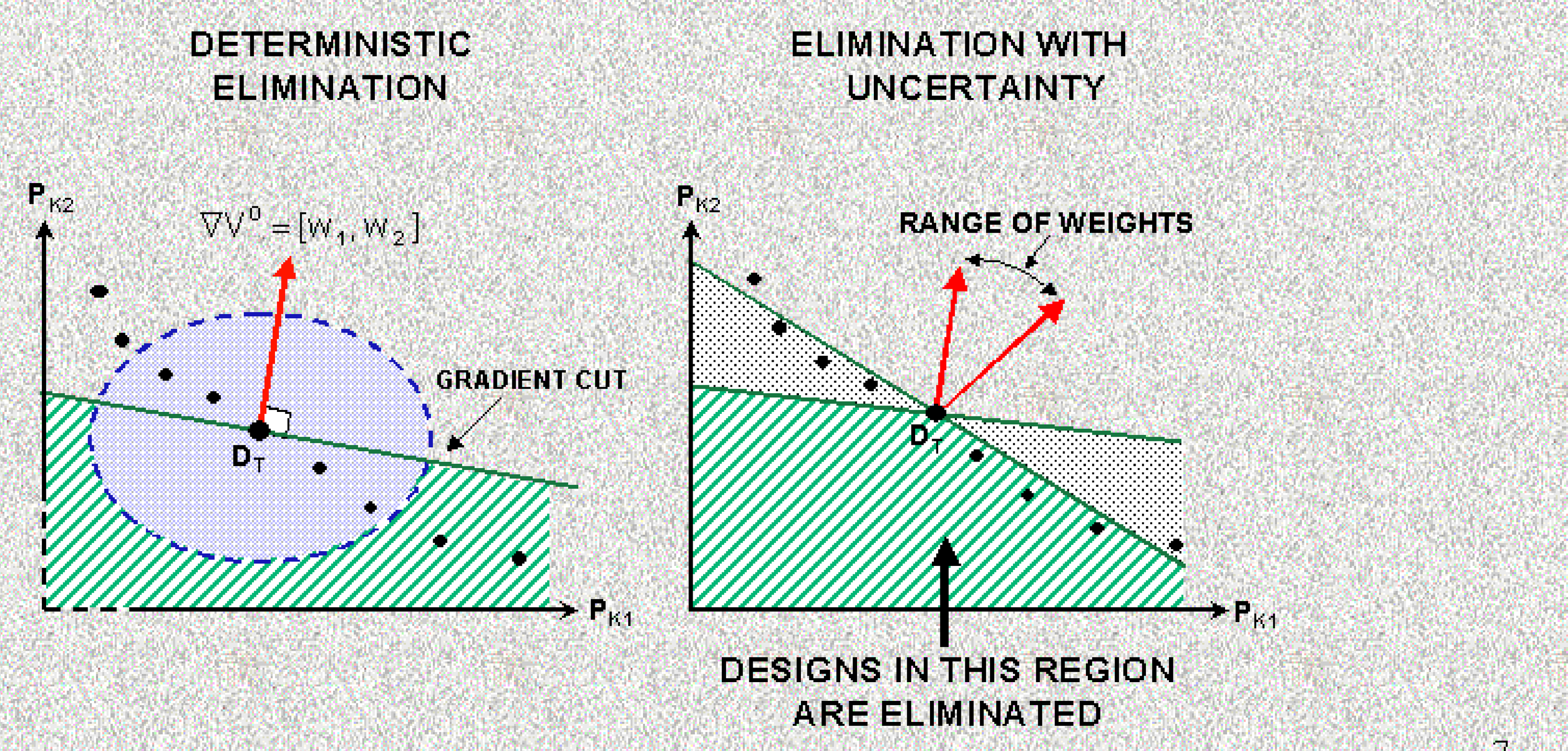
5

Robust Selection



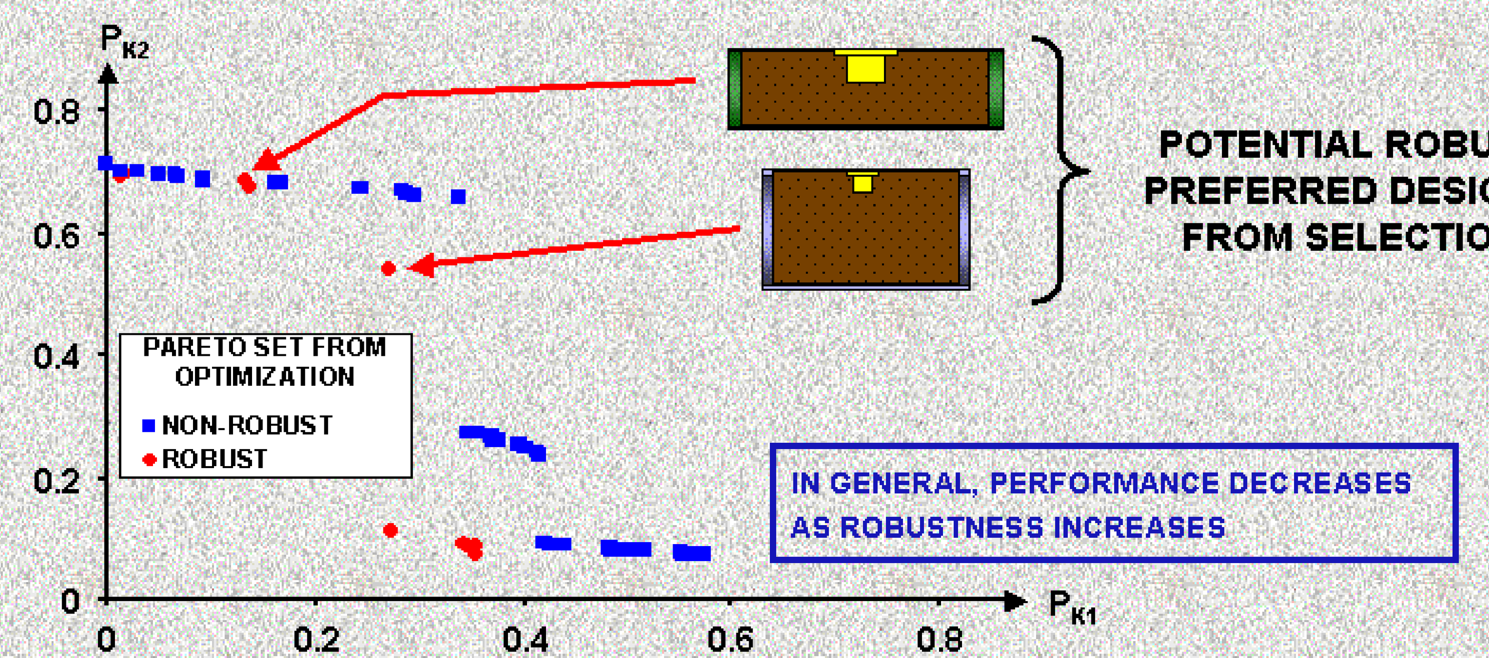
6

Elimination of Less Preferred Designs



7

Warhead Optimization and Selection



8

Summary

- OUR ROBUST OPTIMIZATION METHOD ACCOUNTS FOR VARIABILITY IN DESIGN OBJECTIVES, IS NON-GRADIENT BASED, AND DOES NOT NEED PROBABILITY DISTRIBUTION OF UNCONTROLLABLE PARAMETERS
- OUR ROBUST SELECTION METHOD ACCOUNTS FOR VARIABILITY IN DECISION MAKER'S TRADEOFF PREFERENCES, AND DOES NOT REQUIRE KNOWING THE FORM OF VALUE FUNCTION AS LONG AS IT IS QUASI-CONCAVE

9