



B-52 Radar Modernization Test Design Considerations



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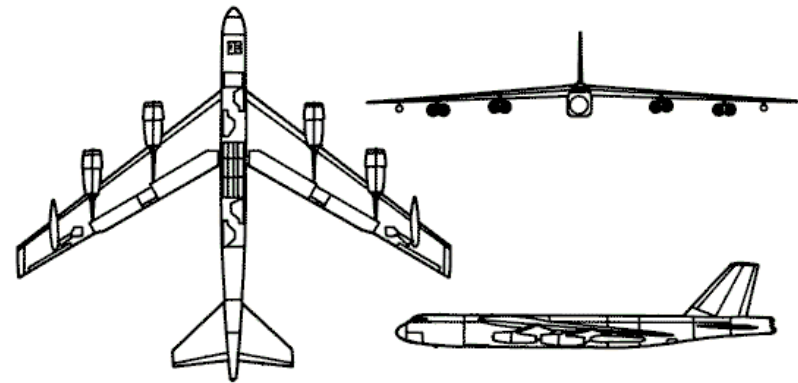
Release Date: 12 Mar 2018



Overview



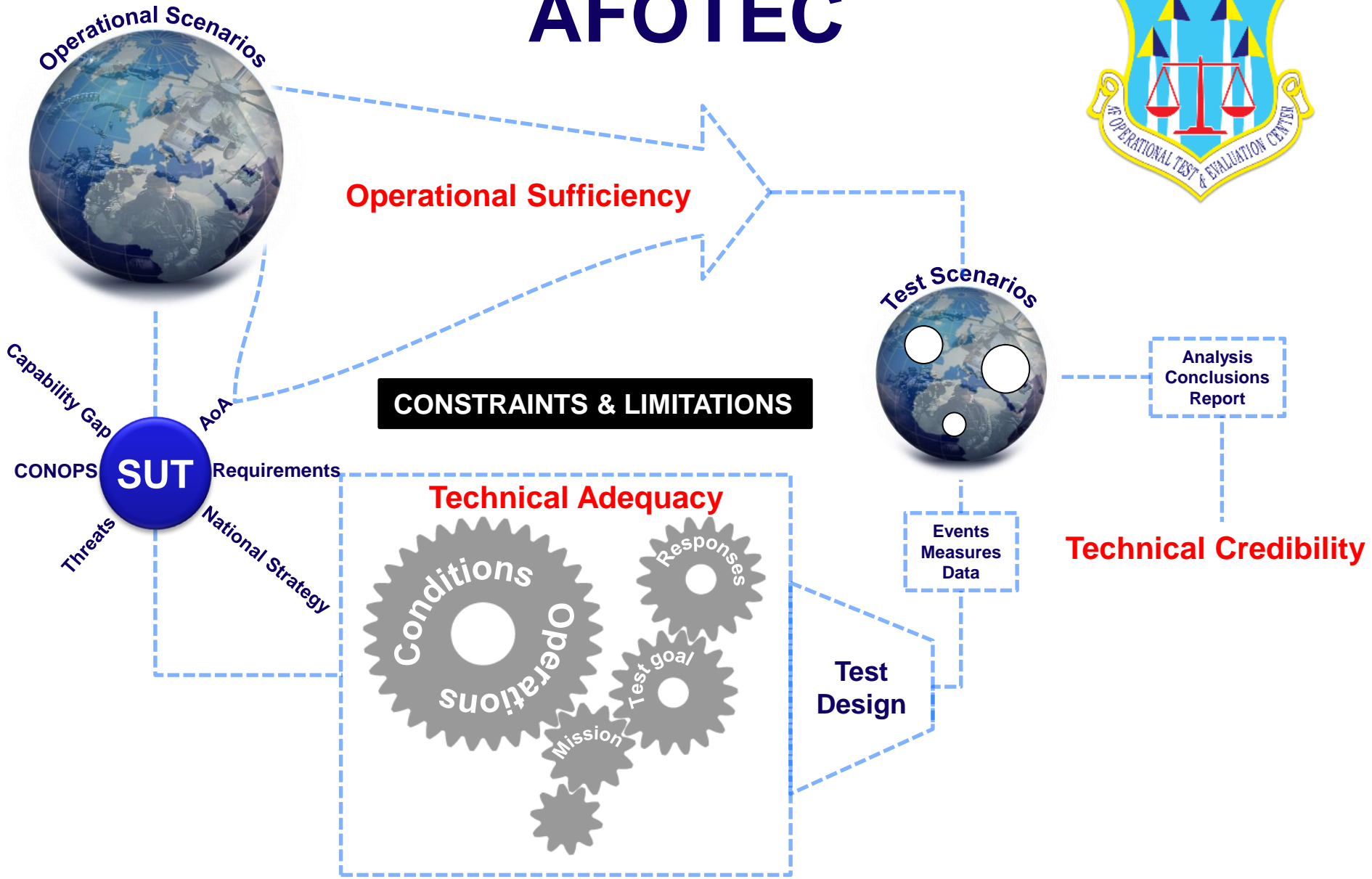
- **The B-52 Radar Modernization Program (RMP) test design is used to present tradeoffs of different design choices based on notional assumptions.***
 - **Blocking**
 - **Split Plots**
 - **Full Factorial**



- **This study presents the comparison of blocking and split-plot design options when complete randomization is not feasible in operational test**

* Factor levels are unspecified for this purpose as well

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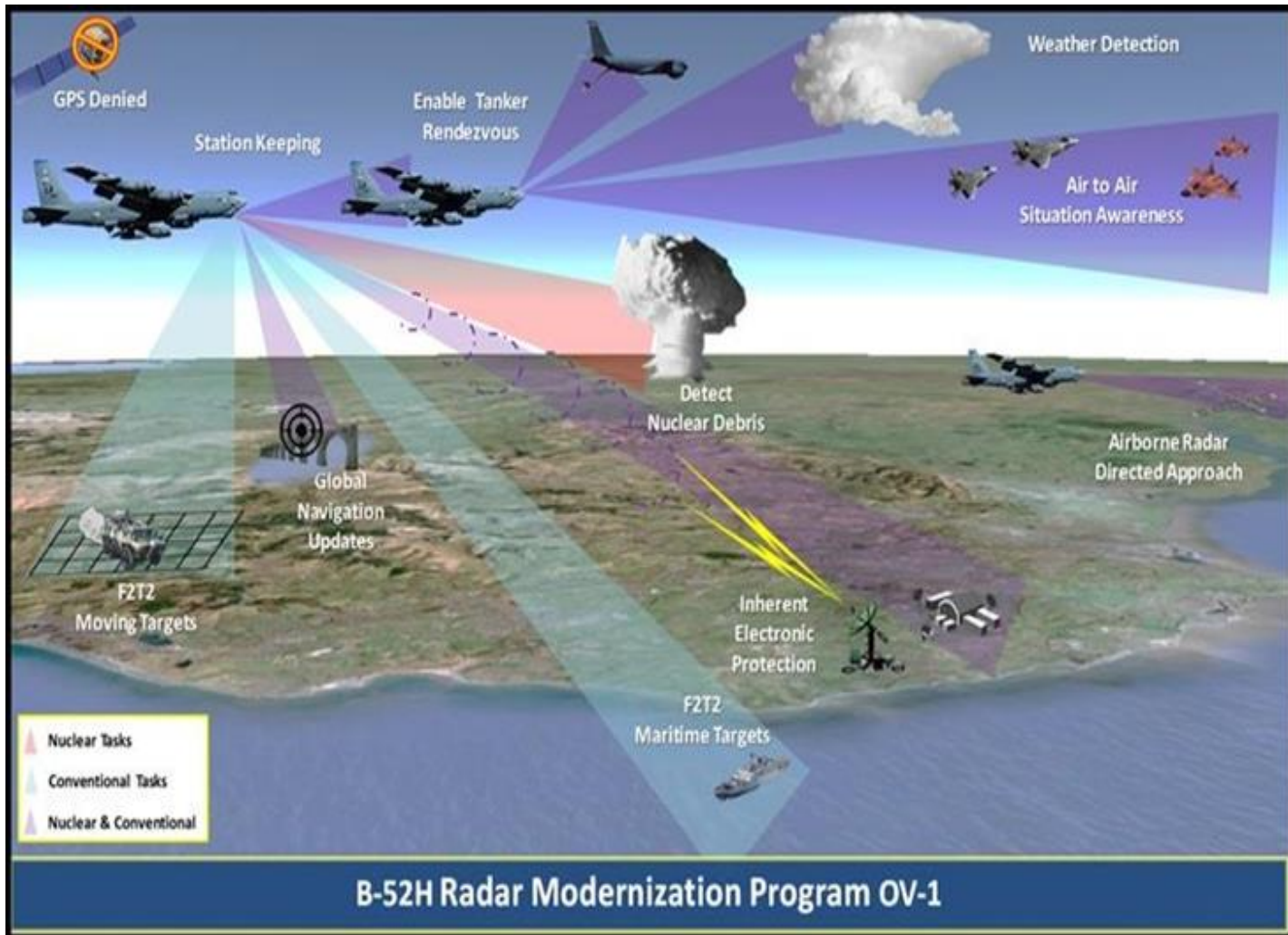
AFOTEC tests and evaluates new capabilities in operationally realistic environments to inform warfighters and influence national resource decisions



B-52 RADAR Employment



- New radar enables high quality navigation and targeting

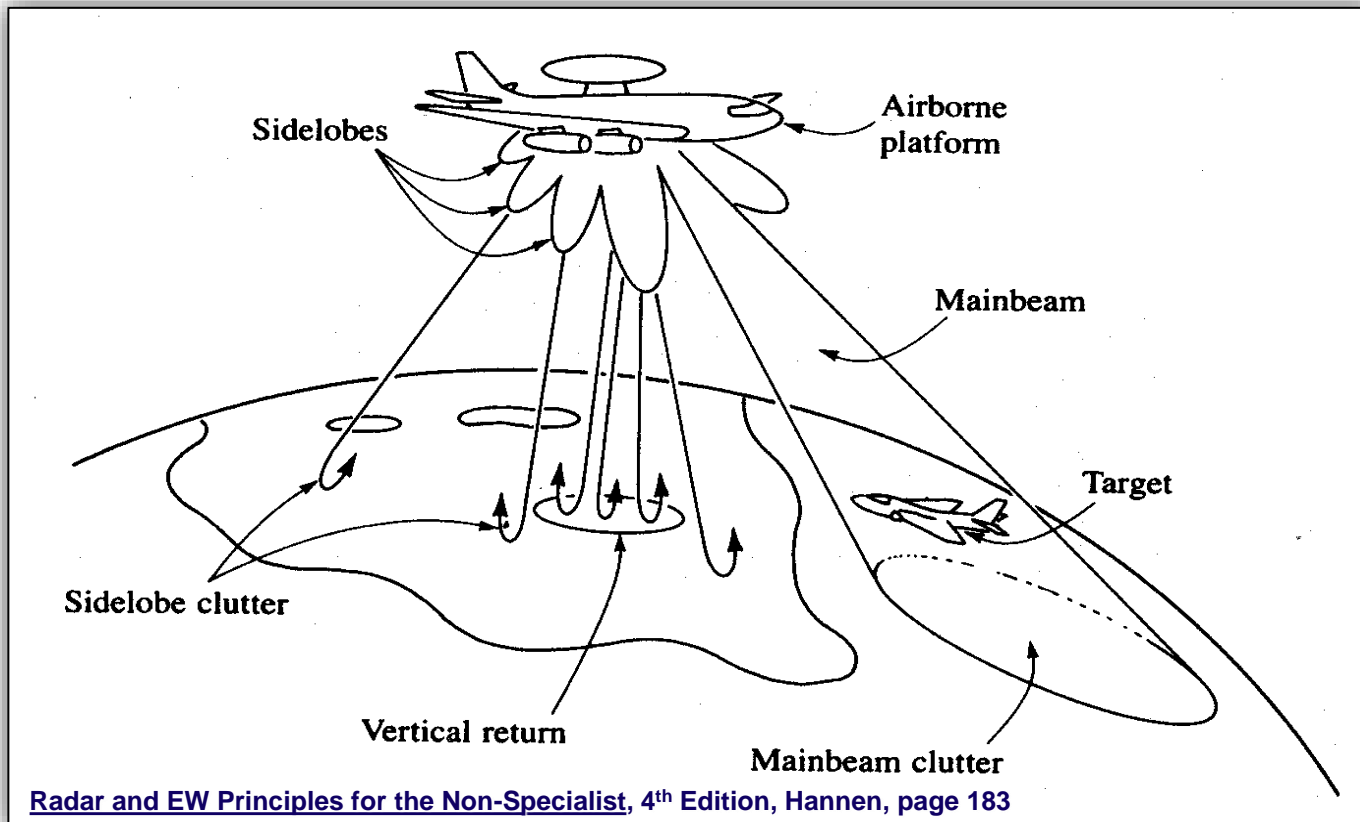




B-52 RMP Battlespace



- Clutter is unwanted signals from objects other than targets that interfere with target detection
 - Earth's surface, atmosphere (rain, sleet, snow, etc), insects, etc.





B-52 RMP Factors



| Factor | Levels |
|-----------------------------------|---|
| Target Environment* | Desert, Urban, Forest, Littoral, Open Water |
| Target Size | Small, Medium, Large |
| Target Speed | Low, High |
| Track Density | Low, High |
| * Indicates Hard to Change Factor | |



Constraints and Limitations



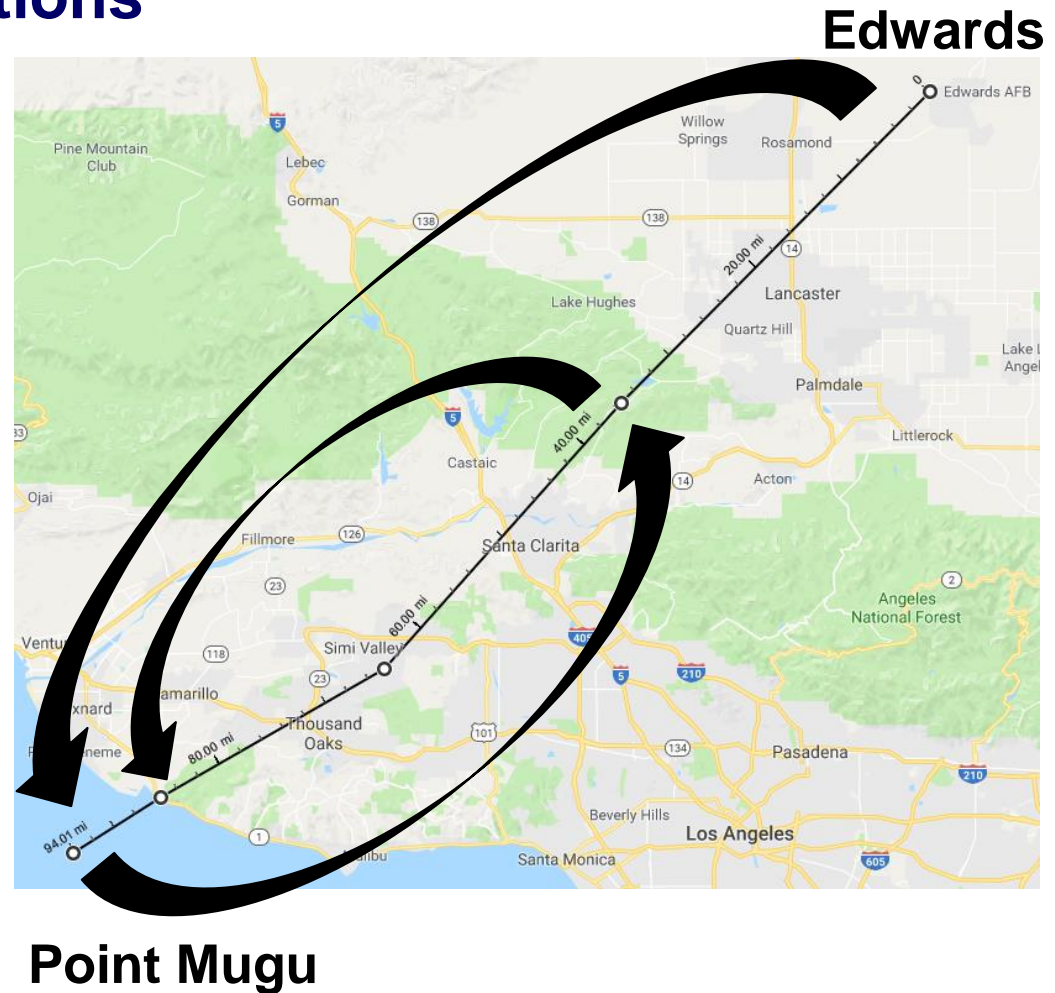
• Randomization Restrictions

– Hard to change factor

| Target Environment |
|--------------------|
| Desert |
| Urban |
| Forest |
| Littoral |
| Open Water |

– Notional Assumptions:

- \$68k/hr flying cost
- 450 knot cruise
- 45 nm per change



Blocking and Split-Plot designs can address randomization restrictions



Blocking Design



- Methodology for organizing or grouping trials to control variability (between periods)
 - Day
 - Different ranges
- Nuisance variables affect the outcome, but we don't necessarily care
 - Tail numbers
 - Aircrew

| Factor | Change | Levels |
|--------|--------|--------|
| 1 | Hard | 5 |
| 2 | Easy | 3 |
| 3 | Easy | 2 |
| 4 | Easy | 2 |

} 12

Block 1
12 Points

Block 2
12 Points

Block 3
12 Points

Block 4
12 Points

Block 5
12 Points

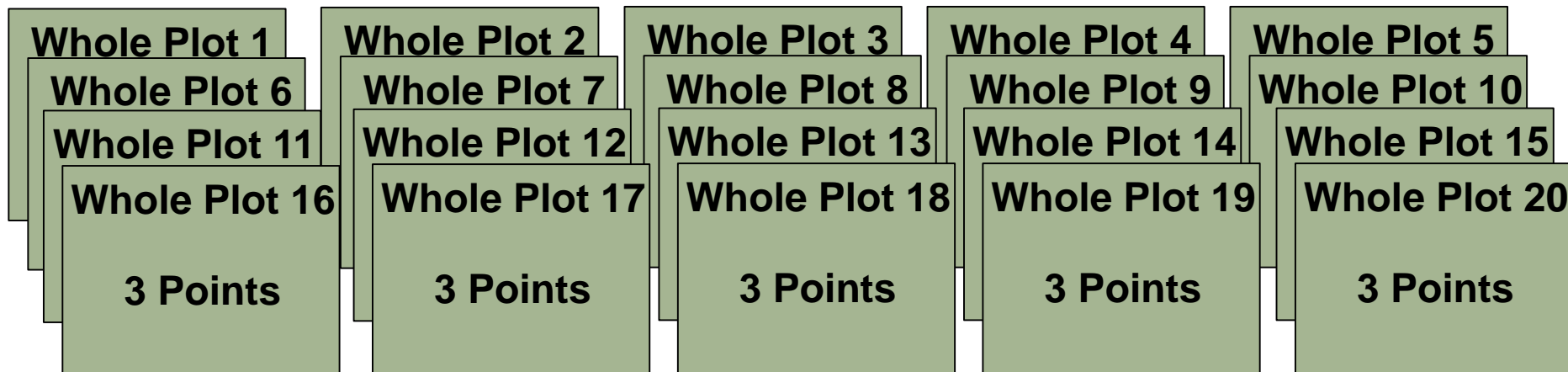


Split-Plot Design 1



- **When randomization is not possible**
 - **Group factors into “hard to change” and “easy to change”**
- **The “hard to change” factor is the one preventing randomization**
 - **Builds the design by “whole plots,” within which “hard to change” factors remain at a single level**

| Factor | Change | Levels |
|--------|--------|--------|
| 1 | Hard | 5 |
| 2 | Easy | 3 |
| 3 | Easy | 2 |
| 4 | Easy | 2 |





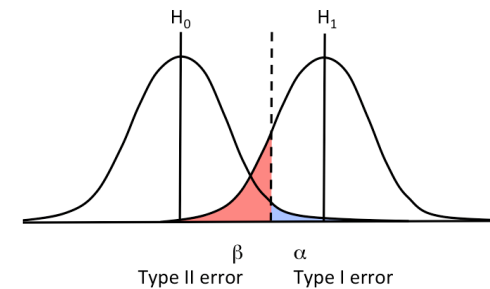
Design Options



| Design | Blocking | Split Plot 1 | Split Plot 2 | Split Plot 3 | Randomized |
|-----------------------------|--------------|--------------|--------------|--------------|--------------|
| # of Environmental Changes | 4 | 19 | 19 | 24 | 59 |
| Total Points | 60 | 60 | 120 | 75 | 60 |
| Min Power @ SNR 1.5, 2.0 | 0.95 0.99 | 0.49 0.67 | 0.53 0.72 | 0.57 0.76 | 0.73 0.91 |

Note: Power with $\alpha = 0.2$, avoid type 2 error

- **Test points are easy to collect**
- **Goal for power: 0.8 @ 1.5 SNR**



- **Blocking Pros**

- **Fewer Changes**
- **Easier to Execute**
- **Simpler Analysis**

- **Split-Plot Pros**

- **Characterize hard-to-change factor**
- **Can estimate interactions**



Cost Considerations



- **DoD is in a Resource Constrained Environment**
 - **Looking for efficiencies in test**

| Design | Blocking | Split Plots 1 & 2 | Split Plot 2 | Randomized |
|----------------------------|-----------------|----------------------------------|---------------------|-------------------|
| # of Environmental Changes | 4 | 19 | 24 | 59 |
| Movement Time (hrs) | 0.40 | 1.9 | 2.4 | 5.9 |
| Movement Cost (\$1000) | 27 | 130 | 160 | 400 |

- **Cost to conduct B-52 RMP testing**
 - **\$68k/hr**
 - **450 knot cruise**
 - **45 nm per level change**



Trade-Offs



| Design | Blocking | Split Plot 1 | Split Plot 2 | Split Plot 3 | Randomized |
|-------------------------|----------|--------------|--------------|--------------|------------|
| Design Balance | Green | Green | Green | Yellow | Green |
| Power | Yellow | Yellow | Yellow | Yellow | Green |
| Runs | Green | Green | Yellow | Green | Green |
| Execution | Green | Yellow | Yellow | Yellow | Red |
| Operational Information | Red | Green | Green | Green | Green |
| Analysis Complexity | Green | Yellow | Yellow | Yellow | Green |

Conclusion:

- Important hard-to-change factor
- Split-Plot Design as a solution
- Present tradeoffs

Analyst presents objective design considerations

→ Decision-maker makes subjective decision



Questions