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Accelerating Knowledge Gain from Test Data

ITEA TIW
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Agenda

- The Four Pillars of Design of Experiments (DOE)
- A Case Study to Compare the Results of Analyzing Test Data with and without the use of DOE
- Examples of the use of DOE to Accelerate Knowledge Gain from Test Data

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Famous Quote

**“All experiments (tests) are designed;
some are poorly designed,
some are well designed.”**

George Box (1919-2013), Professor of Statistics, DOE Guru

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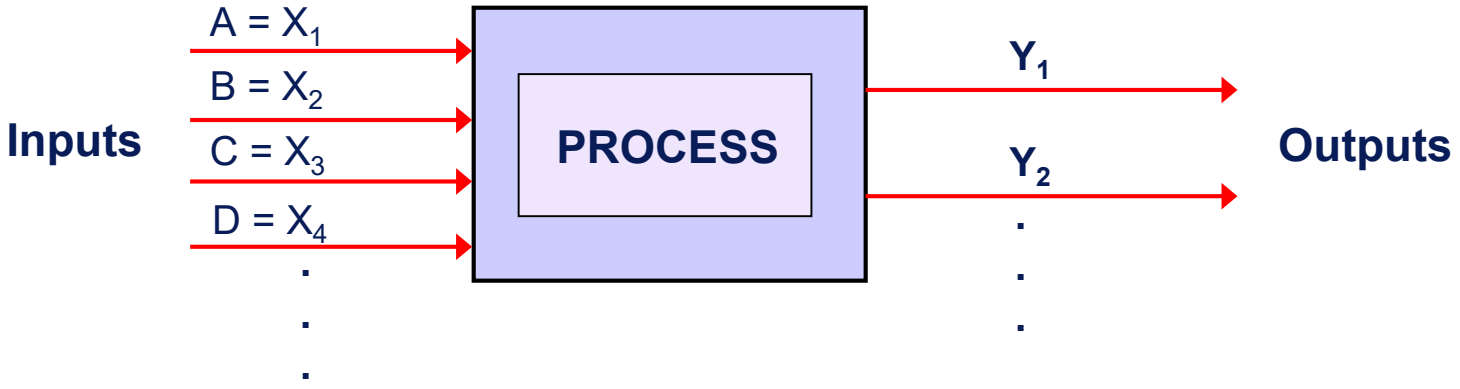
What is a DOE ?

Purposeful and systematic changes of the inputs (factors) in order to observe corresponding changes in the output (response).



Run	X_1 X_2 X_3 X_4	Y_1 Y_2	$\bar{Y}$	S_Y
1				
2				
3				
.				
.				

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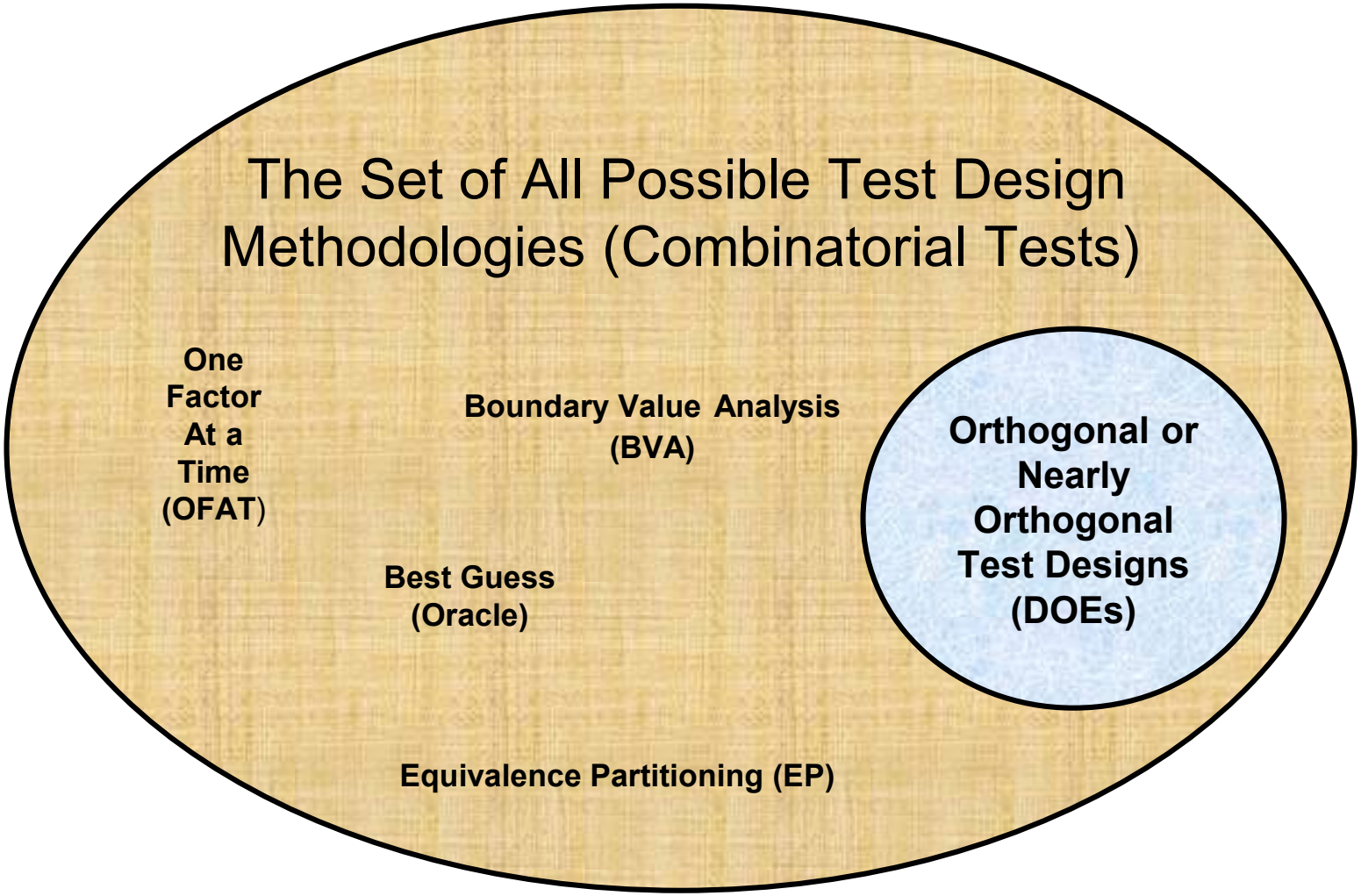
Design of Experiments (DOEs): A Subset of All Possible Test Design Methodologies



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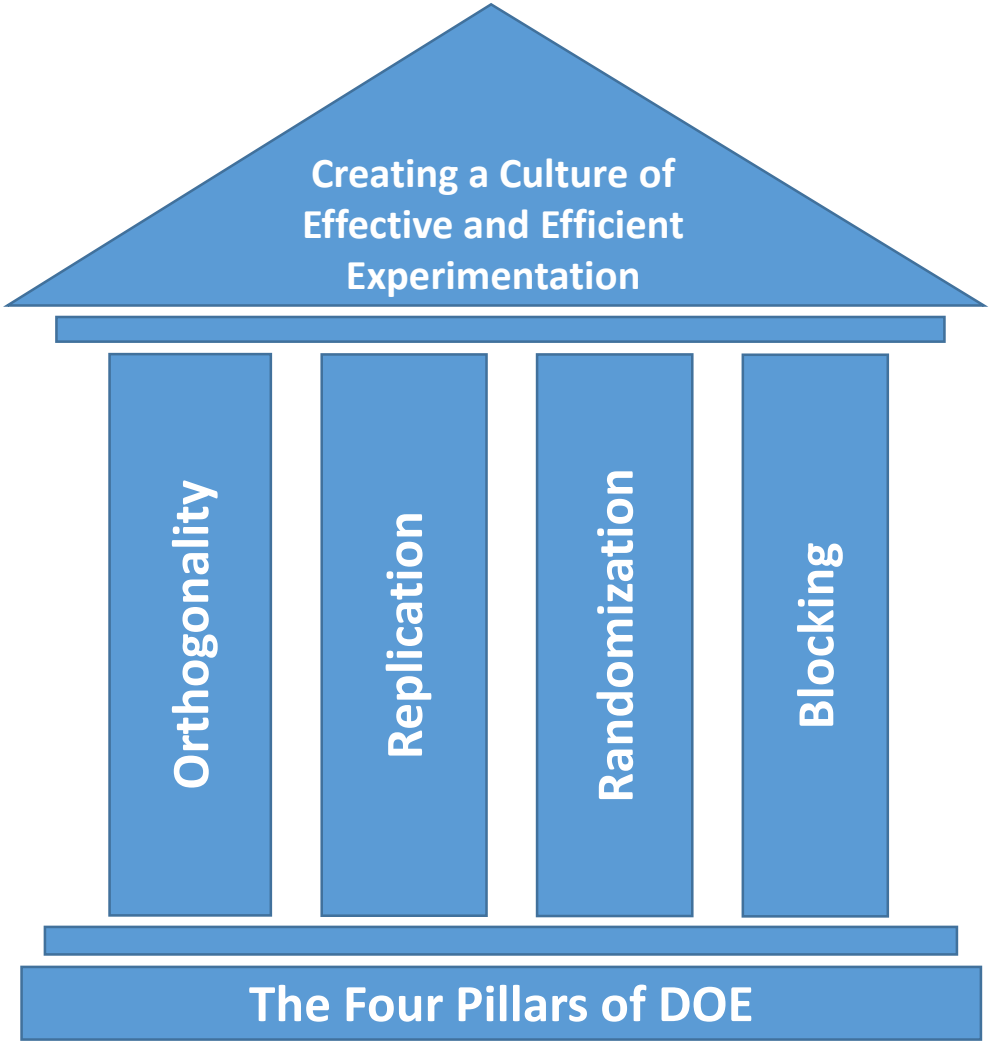
The Foundations of Design of Experiments (DOE)



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Design of Experiments (DOE)

- An optimal data collection methodology
- “Interrogates” the process or product
- Used to identify important relationships between inputs (factors) and outputs (response variables)
- Identifies important interactions between input variables
- Can be used to characterize and optimize a process
- Can be used to asses risk
- Changes “I think” to “I know”
- Is the science of test and the key connector between test and evaluation

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Three Major Types of DOEs

- **Screening Designs**
  - For testing many factors in order to **separate** the vital few critical factors from the trivial many.
- **Modeling Designs**
  - For building **functions** that can be used to predict outcomes, assess risk, and optimize performance. These **include** the ability to evaluate **interaction and higher order effects**.
- **Performance Verification and Validation Testing**
  - For **confirming** that a system performs in accordance with its specifications/requirements.

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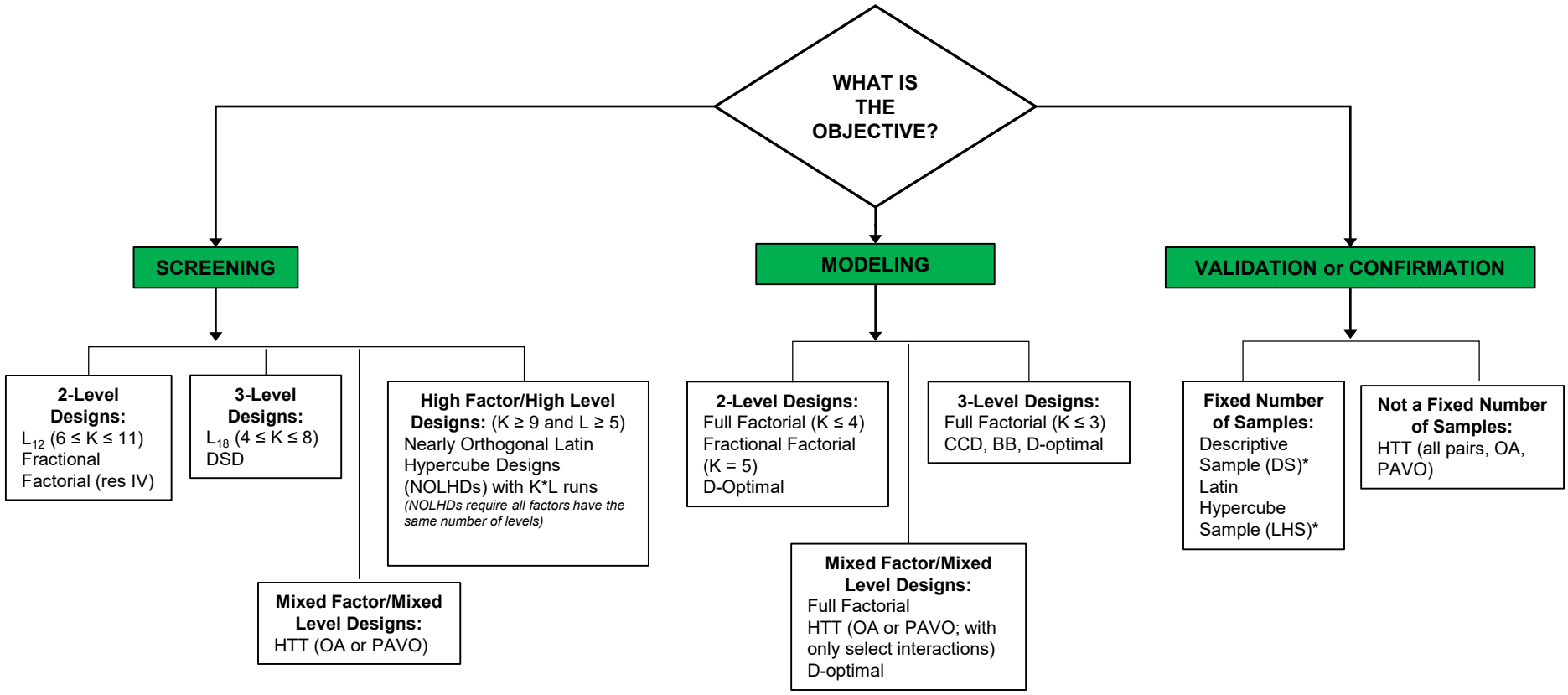
Rules of Thumb for Design Selection



Notes:

1. "Mixed" factors means a combination of quantitative and qualitative (categorical)
2. "Mixed" levels means that not all factors have the same number of levels (settings)
3. "K" = Number of Factors and "L" = Number of Levels
4. HTT = High Throughput Testing
5. DSD = Definitive Screening Design
6. "OA" stands for Orthogonal Array; "PAVO" = Pairwise Value Ordering
7. Software such as HD Tools™, rdExpert™ Lite, Pro-Test™ and Quantum XL™ generate some or all of these designs

* DS and LHS are sampling techniques to generate representative samples according to a specified distribution and a specified sample size

* Representative samples do <u>not</u> give orthogonal designs. They are often used for getting test coverage, validating performance/ determining capability, or creating noise combinations for test

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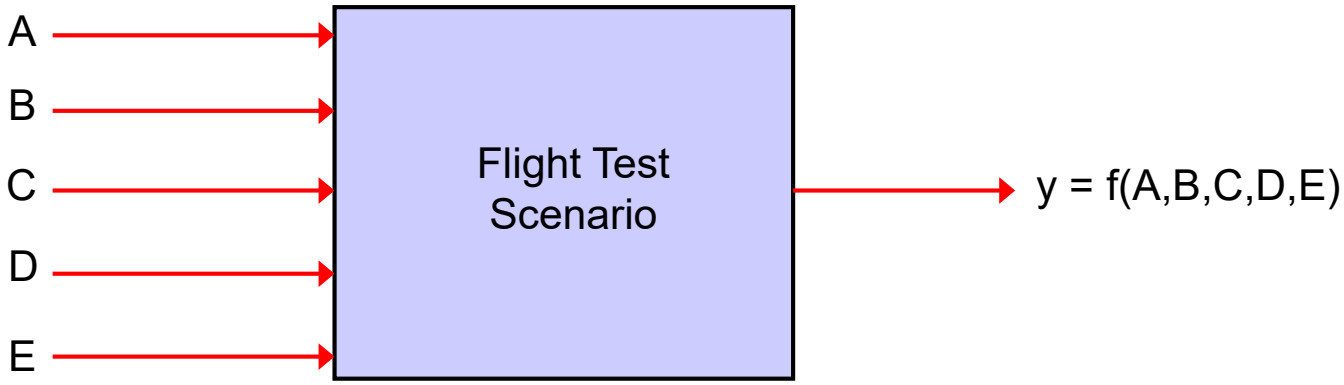
Case Study: Compares Historical Data Modeling vs Modeling Using a DOE



Option 1: Historical Data Analysis (7,105 data points collected)

Option 2: Design of Experiments (48 data points collected = 16 rows x 3 reps)

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Historical Flight Test Data (7,105 data points)

Row #	A	B	C	D	E	y
1	190	-3.3	-2.119944	-8.365184	0	0.1
2	190	-3.82	-0.515662	-7.906818	0	0.15
3	190	-2.79	0.859437	-8.537071	0	0.14
4	190	-2.56	-2.750197	-6.016057	0	-0.15
5	190	-2.02	10.427832	-8.193297	0	0.08
6	190	-2.68	-24.350707	-3.66693	9.4	0
7	190	-2.56	-29.965693	-6.187944	18.9	0.06
8	190	-1.86	5.901465	-10.313241	25	0.14
9	190	-1.5	9.281916	-11.459156	29.7	0.1
10	190	-2.79	4.927437	-6.760902	48.7	0.1
11	190	-2.02	12.49048	-5.213916	58.2	-0.13
12	190	-1.5	8.938142	-5.84417	67.7	0.1
13	190	-1.27	3.151268	-5.328508	77.2	0
14	190	-1.5	0.515662	-8.766254	86.7	-0.08
15	190	-1.69	1.890761	-9.625691	95	0
7091	202	2.21	0	-34.950426	0	2.7
7092	202	2.15	0	-34.950426	0	2.6
7093	202	2.01	0	-34.950426	0	2.5
7094	201	2.07	0	-34.950426	0	2.4
7095	202	2.11	0	-34.950426	0	2.3
7096	201	2.19	0	-34.950426	0	2.19
7097	201	2.08	0	-34.950426	0	2
7098	201	2.19	0	-34.950426	0	1.9
7099	200	2.05	0	-34.950426	0	1.79
7100	200	2.08	0	-34.950426	0	1.68
7101	199	2.03	0	-34.950426	0	1.58
7102	199	2.06	0	-34.950426	0	1.47
7103	199	1.92	0	-34.950426	0	1.47
7104	199	1.91	0	-34.950426	0	1.36
7105	189	2.47	0	-34.950426	0	-0.12

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Regression Analysis Model on Historical Data

$$Y = -2.1 + 3.086A - 2.577B + 6.263C + \ldots.$$

Almost every term in the model appears to be significant. But we cannot trust the p-values.

Why? The Tolerances (Tols) are bad. $0 \le Tol \le 1$ and the bigger the better.

Why are the Tolerances bad?

Factor	Name	Coeff	P(2 Tail)	Tol	Active
Const		-2.100	0.0000		
A	A	3.086	0.0001	0.0075	X
B	B	-2.577	0.0000	0.0327	X
C	C	6.263	0.0000	0.0099	X
D	D	2.471	0.0052	0.0015	X
E	E	0.80874	0.0133	0.0073	X
AA		-3.049	0.0000	0.0490	X
AB		3.732	0.0000	0.0413	X
AC		-3.676	0.0665	0.0102	X
AD		0.42562	0.7842	0.0020	X
AE		-4.615	0.0000	0.0052	X
BB		-0.60078	0.0056	0.1633	X
BC		9.843	0.0000	0.0105	X
BD		5.001	0.0000	0.0051	X
BE		2.406	0.0000	0.0149	X
CC		1.059	0.0000	0.5875	X
CD		-7.333	0.0003	0.0077	X
CE		3.193	0.0007	0.0141	X
DD		0.70985	0.0000	0.3126	X
DE		2.263	0.0120	0.0026	X
EE		0.94591	0.0000	0.1848	X
ABC		-13.243	0.0057	0.0122	X
ABD		-5.994	0.0003	0.0125	X
ABE		-15.048	0.0000	0.0124	X
ACD		-1.162	0.6963	0.0174	X
ACE		1.982	0.1163	0.0483	X
ADE		7.305	0.0000	0.0042	X
BCD		-2.269	0.0665	0.0587	X
BCE		4.257	0.0001	0.0305	X
BDE		7.159	0.0000	0.0079	X
CDE		-5.728	0.0002	0.0146	X

Correlation Matrix

	A	B	C	D	E
A	1.0	0.655627	0.231945	0.695674	0.590646
B		1.0	0.203561	0.731725	0.592057
C			1.0	0.183731	0.459968
D				1.0	0.658302
E					1.0

Summary

Mean	238.163	9.7792	1.1304	-10.311	33.441
StDev	41.86	8.1442	5.7971	15.63	32.393
Count	7105	7105	7105	7105	7105

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Reducing the Model to Improve the Independent Evaluation of Effects

Original Model (partially shown)

Factor	Name	Coeff	P(2 Tail)	Tol	Active
Const		-2.100	0.0000		
A	A	3.086	0.0001	0.0075	X
B	B	-2.577	0.0000	0.0327	X
C	C	6.263	0.0000	0.0099	X
D	D	2.471	0.0052	0.0015	X
E	E	0.80874	0.0133	0.0073	X
AA		-3.049	0.0000	0.0490	X
AB		3.732	0.0000	0.0413	X
AC		-3.676	0.0665	0.0102	X
AD		0.42562	0.7842	0.0020	
AE		-4.615	0.0000	0.0052	X
BB		-0.60078	0.0056	0.1633	X
BC		9.843	0.0000	0.0105	X
BD		5.001	0.0000	0.0051	X
BE		2.406	0.0000	0.0149	X
CC		1.059	0.0000	0.5875	X
CD		-7.333	0.0003	0.0077	X
CE		3.193	0.0007	0.0141	X
DD		0.70985	0.0000	0.3126	X
DE		2.263	0.0120	0.0026	X
EE		0.94591	0.0000	0.1848	X

all 3-way interaction effects not shown

New Reduced Model

Factor	Name	Coeff	P(2 Tail)	Tol	Active
Const		-0.20974	0.2582		
A	A	4.066	0.0000	0.0402	X
B	B	-1.423	0.0000	0.0876	X
C	C	2.170	0.0000	0.1303	X
D	D	-2.642	0.0000	0.0198	X
E	E	0.72037	0.0000	0.0375	X
AA		-3.058	0.0000	0.0735	X
AB		7.289	0.0000	0.1389	X
AE		1.110	0.0000	0.1198	X
BB		-2.372	0.0000	0.2092	X
BC		1.606	0.0038	0.1160	X
BD		-4.211	0.0000	0.0877	X
BE		0.32886	0.0361	0.1346	X
CC		1.215	0.0000	0.6170	X
CD		-0.94967	0.0000	0.7128	X
CE		0.98181	0.0004	0.1714	X
DD		0.71839	0.0001	0.3166	X
DE		-0.53856	0.0358	0.0342	X
EE		0.85207	0.0000	0.2343	X

change in the sign of the coefficient

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Option 2: Do a 16-Run DOE with 3 Replications
(48 total data points)

												Mean	Std Dev
Row #	A	B	C	D	E		Y1	Y2	Y3			Y	S
1	190	-5	-6	-30	80		1.7617	2.0613	1.8141			1.879033	0.160007
2	190	-5	-6	8	20		0.2052	0.9104	-0.1851			0.310167	0.555242
3	190	-5	10	-30	20		-0.7498	-0.7461	-0.7563			-0.75073	0.005164
4	190	-5	10	8	80		-1.9851	-2.7369	-0.6674			-1.79647	1.047566
5	190	15	-6	-30	20		-0.7224	-0.1055	-1.2334			-0.6871	0.564778
6	190	15	-6	8	80		1.6513	-0.0808	4.1669			1.912467	2.135859
7	190	15	10	-30	80		0.8139	0.9091	0.91			0.877667	0.055225
8	190	15	10	8	20		0.0575	-0.0253	0.5457			0.192633	0.308555
9	280	-5	-6	-30	20		-6.6067	-7.5179	-5.6145			-6.5797	0.951987
10	280	-5	-6	8	80		9.1227	5.5677	13.4362			9.375533	3.940338
11	280	-5	10	-30	80		2.2185	1.235	3.3684			2.273967	1.067781
12	280	-5	10	8	20		-7.1673	-8.0054	-5.9489			-7.04053	1.034094
13	280	15	-6	-30	80		-10.8558	-9.8036	-11.6095			-10.7563	0.907052
14	280	15	-6	8	20		-0.186	-0.9244	1.0649			-0.01517	1.005593
15	280	15	10	-30	20		1.9779	3.0527	0.8235			1.951367	1.114837
16	280	15	10	8	80		3.6475	1.7148	5.0905			3.484267	1.69376

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Regression Analysis Model from DOE Data

Y-hat Model

Factor	Name	y Coeff	P(2 Tail)	Tol	Active
Const		-0.33556	0.0999		
A	A	-0.57776	0.0063	1	X
B	B	-0.04446	0.8239	1	X
C	C	0.23458	0.2451	1	X
D	D	1.138	0.0000	1	X
E	E	1.242	0.0000	1	X
AB		-0.37617	0.0665	1	X
AC		0.84601	0.0002	1	X
AD		1.226	0.0000	1	X
AE		0.76586	0.0005	1	X
BC		1.772	0.0000	1	X
BD		0.63515	0.0030	1	X
BE		-1.982	0.0000	1	X
CD		-2.327	0.0000	1	X
DE		1.199	0.0000	1	X

R^2	0.9405
Adj R^2	0.9153
Std Error	1.3732
F	37.2814
Sig F	0.0000
F_{LOF}	0.1180
Sig F_{LOF}	0.7335

Source	SS	df	MS
Regression	984.2	14	70.3
Error	62.2	33	1.9
$Error_{Pure}$	62.0	32	1.9
$Error_{LOF}$	0.2	1	0.2
Total	1046.4	47	

Factor	Name	Low	High	Exper
A	A	190	280	235
B	B	-5	15	5
C	C	-6	10	2
D	D	-30	8	-11
E	E	20	80	50

Multiple Response Prediction

	Y-hat	S-hat	99% Confidence Interval Lower Bound	Upper Bound
y	-0.3356	1.0342	-3.438	2.767

Correlation Matrix

	A	B	C	D	E
A	1.0	0.0	0.0	0.0	0.0
B		1.0	0.0	0.0	0.0
C			1.0	0.0	0.0
D				1.0	0.0
E					1.0

Summary

Mean	235.0	5.0	2.0	-11.0	50.0
StDev	46.476	10.328	8.2624	19.623	30.984
Count	16	16	16	16	16

S-hat Model

	Factor	Name	y Coeff	P(2 Tail)	Tol	Active
	Const		1.034	0.0000		
C	A	A	0.43019	0.0011	1	X
C	C	C	-0.24337	0.0191	1	X
C	D	D	0.43089	0.0010	1	X
C	E	E	0.34171	0.0038	1	X
	AB		-0.22309	0.0274	1	X
	CD		-0.20077	0.0410	1	X
	CE		-0.16650	0.0769	1	X
	DE		0.39755	0.0017	1	X

R^2	0.9479
Adj R^2	0.8884
Std Error	0.3213
F	15.9328
Sig F	0.0008
F_{LOF}	NA
Sig F_{LOF}	NA

Source	SS	df	MS
Regression	13.2	8	1.6
Error	0.7	7	0.1
$Error_{Pure}$	NA	0	NA
$Error_{LOF}$	NA	0	NA
Total	13.9	15	

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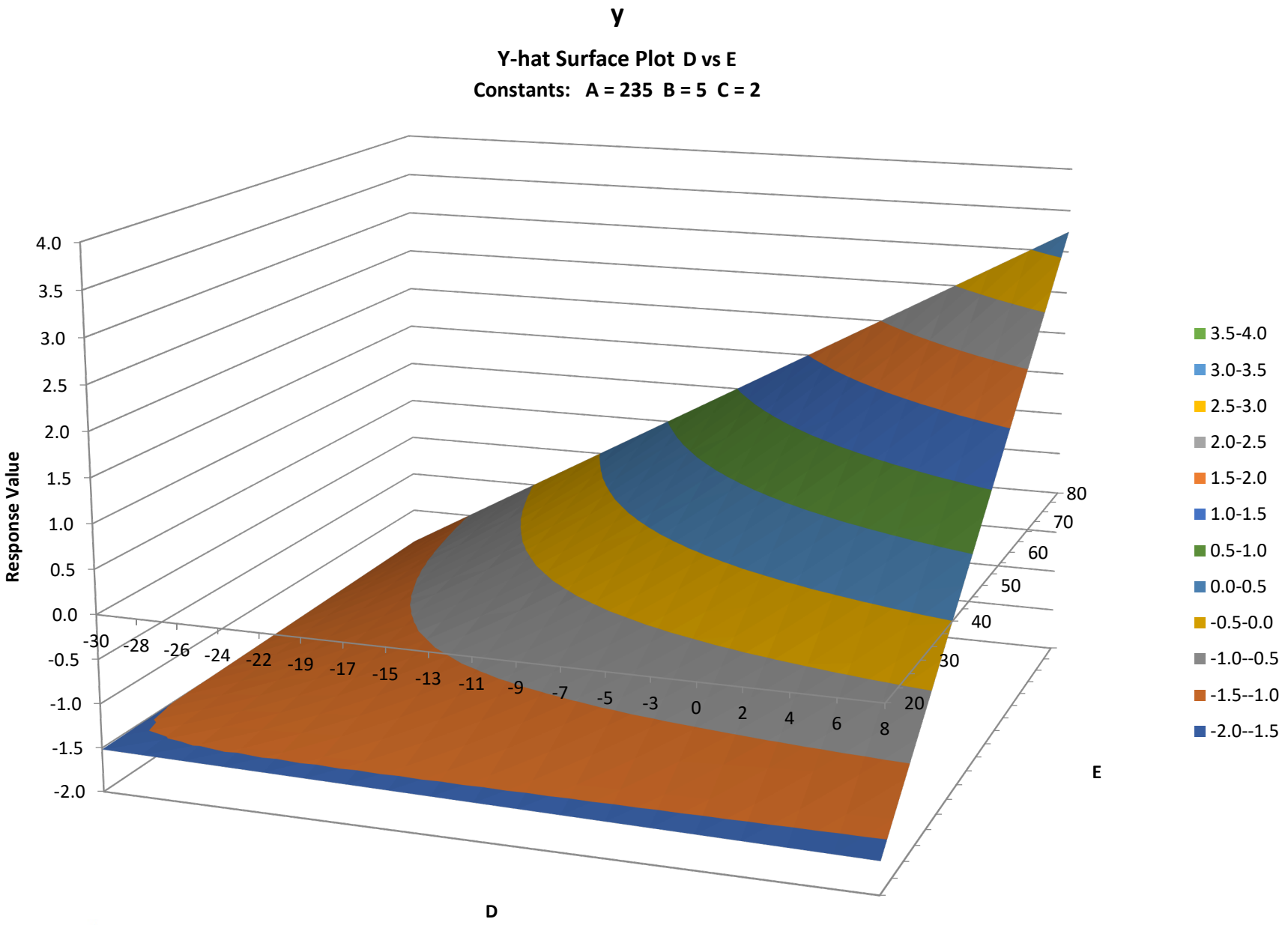
Surface Plot of Factor D vs Factor E



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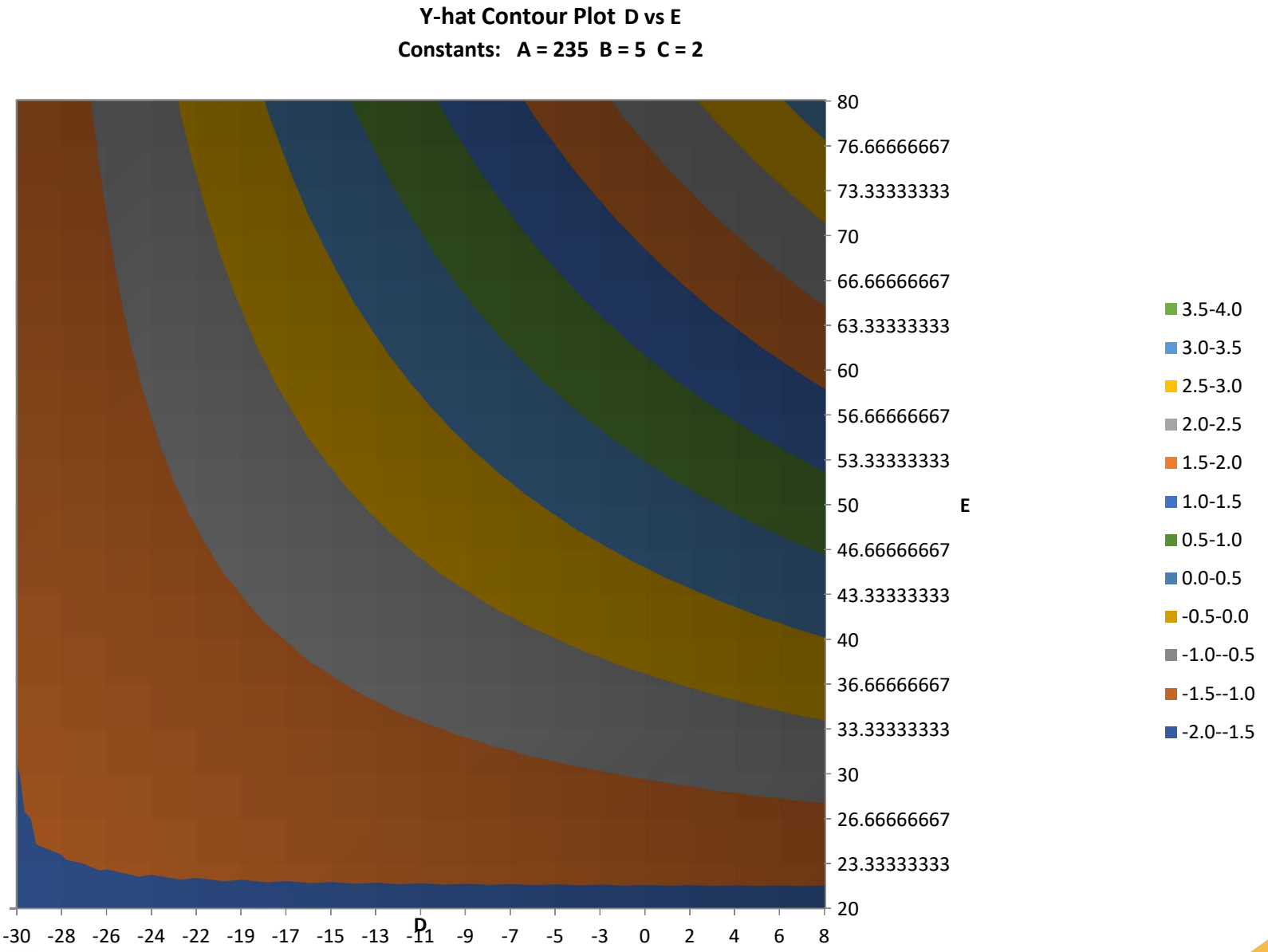
Contour Plot of Operating Region for y



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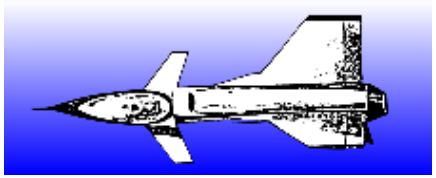
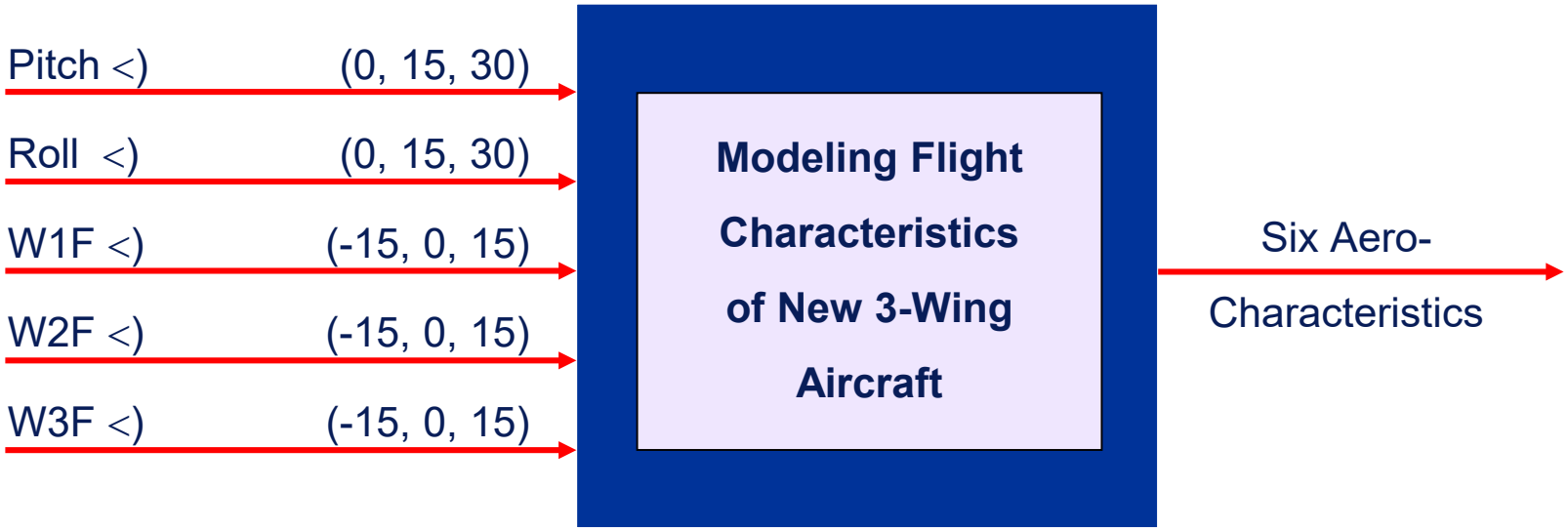
Value Delivery: Reducing Time to Market for New Technologies



INPUT **OUTPUT**



- **Total # of Combinations = 3^5 = 243**
- **Central Composite Design: n = 30**

Patent Holder: Dr. Bert Silich

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Aircraft Equations (predictive models)

$C_L = .233 + .008(P)^2 + .255(P) + .012(R) - .043(WD1) - .117(WD2) + .185(WD3) + .010(P)(WD3) - .042(R)(WD1) + .035(R)(WD2) + .016(R)(WD3) + .010(P)(R) - .003(WD1)(WD2) - .006(WD1)(WD3)$

$C_D = .058 + .016(P)^2 + .028(P) - .004(WD1) - .013(WD2) + .013(WD3) + .002(P)(R) - .004(P)(WD1) - .009(P)(WD2) + .016(P)(WD3) - .004(R)(WD1) + .003(R)(WD2) + .020(WD1)^2 + .017(WD2)^2 + .021(WD3)^2$

$C_Y = -.006(P) - .006(R) + .169(WD1) - .121(WD2) - .063(WD3) - .004(P)(R) + .008(P)(WD1) - .006(P)(WD2) - .008(P)(WD3) - .012(R)(WD1) - .029(R)(WD2) + .048(R)(WD3) - .008(WD1)^2$

$C_M = .023 - .008(P)^2 + .004(P) - .007(R) + .024(WD1) + .066(WD2) - .099(WD3) - .006(P)(R) + .002(P)(WD2) - .005(P)(WD3) + .023(R)(WD1) - .019(R)(WD2) - .007(R)(WD3) + .007(WD1)^2 - .008(WD2)^2 + .002(WD1)(WD2) + .002(WD1)(WD3)$

$C_{YM} = .001(P) + .001(R) - .050(WD1) + .029(WD2) + .012(WD3) + .001(P)(R) - .005(P)(WD1) - .004(P)(WD2) - .004(P)(WD3) + .003(R)(WD1) + .008(R)(WD2) - .013(R)(WD3) + .004(WD1)^2 + .003(WD2)^2 - .005(WD3)^2$

$C_e = .003(P) + .035(WD1) + .048(WD2) + .051(WD3) - .003(R)(WD3) + .003(P)(R) - .005(P)(WD1) + .005(P)(WD2) + .006(P)(WD3) + .002(R)(WD1)$

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The Value of Predictive Models

- Simple and compact way of understanding relationships between performance measures or response variables (Y's) and the factors (X's) that influence them.
- Allows us to
  - Predict the response variable (y), with associated risk levels, before any change in the product or process is made.
  - Assess the product/process capability in the presence of uncontrolled variation or noise using Monte Carlo Simulation (DFSS tool: Expected Value Analysis).
  - Understand the impact on performance when factors change (sensitivity analysis)
  - Optimize performance easily using DFSS tools such as parameter design and tolerance allocation.
- Greatly enhance one's knowledge of a product or process.
- In general, they are the gateway to systematic innovation.

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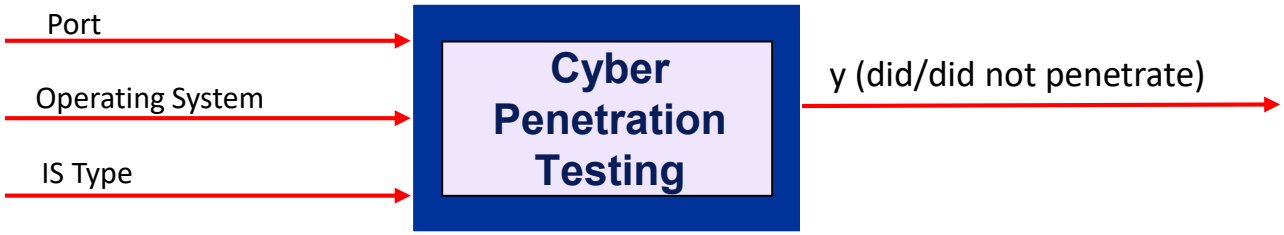
Cyber Penetration Testing Example*



Putting these factor names and their levels, along with the test constraints, into Pro-Test software yields these 14 optimal test configurations:

Factors and Levels

	Factor 1	Factor 2	Factor 3
Factor Name:	**Port**	**OS**	**IS Type**
Level 1	21	Linux	network
Level 2	22	Windows	storage
Level 3	23		server
Level 4	25		
Level 5	80		

With Constraints

	If Factor ...	is at level ...	then Factor ...	can't be ...
Constraint 1	Port	25	IS Type	network
Constraint 2	Port	25	IS Type	storage
Constraint 3	IS Type	network	OS	Windows
Constraint 4	IS Type	storage	OS	Windows

Produces 14 Optimized Test Configurations

	Factor_A	Factor_B	Factor_C
Factor Name	Port	OS	IS Type
Case 1	25	Windows	server
Case 2	21	Linux	storage
Case 3	22	Linux	storage
Case 4	80	Windows	server
Case 5	21	Windows	server
Case 6	23	Windows	server
Case 7	80	Linux	network
Case 8	23	Linux	storage
Case 9	21	Linux	network
Case 10	22	Windows	server
Case 11	22	Linux	network
Case 12	23	Linux	network
Case 13	25	Linux	server
Case 14	80	Linux	storage

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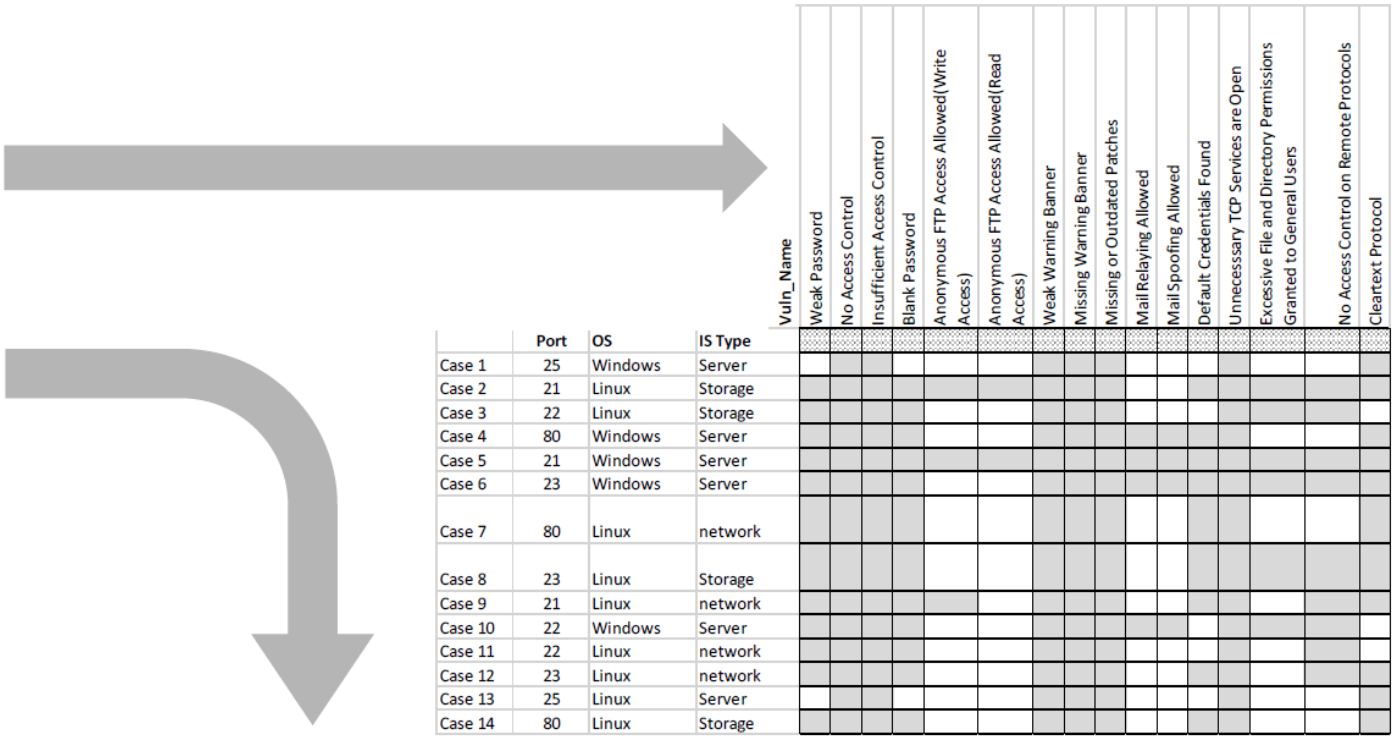
* Courtesy of Raytheon

Penetration Vulnerability Test Design Matrix*

Apply known vulnerability test

To applicable Test Configurations



	Port	OS	IS Type	Weak Password	No Access Control	Insufficient Access Control	Blank Password	Anonymous FTP Access Allowed(Write Access)	Anonymous FTP Access Allowed(Read Access)	Weak Warning Banner	Missing Warning Banner	Missing or Outdated Patches	Mail Relaying Allowed	Mail Spoofing Allowed	Default Credentials Found	Unnecesssary TCP Services are Open	Excessive File and Directory Permissions Granted to General Users	No Access Control on Remote Protocols	Cleartext Protocol
Case 1	25	Windows	Server		■	■				■	■	■			■	■			■
Case 2	21	Linux	Storage	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Case 3	22	Linux	Storage	■	■	■	■			■	■	■			■	■	■	■	
Case 4	80	Windows	Server	■	■	■	■			■	■	■	■	■	■	■	■	■	■
Case 5	21	Windows	Server	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Case 6	23	Windows	Server	■	■	■	■			■	■	■	■	■	■	■	■	■	■
Case 7	80	Linux	network	■	■	■	■			■	■	■			■	■			■
Case 8	23	Linux	Storage	■	■	■	■			■	■	■			■	■	■	■	■
Case 9	21	Linux	network	■	■	■	■	■		■	■	■			■	■	■	■	■
Case 10	22	Windows	Server	■	■	■	■			■	■	■	■	■		■	■	■	
Case 11	22	Linux	network	■	■	■	■			■	■	■				■		■	
Case 12	23	Linux	network	■	■	■	■			■	■	■			■	■	■	■	■
Case 13	25	Linux	Server		■	■				■	■	■			■	■			■
Case 14	80	Linux	Storage	■	■	■	■			■	■	■			■	■			■

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Command and Control Test Design Example

(15 factors each at various levels)
Total Combinations: 20,155,392

Variable or Factor	Levels	(# of levels)
Mission Snapshots	Entry, Operations, Consolidation	(3)
Network Size	10 Nodes, 50 Nodes, 100 Nodes	(3)
Network Loading	Nominal, 2X, 4X	(3)
Movement Posture	ATH, OTM1, OTM2	(3)
SATCOM Band	Ku, Ka, Combo	(3)
SATCOM Look Angle	0, 45, 75	(3)
Link Degradation	0%, 5%, 10%, 20%	(4)
Node Degradation	0%, 5%, 10%, 20%	(4)
EW	None, Terrestrial, GPS	(3)
Interoperability	Joint Services, NATO	(2)
IA	None, Spoofing, Hacking, Flooding	(4)
Security	NIPR, SIPIR	(2)
Message Type	Data, Voice, Video	(3)
Message Size	Small, Medium, Large, Mega	(4)
Distance Between Nodes	Short, Average, Long	(3)

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Command and Control Test Example (cont.)

All Pairs Testing from Pro-Test generates 26 test cases

	Factor_A	Factor_B	Factor_C	Factor_D	Factor_E	Factor_F	Factor_G	Factor_H	Factor_I	Factor_J	Factor_K	Factor_L	Factor_M	Factor_N	Factor_O
Factor Name	Mission	Network Size	Network Load	Movement	SATCOM Band	SATCOM Angle	Link Degradation	Node Degradation	EW	Interoperability	IA	Security	Message Type	Size of Message	Node Distance
Case 1	Entry	100 nodes	4X	OTM2	Combo	0	0%	0%	None	NATO	None	SIPIR	Voice	Medium	Short
Case 2	Consolidation	10 nodes	Normal	ATH	Ka	45	5%	5%	GPS	NATO	Spoofing	NIPR	Video	Large	Normal
Case 3	Operation	50 nodes	2X	OTM1	Ku	75	20%	20%	Terrestrial	Joint Serv	Hacking	NIPR	Voice	Small	Long
Case 4	Entry	50 nodes	2X	ATH	Ku	45	10%	10%	None	NATO	Flooding	NIPR	Data	Mega	Short
Case 5	Operation	100 nodes	Normal	OTM1	Combo	75	10%	10%	GPS	NATO	Spoofing	SIPIR	Data	Small	Normal
Case 6	Operation	10 nodes	4X	OTM2	Combo	45	0%	5%	Terrestrial	Joint Serv	None	NIPR	Video	Mega	Long
Case 7	Consolidation	100 nodes	4X	ATH	Ka	75	20%	10%	Terrestrial	NATO	Hacking	SIPIR	Video	Medium	Long
Case 8	Operation	10 nodes	Normal	ATH	Ka	0	20%	0%	Terrestrial	Joint Serv	Flooding	NIPR	Data	Large	Short
Case 9	Consolidation	10 nodes	2X	OTM2	Ku	45	5%	20%	None	Joint Serv	Flooding	SIPIR	Voice	Medium	Normal
Case 10	Consolidation	50 nodes	2X	OTM1	Combo	0	0%	20%	GPS	NATO	None	NIPR	Data	Mega	Normal
Case 11	Entry	50 nodes	Normal	OTM2	Ka	75	10%	5%	GPS	Joint Serv	Hacking	SIPIR	Voice	Large	Long
Case 12	Entry	50 nodes	4X	OTM1	Ku	0	5%	0%	None	Joint Serv	Spoofing	SIPIR	Video	Small	Long
Case 13	Consolidation	100 nodes	4X	OTM2	Ku	45	20%	5%	GPS	Joint Serv	Flooding	NIPR	Data	Small	Short
Case 14	Entry	10 nodes	2X	OTM1	Ka	75	5%	0%	None	Joint Serv	Hacking	SIPIR	Data	Mega	Normal
Case 15	Entry	50 nodes	2X	ATH	Ka	75	0%	20%	Terrestrial	NATO	Spoofing	NIPR	Video	Large	Short
Case 16	Consolidation	10 nodes	4X	ATH	Ku	0	10%	20%	Terrestrial	NATO	None	NIPR	Video	Small	Normal
Case 17	Operation	50 nodes	Normal	OTM1	Ku	75	0%	5%	None	Joint Serv	Flooding	NIPR	Data	Medium	Short
Case 18	Operation	10 nodes	Normal	OTM1	Ka	75	20%	10%	None	Joint Serv	None	SIPIR	Video	Large	Normal
Case 19	Operation	100 nodes	2X	OTM2	Combo	0	5%	10%	Terrestrial	NATO	Hacking	SIPIR	Data	Large	Short
Case 20	Consolidation	100 nodes	Normal	ATH	Combo	0	20%	20%	Terrestrial	Joint Serv	Spoofing	NIPR	Voice	Mega	Short
Case 21	Consolidation	50 nodes	2X	OTM1	Ka	45	10%	0%	GPS	Joint Serv	Spoofing	SIPIR	Data	Medium	Normal
Case 22	Entry	100 nodes	Normal	OTM1	Combo	0	20%	5%	GPS	NATO	Flooding	NIPR	Video	Medium	Long
Case 23	Operation	10 nodes	Normal	ATH	Ka	45	0%	10%	None	NATO	Hacking	SIPIR	Voice	Small	Normal
Case 24	Entry	50 nodes	4X	ATH	Ku	45	5%	20%	None	NATO	None	NIPR	Video	Large	Long
Case 25	Consolidation	10 nodes	2X	ATH	Ku	75	10%	5%	None	Joint Serv	Spoofing	NIPR	Data	Large	Long
Case 26	Consolidation	100 nodes	Normal	OTM2	Combo	45	5%	20%	GPS	Joint Serv	Spoofing	NIPR	Voice	Mega	Normal

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Takata Airbag Defect Findings: Independent Testing Coalition (ITC) makes key findings

ITC says exposure to **heat** and **humidity,** and the use of **ammonium nitrate** are all required to produce what the commission and the National Highway Traffic Safety Administration (NHTSA) call an “energetic disassembly.”

“You can’t have the energetic disassembly without all three factors," David Kelly, leader of the ITC and former chief of the NHTSA told Automotive News Europe. "You have to have all three.”

In DOE, this is called a significant 3-way interaction effect.

The ITC has named three main technical factors that were all present in violent ruptures of Takata airbags linked to injuries and deaths.
PHOTO BY ADAM BARTLETT

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The Big Picture: What can DOE do for us?

1. Provides systematic and representative coverage of the test region
2. Improves the quality of testing, and gives us
   - Faster detection of problems
   - Higher probability of detecting faults and their causes
   - Cost and time efficiencies
   - Ability to quantify risks inherent to any test program

Better testing **done** ***faster***
at ***lower cost*** **with** ***less risk***

More Effective and Efficient Knowledge Gain

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