

# Six Sigma Statistics using Minitab 17

## Green Belt Edition

13 DOE  
Answer to Exercise

By Rehman Khan

# 13.7 Sequential DOE Exercise

## 13.7.1 Starship Engine Power

You are helping Jock, the Chief Engineer, increase the engine power of the Starship Emoji. Jock has identified 8 factors and level that he wants investigated. Your mission is to boldly identify significant factors and maximise the response, Power, using a Screening DOE. Fold the design to gain better resolution in the Effect that can be detected.

Once significant factors have been identified run a Modeling DOE with the intention of maximising the response using existing levels. If curvature is detected conduct additional runs to characterise the curvature. Clearly identify all significant factors to maximise the response and the levels they should be set. All data for this chapter is in '13 DOE.xlsx'.

The screening DOE factors are listed below using the following format  
Factor Full name (Column Heading, Lo setting, Hi Setting).

Engine Temperature (Temp, 9k, 12k)

Magnetic Field Density (MFD, 180, 230)

Magnetic Field Flux (MFF 26, 49)

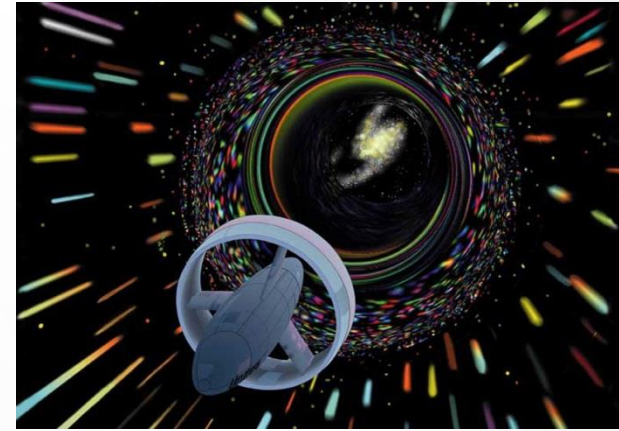
Scones, Cream or Jam (Scones 0,1) Categorical

Reaction Initiation, Crank or Fusion (Initiation 0,1) Categorical

Core Wavelength (Wave 13k, 21k)

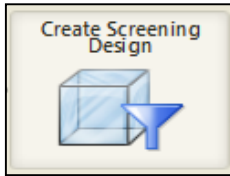
Plasma Input Angle (PIA 14, 26)

Plasma Input Flux (PIF 80, 120)



# Setup-1

1. Start with a new project and then click *Assistant*<<*DOE*<<*Plan and Create*.
2. Click on the **Create Screening Design** box.



3. Enter 'Power' as the response variable.
4. Jock has identified 8 possible factors for an experiment so we will enter 8 as the number of factors.

Response and factors

Enter the name of your response variable:

Number of factors:

5. Enter all the factor details. We need to enter the short factor name, the data type and then the high and low levels to be used for the factors in the experiment. Note that Scone and Initiation are categorical factors.
6. Change the total runs in the design to 24.
7. Click OK to produce the worksheet and the create Summary Report and Report Card.

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# Setup-2

Enter your factor names and settings:

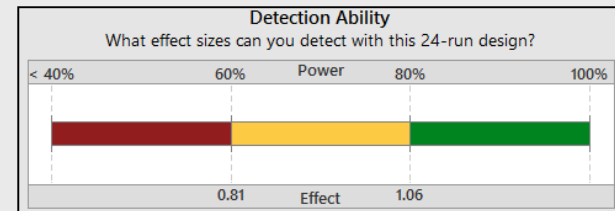
Name	Type	Low	High
Temp	Continuous	9	12
MFD	Continuous	180	230
MFF	Continuous	26	49
Scone	Categorical	0	1
Initiation	Categorical	0	1
Wave	Continuous	13	21
PIA	Continuous	14	26
PIF	Continuous	80	120

Number of runs

Adding runs allows you to detect smaller effect sizes.

Total number of runs in your design:

On the Summary Report the power bar tells us that to achieve a power of 80% the minimum effect that we will be to detect is 1.06 StDevs. In the guidance given below we are told that we will be able to detect down to small to moderate effects of the factors.

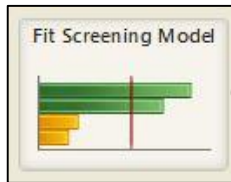


After setup of the worksheet the next step is for the trials to be conducted so that the response data can be gathered. Luckily we have a sheet already prepared for you.

# Setup-3

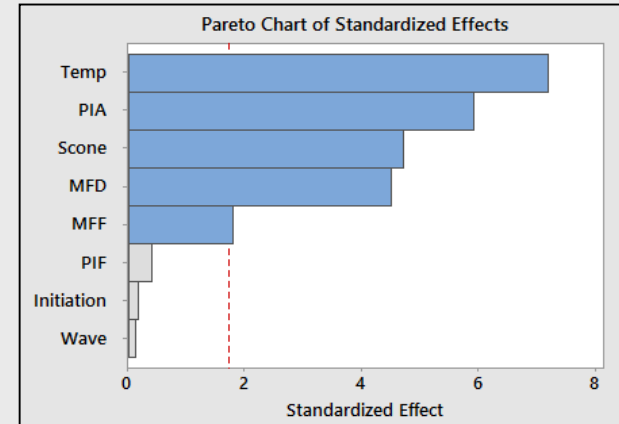
The data for this section is 13 DOE.xlsx worksheet 'Power Screen'.

8. Go to the Minitab worksheet where our modeling DOE worksheet was created. Delete everything but the title bar and then transfer the data from the Excel worksheet into Minitab.
9. Click *Assistant*<<*DOE*<<*Analyze and Interpret*.
10. Click on the *Fit Screening Model* box.

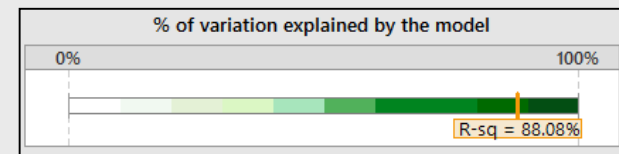


11. Click 'Yes' on the confirmation menu box to produce the Screening Analysis Report.

# Analysis-I



On the top left of the Summary Report the Pareto of Standardized Effects shows us which Main Effects are significant and would be worth exploring further.



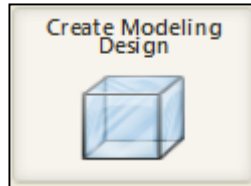
We are told that changes in these five factors could explain 88.08% of changes in the response.

The Report Card does not show any warnings that indicate problems with the model thus far.

# Setup-4

The next step is to take the significant factors into the Modeling design and to check for significant interactions and to check for curvature.

12. Click **Assistant**<<**DOE**<<**Analyze and Interpret**.
13. Click on the **Create Modeling Design** box.



14. A menu box will appear and ask you if you wish to enter new factor levels. Click on No and you are taken to the Modeling Worksheet Creation Menu.
15. Most of the required information should be automatically completed by Minitab, Just check the response variable is 'Power' and the goal is to 'Maximize the response'.

Response	
Enter the name of your response variable:	Power
What is your response goal?	Maximize the response

16. Also check the levels and types for the 5 factors we are taking forward to the Modeling Design. Also, we are going to use 2 replicates making 40 runs in total.
17. Click OK to produce the worksheet and the create Summary Report and Report Card.

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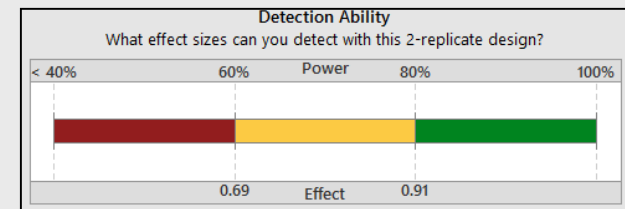
# Setup-5

Number of factors: 5				
Enter your factor names and settings:				
Name	Type	Low	High	
Temp	Continuous	9		
MFD	Continuous	180	2	
MFF	Continuous	26		
PIA	Continuous	14		
Scone	Categorical	0	1	

Replicates	
Adding replicates allows you to detect smaller effect sizes.	
Number of replicates:	2

We don't actually want to print the worksheet so click No. The Summary report indicates that we would be able to detect small effects with this number of experimental runs.

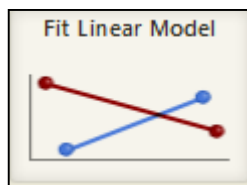


After setup of the worksheet the next step is for the trials to be conducted so that the response data can be gathered. Luckily we have a sheet already prepared for you.

# Setup-6

The data for this section is 13 DOE.xlsx worksheet 'Power Model'.

18. Go to the Minitab worksheet where our modeling DOE worksheet was created. Delete everything but the title bar and then transfer the data from the Excel worksheet into Minitab.
19. Click **Assistant**<<**DOE**<<**Analyze and Interpret**.
20. Click on the **Fit Screening Model** box.



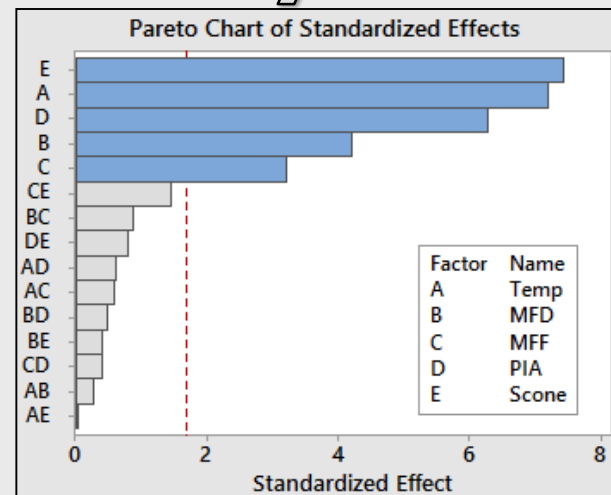
21. A confirmation menu box will appear and ask you to confirm the goal of the experiment. Ensure the goal is set to 'Maximise the response' and then click OK to produce the 5 page Modeling DOE report.

Response variable: Power

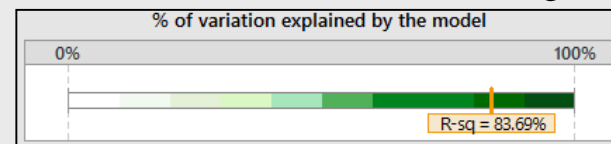
What is your response goal? **Maximize the response**

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# Analysis-2



On the top left of the Summary Report the Pareto of Standardized Effects shows us that the same Main Effects are significant. None of the interactions are significant.



Optimal Factor Settings		Predicted Y
Temp	12	721.787
MFD	230	
MFF	49	
PIA	26	
Score	1	

We are told that changes in these five factors could explain 83.69% of changes in the response. A slight drop from the last experiment. We are also given the optimal factor settings to maximise the response.

# Analysis-3

**Goal: Maximize Power**

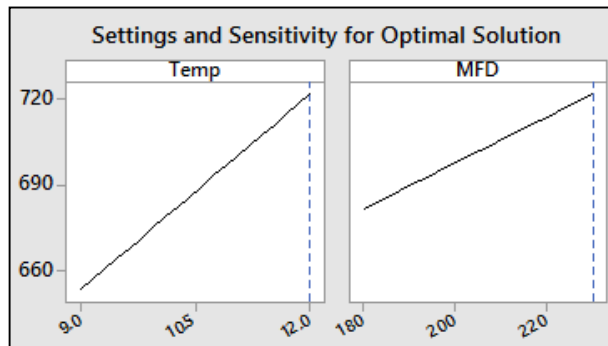
Predicted Y 721.787  
95% PI (662.55, 781.02)

**Solution: Optimal Settings**

A: Temp	12	D: PIA	26
B: MFD	230	E: Scone	1
C: MFF	49		

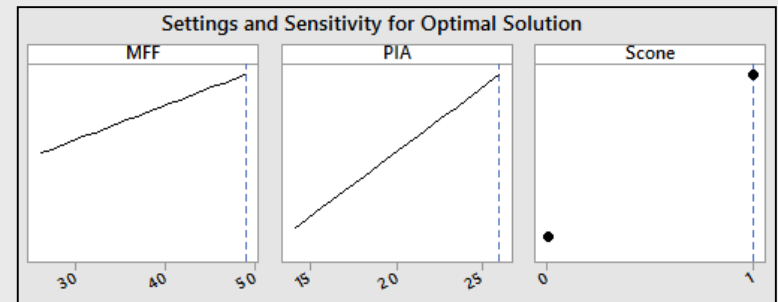
On the Prediction and Optimization Report, in the top centre, we are given the 95% prediction interval we can expect to achieve when conducting runs at the settings given to maximum power. Those settings are shown as the optimal solution.

We are then shown the settings that we need to set in order to achieve the maximum response using main effects plots. For all the factors this is the hi level of the factor



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# Analysis-4



Later in the are shown the top five alternate solutions.

Top Five Alternative Solutions					
A	B	C	D	E	Predict ed Y
12	180	26	26	1	651.099
12	230	26	14	1	631.575
12	230	26	26	0	628.084
9	230	26	26	1	622.702
10.5	205	37.5	20	1	622.385

The Report Card, not shown here, does tell us that Blocks were not significant and there were no other issues with our study. Curvature was not detected so we do not need to add more experimental points in order to explore the model.