Workshop - Uncertainty Quantification - 10 Bar Truss with MSC Nastran

AN MSC NASTRAN UNCERTAINTY QUANTIFICATION TUTORIAL

Questions? Email: christian@ the-engineering-lab.com

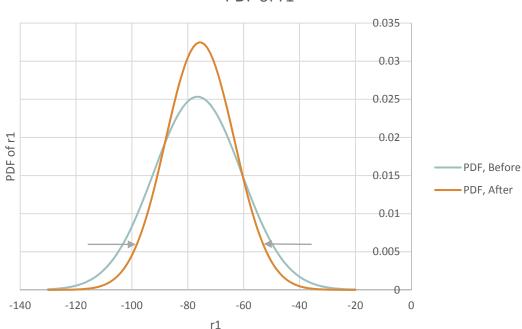


Goal: Use Uncertainty Quantification to Reduce Variance of Response r1

Before

• r1 Standard Deviation: 1.5740647557e+01

• r1 Standard Deviation: 1.2281104131e+01



PDF of r1

After



Goal: Use Uncertainty Quantification to Reduce Variance of Response r2

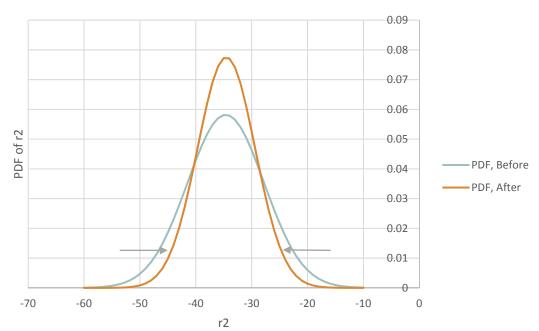
Before

• r2 Standard Deviation: 6.8557433340e+00

• r2 Standard Deviation: 5.1436271240e+00

PDF of r2

After

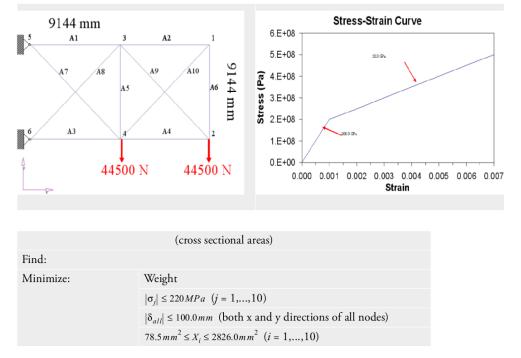




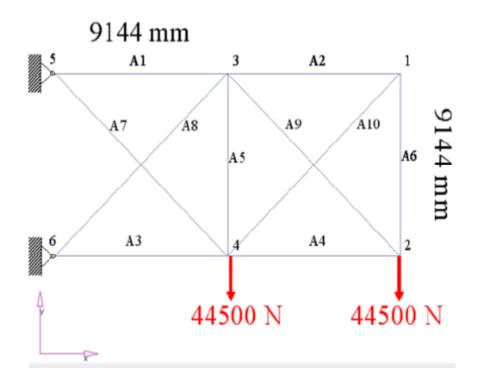
Details of the Structural Model

Examples

Example 1 10 Bar Truss (test library problem: deslo.dat)



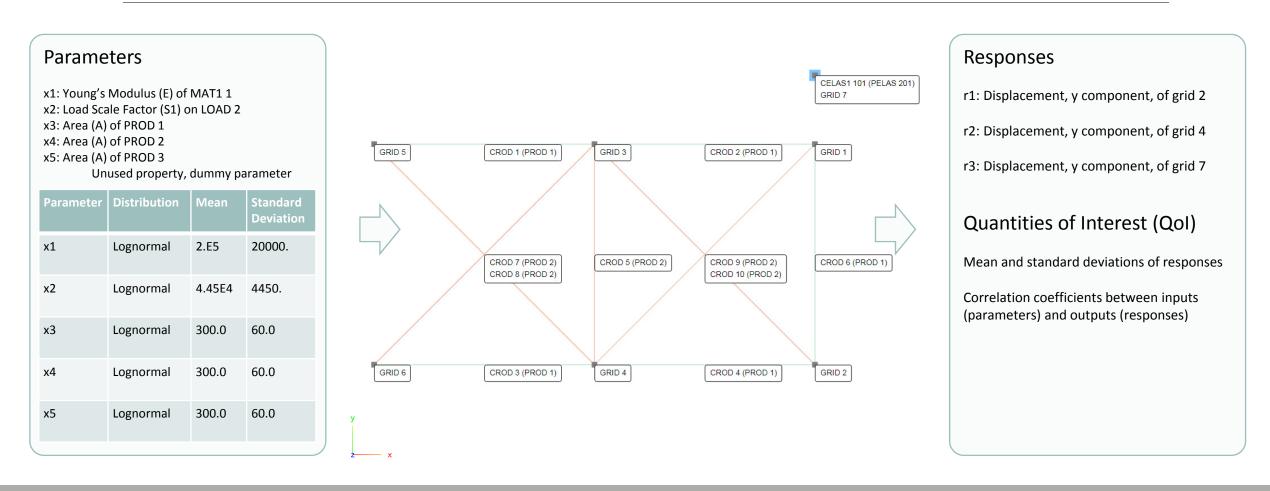
MSC Nastran Design Sensitivity and Optimization User's Guide Chapter 8 – Special Topics - Optimization of Nonlinear Structural Responses





Note that responses r1 and r2 are dependent on parameters x1, x2, x3, x4 and are expected to have non-zero correlation coefficients. Response r3 is dependent on no parameter and is expected to have zero or nearly zero correlation coefficients. Similarly, since parameter x5 is not used by any element, parameter x5 has no influence on any response and will have zero or nearly zero correlation coefficients.

Problem Statement

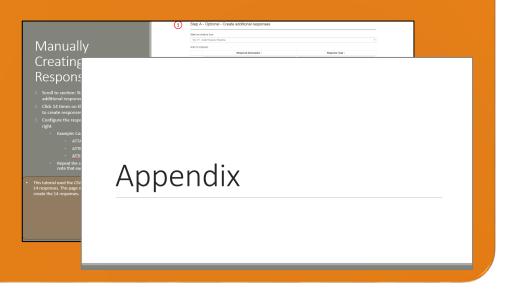




More Information Available in the Appendix

The Appendix includes information regarding the following:

- What is a projection?
- What is Pearson correlation coefficient?
- What is Spearman's correlation coefficient?
- What is skewness?
- What is kurtosis?
- What is a 95% confidence interval?





Contact me

- Nastran SOL 200 training
- Nastran SOL 200 questions
- Structural or mechanical optimization questions
- Access to the SOL 200 Web App

christian@ the-engineering-lab.com



Tutorial

Questions? Email: christian@ the-engineering-lab.com



Tutorial Overview

- 1. Start with a .bdf and .h5 file
- 2. Use the SOL 200 Web App to:
 - Configure an Uncertainty Quantification Task
 - Parameters
 - Responses
 - Samples
 - Perform Uncertainty Quantification
- 3. Display Uncertainty Quantification Results

Special Topics Covered

Uncertainty Quantification - There are many methods available to perform uncertainty quantification. This exercise details the sampling method for uncertainty quantification. The goal is to reduce the variance of outputs due to uncertain inputs. The Latin hypercube sampling method is used to generate samples. Quantities of interest include the mean, standard deviation and correlation coefficients.



SOL 200 Web App Capabilities

Compatibility

- Google Chrome, Mozilla Firefox or Microsoft Edge Installable on a company laptop, workstation or
- Windows and Red Hat Linux

server. All data remains within your company.

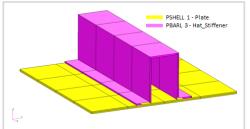
The Post-processor Web App and HDF5 Explorer are free to MSC Nastran users.

Benefits

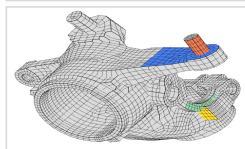
entries.

- REAL TIME error detection. 200+
- error validations.
- REALT TIME creation of bulk data •
- Web browser accessible
- Free Post-processor web apps
- +80 tutorials

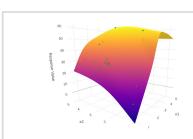
Web Apps



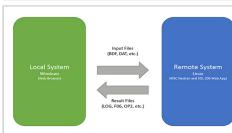
Web Apps for MSC Nastran SOL 200 Pre/post for MSC Nastran SOL 200. Support for size, topology, topometry, topography, multi-model optimization.



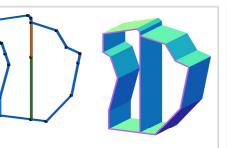
Shape Optimization Web App Use a web application to configure and perform shape optimization.



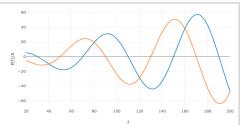
Machine Learning Web App Bayesian Optimization for nonlinear response optimization (SOL 400)



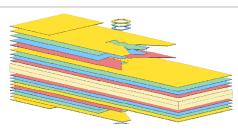
Remote Execution Web App Run MSC Nastran jobs on remote Linux or Windows systems available on the local network



PBMSECT Web App Generate PBMSECT and PBRSECT entries graphically



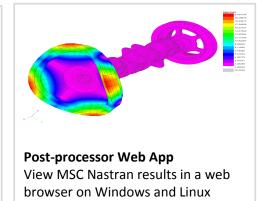
Dynamic Loads Web App Generate RLOAD1, RLOAD2 and DLOAD entries graphically



Ply Shape Optimization Web App Optimize composite ply drop-off locations, and generate new PCOMPG entries



Stacking Sequence Web App Optimize the stacking sequence of composite laminate plies



The manufacture of the second se

HDF5 Explorer Web App Create graphs (XY plots) using data from the H5 file



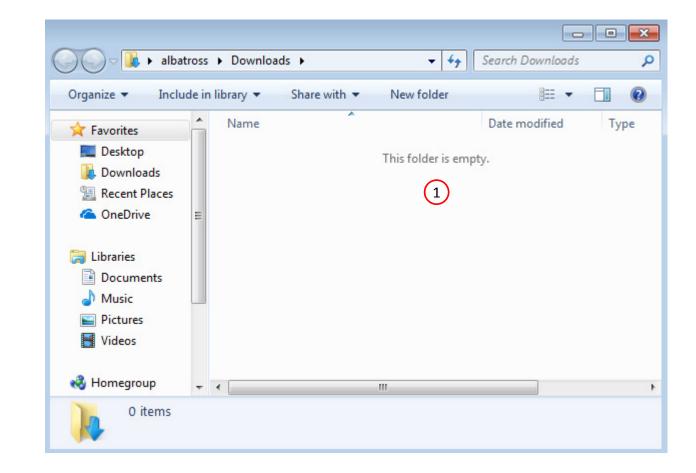
Part A – Initial Sampling

Questions? Email: christian@ the-engineering-lab.com



Before Starting

1. Ensure the Downloads directory is empty in order to prevent confusion with other files



Questions? Email: christian@ the-engineering-lab.com



The Engineering Lab

Go to the User's Guide

1. Click on the indicated link

• The necessary BDF files for this tutorial are available in the Tutorials section of the User's Guide.

Select a web app to begin Before After Optimization for SOL 200 Multi Model Optimization Machine Learning | Parameter HDF5 Explorer Viewer Study (1) Tutorials and User's Guide Full list of web apps

SOL 200 Web App

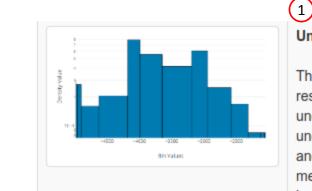
Questions? Email: christian@ the-engineering-lab.com



13

Obtain Starting Files

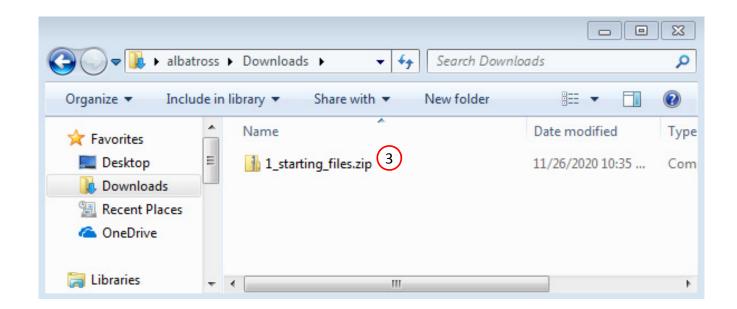
- 1. Find the indicated example
- 2. Click Link
- 3. The starting file has been downloaded



Uncertainty Quantification - 10 Bar Truss with MSC Nastran

This example details the use of uncertainty quantification to reduce the variability of responses when uncertain parameters are present. Forward propagation of uncertainty is the focuse of this exercise and the sampling method is used for uncertainty quantification. A 10 bar truss with 4 uncertain parameters is considered and a Latin Hypercube sampling is used. The quantities of interest include the mean and standard deviation values of the responses and correlation coefficients between the inputs (parameters) and outputs (responses).

Starting BDF Files Link 2 Solution BDF Files: Link





Obtain Starting Files

- 1. Right click on the zip file
- 2. Select Extract All...
- 3. Click Extract
- 4. The starting files are now available in a folder

→ ↓ albatross → Downloads →	 ✓ ✓ Search Downloads 	Q		• 1_starting_files
Organize 👻 😭 Open 👻 Share with	▼ New folder			
Favorites	Date modifie	d Type	Organize 🔻 🛛 Inclu	de in library 🔻 🛛 »
Develop				 Name
Downloads Recent Places	Open	Com	🗙 Favorites	
CneDrive	Open in new window		Desktop	📓 deslo_u
🗃 Libraries	2 Extract All		🗼 Downloads	=
Documents =	Edit with Notepad++ Open with		🖳 Recent Places	
a) Music	Share with	•		
Pictures Videos	Restore previous versions		📷 Libraries	
	Send to	•	Documents	
👶 Homegroup	Cut		J Music	
🖳 Computer	Сору		Pictures	
	Create shortcut		🛃 Videos	▼
Network	Delete	E E	1 item	
1_starting_files.zip Date n Compressed (zipped) Folder	Nodified Rename			
	Properties		· · ·	
0		×		
Extract Compressed (Zipped) Fold	ers			
Select a Destination and Extra	act Files			
Files will be extracted to this folder:				
C:\Users\albatross\Downloads\1_star	ting_files B	rowse		
Show extracted files when complet	e			
show extracted files when complete	-			
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	3 Extract	Cancel		

Questions? Email: christian@ the-engineering-lab.com



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deslo_uq.dat (4)

Create the Starting H5 File

(1

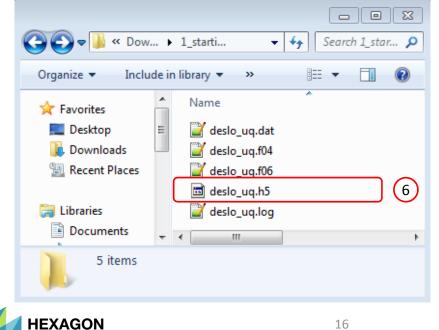
MSC Nastran

A starting H5 file must be created. This H5 file will be used to configure the responses later on.

- 1. Double click the MSC Nastran desktop shortcut
- 2. Navigate to the directory named 1_starting_files
- Select the indicated file
- 4. Click Open
- 5. Click Run
- 6. The starting H5 file is created

Na Select MSC.NASTRAN	Input File	✓ 4y Search 1_starting_files
Organize 🔻 New	folder	iii 🕶 🔳 🔞
🔆 Favorites	A Name	Date modified Type
🧫 Desktop	deslo_uq.dat 3	8/27/2024 8:23 AM Notepad
 Downloads Recent Places Libraries Documents Music Pictures Videos 	E	
📧 Computer	• • III	•
F	ile name: deslo_uq.dat	 ✓ Input Files (*.bdf;*.dat) ✓ ✓

MSC/NASTRAN Comm	and Information	—X —
MSC/NASTRAN Input Fi	le	
C:\Users\user\Downloa	ds\1_starting_files\deslo_sol_200_e	entries File
Optional keywords		
1		
Run	Cancel	Clear
5		



Technology Partner



Use the same MSC Nastran version throughout this exercise

The following applies if you have multiple versions of MSC Nastran installed.

To ensure compatibility, <u>use the same MSC Nastran version throughout this exercise</u>. For example, scenario 1 is OK but scenario 2 is NOT OK.

- Scenario 1 OK
 - MSC Nastran 2021 is used to create the starting H5 file.
 - MSC Nastran 2021 is used for each run during Machine Learning or Parameter study.
- Scenario 2 NOT OK
 - MSC Nastran 2018.2 is used to create the starting H5 file.
 - MSC Nastran 2021 is used for each run during Machine Learning or Parameter study.

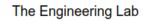
Using the same MSC Nastran version is critical for consistent response extraction from the H5 file. A response configured for Nastran version X may not match in Nastran version Y, which leads to unsuccessful response extraction from the H5 files. The goal is to make sure all H5 files generated are from the same MSC Nastran version.



Open the Correct Page

1. Click on the indicated link

- MSC Nastran can perform many optimization types. The SOL 200 Web App includes dedicated web apps for the following:
 - Optimization for SOL 200 (Size, Topology, Topometry, Topography, Local Optimization, Sensitivity Analysis and Global Optimization)
 - Multi Model Optimization
 - Machine Learning
- The web app also features the HDF5
 Explorer, a web application to extract results from the H5 file type.







Select BDF Files

- 1. Click Select files
- 2. Select the indicated file
- 3. Click Open
- 4. Click Upload files

 When starting the procedure, all the necessary BDF, or DAT, files must be collected and uploaded together. Relevant INCLUDE files must also be collected and uploaded.

Select BDF Files

	6		
4 2. Upload files			
Open			
→ ↓ caparici → Downloads → 1_starting_files	→ 49	Search 1_starting_files	
Organize 🔻 New folder			
Favorites	Date modified	Type Siz	e
Desktop Downloads Recent Places Libraries Documents	8/27/2024 8:23 AM	Notepad++ Docu	2 K
Music			



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Samples

- 1. Click Samples
- 2. Set Design to Latin Hypercube, Uncertain Parameters
- 3. Set Number of Samples to 40

SOL 200 Web App - Machine Learning	Parameters	1 Samples	Responses	Download	Results		
Configure Samples							
Design							
Latin Hypercube, Uncertain Parameters 2							~
+ Info							
Number of Samples							
40 3							
Questions? Email: christian@ the-enginee	ering-lab.com		EXAGON nology Partner			20	

Parameters

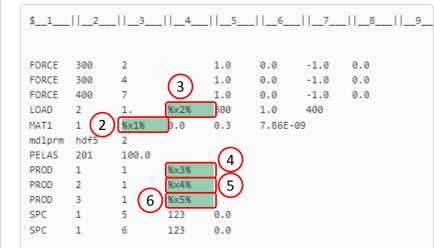
- 1. Click Parameters
- 2. Click the indicated field to create parameter x1
- Click the indicated field to create parameter x2
- 4. Click the indicated field to create parameter x3
- 5. Click the indicated field to create parameter x4
- 6. Click the indicated field to create parameter x5
- Modify the distribution, mean and standard deviation to match the values in the table below

Parameter	Distribution	Mean	Standard Deviation
x1	Lognormal	2.E5	20000.
x2	Lognormal	4.45E4	4450.
x3	Lognormal	300.0	60.0
x4	Lognormal	300.0	60.0
x5	Lognormal	300.0	60.0

- SOL 200 Web App Machine Learning Parameter
 - Parameters Samples

Settings U

Select Parameters



Configure Parameters

×1 ♥ Lognorm ♥ 2.E5 20000. × ×2 ♥ Lognorm ♥ 4.45E4 4450. × x3 ♥ Lognorm ♥ 300.0 60.0 × x4 ♥ Lognorm ♥ 300.0 60.0 × x5 ♥ Lognorm ♥ 300.0 60.0	Delete	Parameter	Status	Distribution	Mean	Standard Deviation
X3 Image: Constraint of the second seco	×	x1	•	Lognorm 🗸	2.E5	20000.
X4 Image: Constraint of the second	×	x2	0	Lognorm 🗸	4.45E4	4450.
	×	x 3	0	Lognorm 🗸	300.0	60.0
x5	×	x4	0	Lognorm 🗸	300.0	60.0
	×	x 5	0	Lognorm 🗸	300.0	60.0
					7	



Samples

Inspect the samples.

- 1. Click Samples
- 2. 40 samples have been generated
 - The samples are randomly selected, so different values should be expected
- Only 5 rows are displayed. The indicated controls maybe used to display 5, 10, 20, 30, 40 or 50 rows.
- 4. The indicated controls maybe used to view different rows of the table.

SOL 200 Web App - Machine Learning	Parameters	Samples	Responses	Download	Results		Settings	User's Guid	de H
									<
Configure Samples			Samples to	o Run					
Design Latin Hypercube, Uncertain Parameters		~	+ Options	2					
+ Info				Paramete	rs				
Number of Samples			Sample Numbe	r x1	x2	x3	x4		x5
40			1	174884.7	37349.77	274.5433	287.997	345.	.8363
			2	186008.8	46815.2	324.7452	314.7711	276.	9808
			3	223038.3	43149.24	247.141	357.8247	296.	7125
			4	205646.5	40630.63	215.1798	273.7796	320.	5307

5

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1

(1)



197142.4

2 3 4 5 6 7 8 »

(4)

49808.8

364.0946

317.9633

10

20

22

5

50

310.366

30

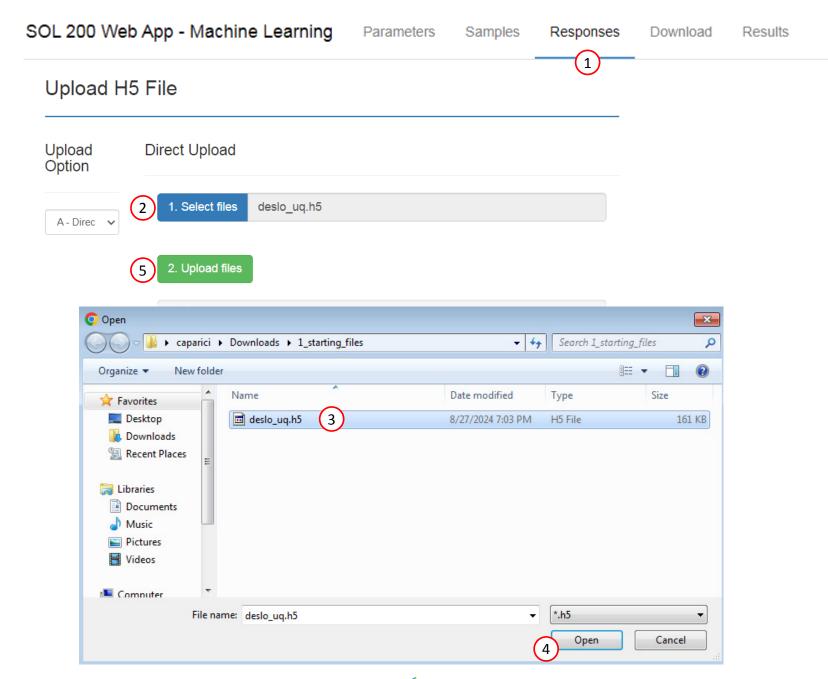
3

< >

Home

Responses

- 1. Click Responses
- 2. Click Select files
- 3. Select the indicated file
- 4. Click Open
- 5. Click Upload files
- On this page, the H5 file is uploaded to the web app.





Adjust the Column Width

- Description of the set of the
- Optional Use the indicated buttons to adjust the width of the column Select Dataset

 IMPORTANT! This image is not meant to match exactly what you see in your view. The text in this image is expected to be different from your view. The purpose of this page and image is to demonstrate how to increase the width of the indicated sections.

Select Res	ponse	s to Monif	or		Sessio	on ID: 3981	₩ HDF5	View f	Respo	nses	to Monit	or		
						2		Monitored	d Respon	ses		II Hide/Shov	v Columns 🔻 R	leset Filters 🛃 Download C
elect Dataset		Acquired Data			, li Res									Monitor the respons
		ID	мо	S	МХ	xx		Delete	Label	Status	Objective	Lower Bound	Upper Bound	of the FINAL desig cycle (SOL 200 only
	-								r1					
)L 200 Web A	op - Mac	hine Learnin	g Parameter	rs Samples	Responses	Download R	Results	×		0	~	Lower	Upper	Is User's Guide
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OL 200 Web A Select Res Select Dataset		es to Monit	tor	taset	Responses	Sessio	I I I I I I I I I I I I I I I I I I I	View F	Respo	onses		or	Setting	is User's Guide



Select Responses

- 1. Select the following dataset: NODAL/DISPLACEMENT
- 2. Select the indicated cell
- 3. Select the indicated cell
- 4. Select the indicated cell
- 5. The newly created Response to Monitor is listed as r1, r2, r3
- The column ID lists the grid ID for each row. The y-component of displacement for grids 2, 4 and 7 are set as responses for the uncertainty quantification.

Specify Entities	Grid identifier	X component	Y compor
1, 2, 3, 4, 5, 6, 7			
Grid identifier (ID) Examples: 1, 2, 3, etc.			
Auto Execute	1	15.2583773	-68 306230
	2	-17.1387563	-70.906076
Acquire Dataset	3	12.6585312	-30.135677
	4	-13.2591757	-32.435201
 Acquisition complete and successful 	5	0	0
	6	0	0
	7	0	-0.01

Parameters

Acquired Dataset

ID

NODAL/DISPLACEMENT - 1, 2, 3, 4, 5, 6, 7

х

Samples

Responses

Y

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(2)

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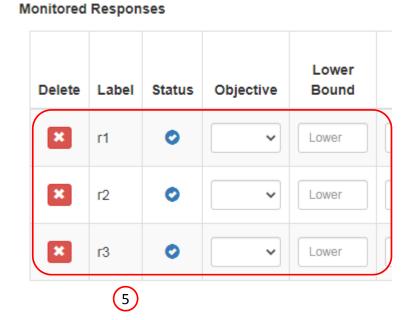
SOL 200 Web App - Machine Learning

Select Responses to Monitor

ELEMENTAL/STRESS/ELAS1

Select Dataset

View Responses to Monitor

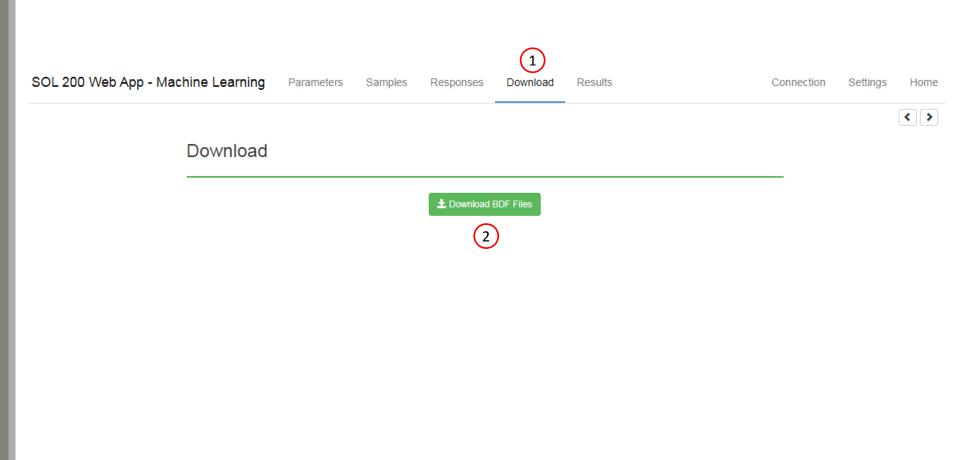




Download

1. Click Download

2. Click Download BDF Files





Start MSC Nastran

A new .zip file has been downloaded

- 1. Right click on the file
- 2. Click Extract All
- 3. Click Extract on the following window
- Always extract the contents of the ZIP file to a new, empty folder.

🔾 🗢 🚺 🕨 albatross	▶ Downloads ▶	✓ Search	n Downloads		٩	
Organize 🔻 🛛 🔭 Open	✓ Share with ▼	New folder		i≡ - □	0	
🔆 Favorites	Name	A	Date mo	odified	Туре	
🧮 Desktop	1_starting_files		11/26/20	020 10:57	File folde	
🝌 Downloads	1_starting_files.zip	0	11/26/20	020 10:35	Compre:	
🔛 Recent Places	🚺 nastran_working_	directory.zip		020 11-25	Compre	
ineDrive 🍊 🗠	(1)		Open Open in new	window		
🔚 Libraries		(2)	Extract All			
Documents			Edit with Not	epad++		
J Music			Open with			
Pictures Videos			Share with		+	
Videos			Restore previo	ous versions		
🤣 Homegroup			Send to		•	
🖳 Computer			Cut			
			Сору			
👊 Network			Create shortc	ut		
			Delete			
	•		Rename			
nastran_worki Compressed (zi	ng_directory.zip Date m	odified: 11/26/2 Size: 112 MB	Properties	💮 🚹 Б	dract Com	pressed (Zipped) Folders
Compressed (2)	pped) Folder	512C, 112 WID		Sele	ct a Dest	ination and Extract Files
				Files v	vill be extra	icted to this folder:
						oss\Downloads\nastran_working_directory Browse
				🔽 Shi	ow extracte	d files when complete
						3 Extract Cancel



Start Desktop App

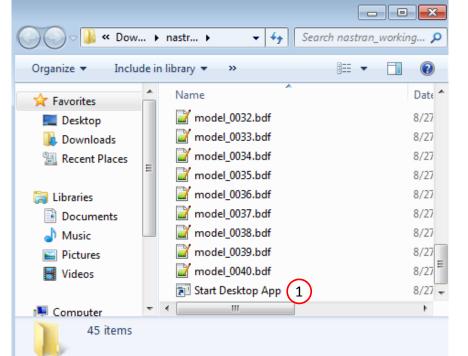
- 1. Inside of the new folder, double click on Start Desktop App
- 2. Click Open, Run or Allow Access on any subsequent windows
- 3. The Desktop App will now start
 - One can run the Nastran job on a remote machine as follows:
 1) Copy the BDF files and the INCLUDE files to a remote machine. 2) Run the MSC Nastran job on the remote machine. 3) After completion, copy the BDF, F06, LOG, H5 files to the local machine. 4) Click "Start Desktop App" to display the results.

Using Linux?

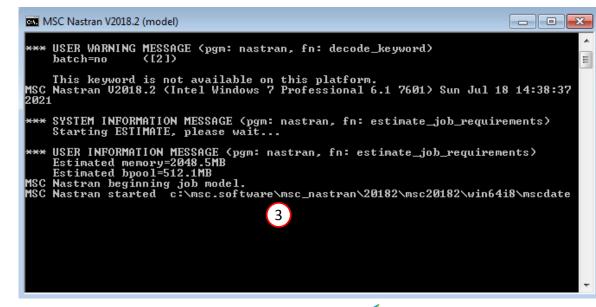
Follow these instructions:
1) Open Terminal
2) Navigate to the nastran_working_directory cd ./nastran_working_directory
3) Use this command to start the process ./Start_MSC_Nastran.sh

In some instances, execute permission must be granted to the directory. Use this command. This command assumes you are one folder level up.

sudo chmod -R u+x ./nastran_working_directory



Open File - Security V	Varning 💽
Do you want to op	pen this file?
Publisher: Type:	astran_working_directory\Start Desktop App.Ink Unknown Publisher Shortcut C:\Users\special-sunshine\Downloads\nastran
	2 Open Cancel
Always ask before	opening this file
potentially h	rom the Internet can be useful, this file type can arm your computer. If you do not trust the source, do not vftware. <u>What's the risk?</u>



Questions? Email: christian@ the-engineering-lab.com



Status

• While MSC Nastran is running, a status page will show the current state of MSC Nastran

SOL 200 Web App - Status

Status

n Python

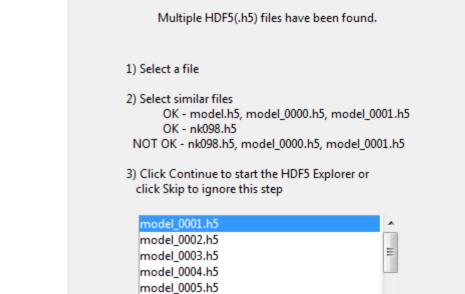
Name	Status of Job	Design Cycle	RUN TERMINATED DUE TO	
model.bdf	Running	None		



MSC Nastran

Machine Learning Results

1. After the process is complete, you will be asked to start the HDF5 Explorer. You can click Skip to skip opening the HDF5 Explorer.



MSC Nastran SOL 200 Web App Alert

model_0006.h5 model_0007.h5 model_0008.h5 model_0009.h5 model_0010.h5

Questions? Email: christian@ the-engineering-lab.com



Continue

Skip

- 0 X

Results

After each MSC Nastran analysis is complete, multiple web apps are automatically opened to display the results.

- 1. Use the tabs to switch between each web app
- 2. A description of each web app is given in the table.

			1			
Status	×	Monitored Responses	×	Dakota Results	×	+

2

Name of Web App	Purpose	Description
Monitored Responses	• The response value from each sample can be compared.	 After each MSC Nastran analysis, the response values are extracted from the H5 file and contained in a file named app_monitored_responses.csv. The Monitored Responses web app is used to create a bar chart of the values contained in this CSV file.
Dakota Results	 This web app displays the results of a Dakota study. 	 After the responses for all samples are acquired, Sandia Dakota is executed to determine the statistics.



Review Results

- 1. The Monitored Responses web app is opened
- 2. The r1, r2 and r3 responses correspond to the y component of displacement at grids 2, 4 and 7, respectively.

- A. The table titled Monitored Response can be interacted with. Each column in the table contains filters. Once a filter is modified, the Bar Chart will instantly update.
- B. Additional functions include the ability to highlight the MAX and MIN bars, download a CSV file and reset the filters.

								Sample Sa	e 0003 e 0004 e 0005 e 0006 e 0007 e 0008 e 0009 e 0010 e 0011 e 0012 e 0013 e 0014 e 0015	
	r1			r2				r3		
A B Response										
Monitored R				nload CSV		Monitored Responses	-			
Label	Dataset Name	Field	Field Description	Current Value		0001	0002	0003	0004	
r1 1 r2 r3	NODAL/DISPLACEMENT	Y *	Y component							
r1	NODAL/DISPLACEMENT	Y	Y component	-70.9060765290356		-76.42735491111817	-78.50731533683063	-68.90564041084161	-84.23063204367745	-73.:
r2	NODAL/DISPLACEMENT	Y	Y component	-32.435201821223686		-34.60718799959459	-36.15139708944005	-29.167511862165235	-36.61959885618245	-34.9
r3	NODAL/DISPLACEMENT	Y	Y component	-0.01		-0.01	-0.01	-0.01	-0.01	-0.0

2





Sample 0001

File: workspace_d/dakota.out



<<<<< Function evaluation summary (UQ_I): 0 total (0 new, 0 duplicate) Statistics based on 40 samples: Sample moment statistics for each response function: Mean Std Dev Skewness Kurtosis r1 -7.6503177738e+01 1.5740647557e+01 -3.0160263416e-01 1.9898804450e-01 r2 -3.4632432122e+01 6.8557433340e+00 -1.6460111268e-01 -7.8956929011e-02 r3 -1.000000000e-02 5.2704682654e-18 1.0393904031e+00 -2.1081081081e+00 95% confidence intervals for each response function: LowerCI Mean UpperCI Mean LowerCI StdDev UpperCI StdDev r1 -8.1537281050e+01 -7.1469074425e+01 1.2894124891e+01 2.0211550111e+01 **r2** -3.6825005210e+01 -3.2439859033e+01 5.6159576948e+00 8.8030177564e+00 r3 -1.000000000e-02 -1.000000000e-02 4.3173621544e-18 6.7674683057e-18 [...] Simple Correlation Matrix among all inputs and outputs: x1 x2 x3 x5 r1 r2 r3 x4x1 1.00000e+00 x2 -1.10512e-01 1.00000e+00 x3 1.54094e-01 1.69421e-01 1.00000e+00 x4 1.89505e-01 3.46524e-01 2.64909e-01 1.00000e+00 x5 2.22206e-01 -2.01454e-01 -6.08376e-02 -2.87279e-01 1.00000e+00 r1 6.51560e-01 -3.11070e-01 6.56974e-01 3.76223e-01 5.31302e-02 1.00000e+00 r2 6.81976e-01 -2.85070e-01 5.14679e-01 5.51336e-01 -2.56422e-03 9.63153e-01 1.00000e+00 r3 1.31839e-15 -7.16441e-16 6.31439e-16 -9.47159e-16 -2.73739e-15 -4.38885e-16 1.24206e-15 1.00000e+00 Partial Correlation Matrix between input and output: r2 r1 r3 x1 8.60024e-01 8.85721e-01 2.31708e-15 x2 -8.60492e-01 -8.86258e-01 -4.23496e-16 x3 9.12323e-01 8.45796e-01 7.48632e-16 x4 6.98539e-01 8.85942e-01 -2.27173e-15 x5 -8.90610e-02 -1.36330e-01 -3.76261e-15



Review Results

1. In the background, Sandia Dakota was executed to determine the quantities of interest, e.g. mean, standard deviation, etc. The results are contained in the OUT file.

SOL 200 Web App - Dakota Results Upload OUT File Upload Tabular File Scatter Plots Histograms Tables

1

Statistics based on 40 samples

Sample moment statistics for each response function

3	Mean	Standard Deviation	2	Skewness	Kurtosis
r1	-7.6503177738e+01	1.5740647557e+01		-3.0160263416e-01	1.9898804450e-01
r2	-3.4632432122e+01	6.8557433340e+00		-1.6460111268e-01	-7.8956929011e-02
r3	-1.0000000000e-02	5.2704682654e-18		1.0393904031e+00	-2.1081081081e+00

95% confidence intervals for each response function

	LowerCl_Mean	UpperCI_Mean	LowerCI_StdDev	UpperCI_StdDev
r1	-8.1537281050e+01	-7.1469074425e+01	1.2894124891e+01	2.0211550111e+01
r2	-3.6825005210e+01	-3.2439859033e+01	5.6159576948e+00	8.8030177564e+00
r3	-1.000000000e-02	-1.000000000e-02	4.3173621544e-18	6.7674683057e-18

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L Download CSV

34

Review Results

Click Tables

- 2. Note the standard deviation. The goal in this exercise is to reduce the variance, or standard deviation. These standard deviation values will be used for future comparison.
- 3. The mean values based on 40 samples are displayed.

Review Results

- 1. Click Histograms
- 2. The mean and standard deviation values from the previous page are used to build a probability density function (PDF) assuming the response has a normal distribution. The PDF is plotted as the orange plot/trace.
- 3. The horizontal axis represents the response level.
- 4. The vertical axis represents the count or frequency.
- 5. The vertical axis to the right represents the probability density value and is colored orange.

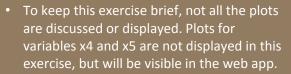
If the blue bars align to the PDF plot, the response's distribution is normal. If the bars do not align, the distribution is not normal.



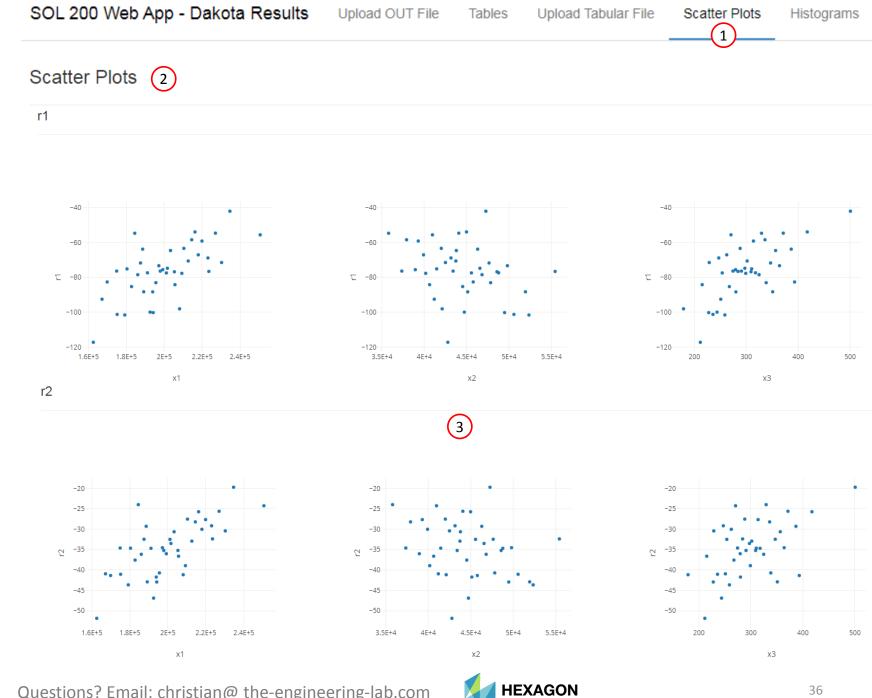


Review Results

- Click Scatter Plots
- 2. Scroll to section Scatter Plots
- Projections for each variable are displayed as scatter plots.



Refer to the Appendix for an explanation of what is a projection.



Technology Partner

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Review Results

Notice some of the following trends.

- 1. For response r1 across x1,
 - The relationship appears linear

r1

r2

-20

-25

-30

-35

-40

-45-

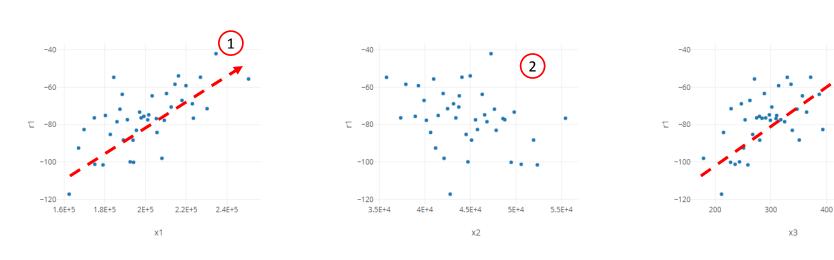
1.6E+5

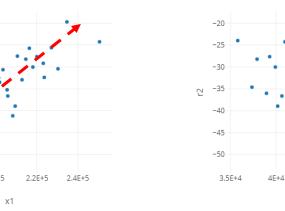
1.8E+5

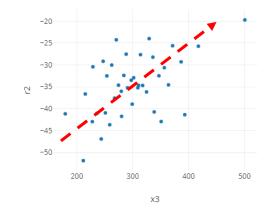
2E+5

2

- 2. For response r1 across x2,
 - There is no clear relationship, linear or nonlinear, that may be defined







Questions? Email: christian@ the-engineering-lab.com



5E+4

4.5E+4

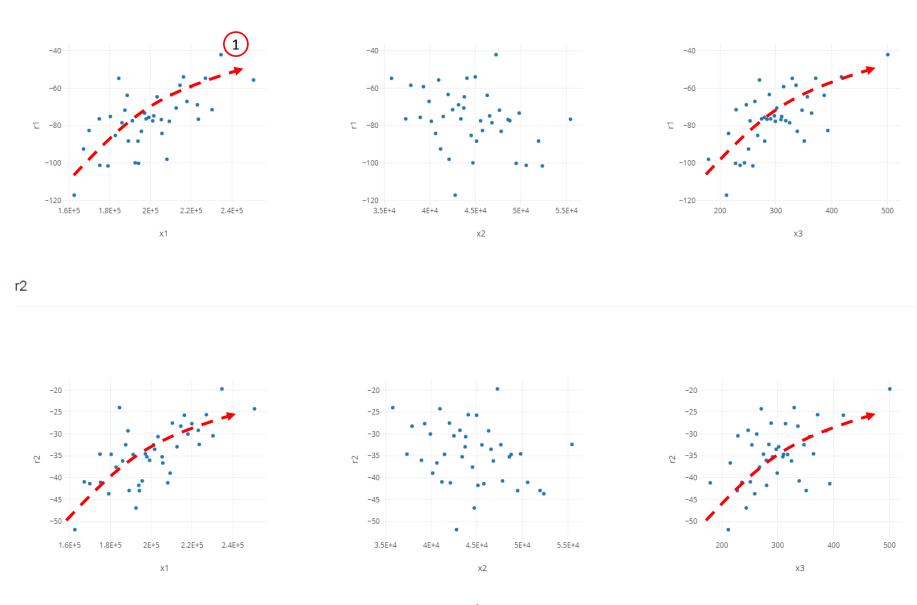
x2

5.5E+4

500

Review Results

 Alternatively, a nonlinear relationship may be defined for some r1





Correlation Coefficients

Dakota outputs 2 types of correlation coefficients.

Pearson Correlation Coefficient

- Simple Correlation Matrix
- Partial Correlation Matrix

Spearman's Correlation Coefficient

- Simple Rank Correlation Matrix
- Partial Rank Correlation Matrix

File: workspace	_d/dakota.out
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Correlation Coefficients

- 1. Use the Pearson type when the relationship is linear. The coefficient is positive if the linear relationship is increasing, else it is negative if decreasing.
- 2. Do NOT use the Pearson type if the relationship is nonlinear.
- 3. Use the Spearman's type when the relationship is nonlinear AND monotonic. Monotonic is when the relationship is always increasing OR decreasing, but not both together.
- Do NOT use the Spearman's type when the relationship is both increasing and decreasing.





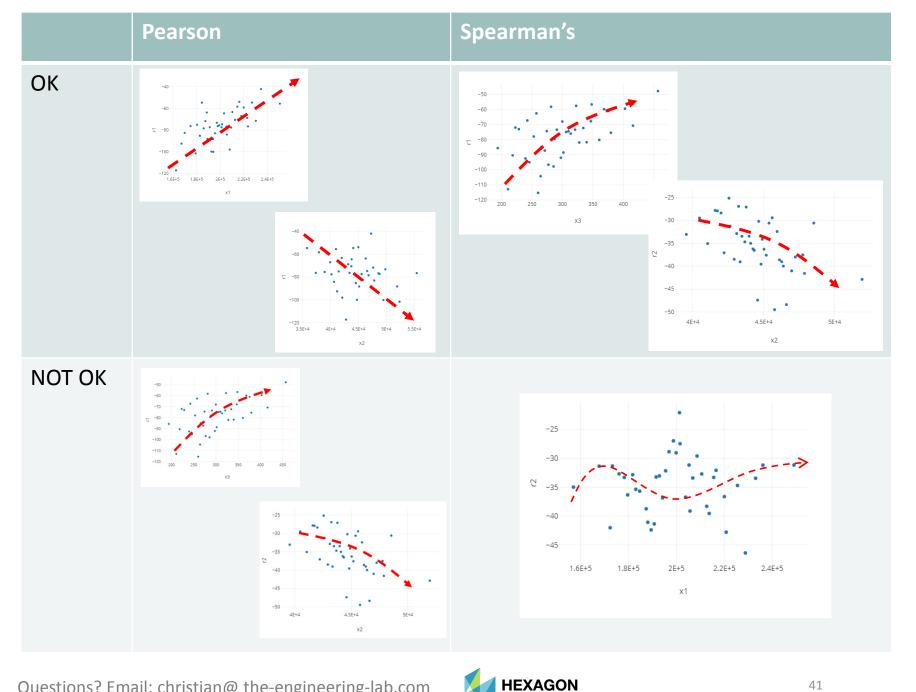
Correlation Coefficients

Decision logic:

Is the relationship linear?

- Yes Use Pearson
 - Is there only one parameter?
 - Yes Use Simple Correlation Matrix
 - No Use Partial Correlation Matrix
- No Is the relationship nonlinear AND monotonic?
 - Yes Use Spearman's
 - Is there only one parameter?
 - Yes Use Simple **Rank Correlation** Matrix
 - No Use Partial **Rank Correlation** Matrix
 - No Do not consider correlation coefficients

It was previously shown the scatter plots suggest a linear relationship between outputs and inputs, so Pearson correlation coefficients are inspected. Since there are 5 parameters involved, the table titled Partial Correlation Matrix is used.



Technology Partne



Review Results

The Pearson correlation coefficients are inspected. The goal is to identify 2 parameters that are strongly correlated to the responses. Once these parameters are identified, these parameters will be adjusted to reduce the variance.

- 1. Navigate to section Simple Correlation Matrix among all inputs and outputs
- A response is strongly correlated to a parameter if its coefficient is close to 1.0. Many practitioners will define "strongly correlated" differently. For this exercise, a strong correlation is any coefficient that is greater than 0.9. If the coefficient is negative, use the absolute value.
- As a preferred alternative, use the partial correlation coefficients. Navigate to section Partial Correlation Matrix between input and output.
- For response r1, parameter x3 has a strong influence on response r1.
- 5. For response r2, parameter x4 has a modest influence on response r2.
- Alternatively, parameter x2 has a stronger influence on response r2. Parameter x2 corresponds to the load factor and is more difficult to control in practice. Since x3 and x4 are both cross section areas, and may be controlled through better manufacturing procedures, these parameters are selected for further adjustment.

	x1	x2	x3	x4	x5	r1	r2	r3
x1	1.00000e+00							
x2	-1.10512e-01	1.00000e+00						
х3	1.54094e-01	1.69421e-01	1.00000e+00					
x4	1.89505e-01	3.46524e-01	2.64909e-01	1.00000e+00				
x5	2.22206e-01	-2.01454e-01	-6.08376e-02	-2.87279e-01	1.00000e+00			
r1 (2)	6.51560e-01	-3.11070e-01	6.56974e-01	3.76223e-01	5.31302e-02	1.00000e+00		
r2	6.81976e-01	-2.85070e-01	5.14679e-01	5.51336e-01	-2.56422e-03	9.63153e-01	1.00000e+00	
r3	1.31839e-15	-7.16441e-16	6.31439e-16	-9.47159e-16	-2.73739e-15	-4.38885e-16	1.38951e-15	1.00000e+00

(1)

Partial Correlation Matrix between input and output (3)

Simple Correlation Matrix among all inputs and outputs

.

	r1	r2	r3
x1	8.60024e-01	8.85721e-01	2.31708e-15
x2	-8.60492e-01 6	-8.86258e-01	-4.23496e-16
x3 (4)	9.12323e-01	8.45796e-01	7.48632e-16
x4	6.98539e-01 5	8.85942e-01	-2.27173e-15
x5	-8.90610e-02	-1.36330e-01	-3.76261e-15



L Download CSV

L Download CSV

Review Results

- 1. Recall that parameter x5 is a dummy parameter and has no influence on the responses. Their correlation coefficients are zero or nearly zero.
- 2. Similarly, response r3 is also a dummy response and is not influenced by any parameter. Its correlation coefficients are zero or nearly zero.
- 3. The same statements may be said for the partial correlation coefficients.

	x1	x2	x3	x4	x5	r1	r2	r3
x1	1.00000e+00							
x2	-1.10512e-01	1.00000e+00						
х3	1.54094e-01	1.69421e-01	1.00000e+00					
x4	1.89505e-01	3.46524e-01	2.64909e-01	1.00000e+00				
x5	2.22206e-01	-2.01454e-01	-6.08376e-02	-2.87279e-01	1.00000e+00			
r1	6.51560e-01	-3.11070e-01	6.56974e-01	3.76223e-01	5.31302e-02	1.00000e+00		
r2	6.81976e-01	-2.85070e-01	5.14679e-01	5.51336e-01	-2.56422e-03	9.63153e-01	1.00000e+00	
r3 (2)	1.31839e-15	-7.16441e-16	6.31439e-16	-9.47159e-16	-2.73739e-15	-4.38885e-16	1.38951e-15	1.00000e+00

Partial Correlation Matrix between input and output

Simple Correlation Matrix among all inputs and outputs

	r1	r2	r3	
x1	8.60024e-01	8.85721e-01	2.31708e-15	
x2	-8.60492e-01	-8.86258e-01	-4.23496e-16	
x3	9.12323e-01	8.45796e-01	7.48632e-16	
x4	6.98539e-01	8.85942e-01	-2.27173e-15	
x5	-8.90610e-02	-1.36330e-01	-3.76261e-15	3



L Download CSV

L Download CSV

.

Part B – Secondary Sampling



Parameters

- Return to the Machine Learning web app
- 2. Click Parameters
- 3. Set the standard deviation of parameters x3 and x4 to 30.0
 - Parameters x3 and x4 were previously identified as having a strong correlation to the responses and are ideal parameters to adjust with the goal of reducing the variance of the responses. The original standard deviation of 60.0 was halved to 30.0 in an attempt to reduce the response's variance. Since parameters x3 and x4 correspond to cross sectional areas, reducing the standard deviation of these parameters may be achieved by improving the manufacturing process of the truss members.

SOL 200 Web App - Machine Learning 2 Parameters Samples Responses Download

-1.0 0.0

0.0

0.0

-1.0

-1.0

400

Select Parameters

2

4

1.

2

1

1

1

5

6

%x1%

100.0

FORCE

FORCE

FORCE

LOAD

MAT1

mdlprm

PELAS

PROD

PROD

PROD

SPC

SPC

300

300

400

1

2

3

1

1

hdf5

201

\$_1__||_2__||_3__||_4__||_5__||_6__||_7__||_8__||_9__||_1

0.0

0.0

0.0

1.0

7.86E-09

1.0

1.0

1.0

0.3

0.0

0.0

%x2% 300

0.0

%x3%

%x4%

%x5%

123

123

Configure Parameters

Delete	Parameter	Status	Distribution	Mean	Standard Deviation	Comments
×	x1	0	Lognorm: 🗸	2.E5	20000.	Field 3 of MAT1 1
×	x2	0	Lognorm: 🗸	4.45E4	4450.	Field 4 of LOAD 2
×	х3	0	Lognorm: 🗸	300.0	30.0	Field 4 of PROD 1
×	x4	0	Lognorm: 🗸	300.0	30.0	Field 4 of PROD 2
×	x5	0	Lognorm: 🗸	300.0	60.0	Field 4 of PROD 3

Settings

Home

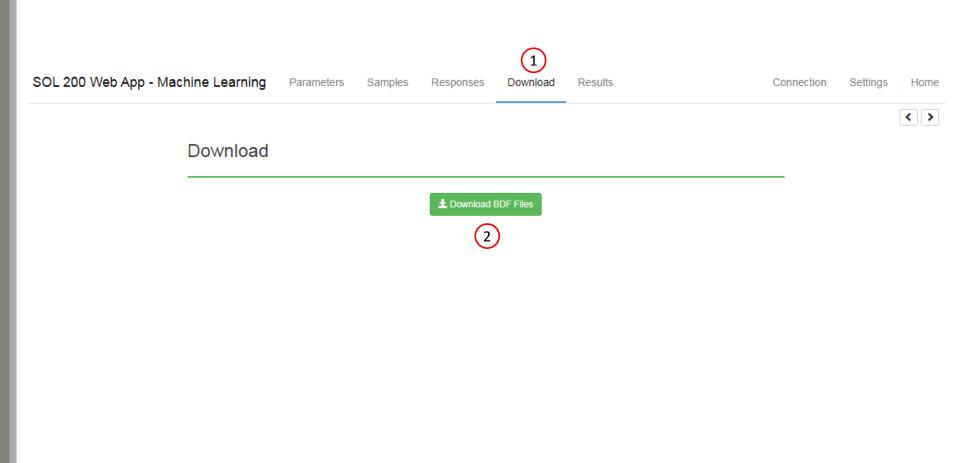
User's Guide



Download

1. Click Download

2. Click Download BDF Files





Start MSC Nastran

A new .zip file has been downloaded

- 1. Right click on the file
- 2. Click Extract All
- 3. Click Extract on the following window
- Always extract the contents of the ZIP file to a new, empty folder.

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Organize 🔻 🛛 🔭 Open	 Share with ▼ E-mail New f 	folder				
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🧮 Desktop	1_starting_files			8/27/2024 7:03 PN	1 File folder	
🗼 Downloads	Inastran_working_directory			8/28/2024 3:49 PN	1 File folder	
E Recent Places	hastran_working_directory.zip			8/27/2024 7:11 PM		
Libraries Documents Music Pictures Videos Computer Computer Coal Disk (C:) Pownloads (\\VBox: Network	nastran_working_directory (1).zip		Open Open in new w Extract All Edit with Note Open with Share with Restore previou Send to Cut Copy Create shortcu Delete	2 pad++ us versions	Compress	
	< است g_directory (1).zip Date modified: 8/28/202 ped) Folder Size: 124 MB		Rename Properties	Se	elect a Desti es will be extrac	pressed (Zipped) Folders ination and Extract Files cted to this folder:
						ci\Downloads\nastran_working_directory (1) Browse
						3 Extract Can



Start Desktop App

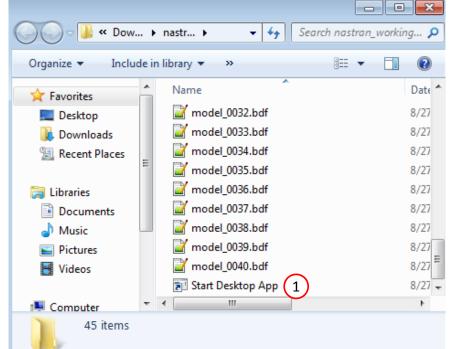
- 1. Inside of the new folder, double click on Start Desktop App
- 2. Click Open, Run or Allow Access on any subsequent windows
- 3. The Desktop App will now start
 - One can run the Nastran job on a remote machine as follows:
 1) Copy the BDF files and the INCLUDE files to a remote machine. 2) Run the MSC Nastran job on the remote machine. 3) After completion, copy the BDF, F06, LOG, H5 files to the local machine. 4) Click "Start Desktop App" to display the results.

Using Linux?

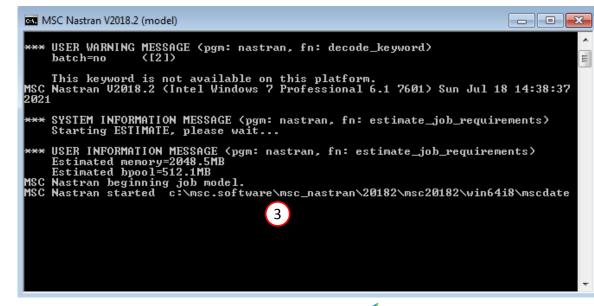
Follow these instructions:
1) Open Terminal
2) Navigate to the nastran_working_directory cd ./nastran_working_directory
3) Use this command to start the process ./Start_MSC_Nastran.sh

In some instances, execute permission must be granted to the directory. Use this command. This command assumes you are one folder level up.

sudo chmod -R u+x ./nastran_working_directory



Open File - S	Security Warning								
Do you want to open this file?									
	Name:astran_working_directory\Start Desktop App.Ink								
	Publisher: Unknown Publisher								
	Type: Shortcut								
	From: C:\Users\special-sunshine\Downloads\nastran								
	2 Open Cancel								
🔽 Always a	ask before opening this file								
🛛 🚺 🛛 po	/hile files from the Internet can be useful, this file type can otentially harm your computer. If you do not trust the source, do not ben this software. <u>What's the risk?</u>								





Status

• While MSC Nastran is running, a status page will show the current state of MSC Nastran

SOL 200 Web App - Status

Status

n Python

Name	Status of Job	Design Cycle	RUN TERMINATED DUE TO
model.bdf	Running	None	

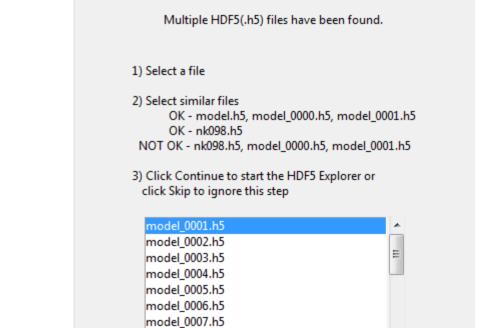
Questions? Email: christian@ the-engineering-lab.com



MSC Nastran

Machine Learning Results

1. After the process is complete, you will be asked to start the HDF5 Explorer. You can click Skip to skip opening the HDF5 Explorer.



MSC Nastran SOL 200 Web App Alert

model_0008.h5 model_0009.h5 model_0010.h5

Questions? Email: christian@ the-engineering-lab.com



Continue

Skip

- 0 X

SOL 200 Web App - Dakota Results Upload OUT File Tables Upload Tabular File Scatter Plots Histograms

User's Guide Home

L Download CSV

Statistics based on 40 samples

Sample moment statistics for each response function

	Mean	Standard Deviation	3	Skewness	Kurtosis
r1	-7.5622608233e+01	1.2281104131e+01		-7.2542475037e-01	2.9380181403e-01
r2	-3.4533539421e+01	5.1436271240e+00		-6.1549999809e-01	3.9912244651e-02
r3	-1.000000000e-02	5.2704682654e-18		1.0393904031e+00	-2.1081081081e+00

95% confidence intervals for each response function

r1

r2

r3

LowerCl_Mean UpperCI Mean LowerCl StdDev UpperCI StdDev -7.9550295882e+01 -7.1694920585e+01 1.0060201773e+01 1.5769373570e+01 4.2134588358e+00 -3.6178551181e+01 -3.2888527660e+01 6.6045997785e+00 -1.000000000e-02 -1.000000000e-02 4.3173621544e-18 6.7674683057e-18

Review Results

- 1. Refer to the Dakota Results web app
- 2. Click Tables
- 3. Note the new standard deviation values. In the next part, a comparison is performed between the original and new standard deviations.



Part C – Comparison of Results



Review Results

Recall the goal was to reduce the variance or standard deviation of the responses r1 and r2. The standard deviations of the responses from parts A and B are record in the shown table.

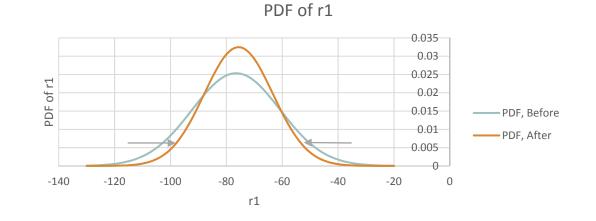
	Initial Uncertainty Quantification (Part A)	Final Uncertainty Quantification (Part B)
r1	1.5740647557e+01	1.2281104131e+01
r2	6.8557433340e+00	5.1436271240e+00



Before

After

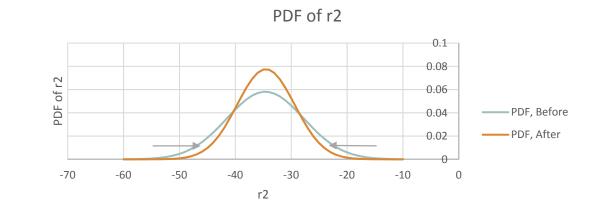
r1 Standard Deviation: 1.5740647557e+01 r1 Standard Deviation: 1.2281104131e+01



Before

After

r2 Standard Deviation: 6.8557433340e+00
 r2 Standard Deviation: 5.1436271240e+00





Review Results

- Assuming a normal distribution for both responses, a probability density function is plotted for both responses by using the means and standard deviations from parts A and B.
- The standard deviations have been reduced for both responses r1 and r2, indicating the variances of the responses has been successfully reduced.
- The PDF plots also indicate the variance of the responses has been successfully reduced.
- When this exercise is repeated, the values are expected to be different since the sampling is random.
 Regardless of the randomization, reducing the variance should be achievable when this exercise is repeated and the procedure is followed.

Excel

Since the mean and standard deviation were determined, Excel may be used to create probability density function (PDF) plots for each response. Then, comparisons may be made between the original and new PDFs.

	5- 0								Book1.xlsx	- Excel		
File	Home Insert	Page Layout Formi	ılas Data Reviev	v View	♀ Tell me wha	at you want to do						
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				-								Styles
SUM	• • • ×	✓ f _x =NORMDI	ST(A7,\$C\$3,\$C\$4,FALS	€())								
	А	В	С	D	E	F	G	Н	<u> </u>	J	K	L
	Response	r1										
2												
	Mean	-3.46E+01	i									
	Standard Deviatio	6.86E+00	5.14E+00									
5	_											
-		PDF, Before	PDF, After									
7	-60	l	=NORMDIST(A7									
8	-59	0.000105094		, standard_dev,	cumulative)							
9	-58	0.000174629						DDF (-			
10	-57	0.000284063						PDF of r	2			
11	-56	0.000452348								0.0	9	
12 13	-55 -54	0.000705165						_		0.08	8	
13 14	-54	0.001076139					/			0.0	7	
14 15	-53	0.002351275								0.0	6	
15 16	-52	0.003366362		2								
17	-51	0.004718221		= of r2						0.0		
18	-30	0.006473746		PDF						0.04	4	PDF, Before
10 19	-48	0.008695467								0.03	3	PDF, After
20	-47	0.011433788								0.02	2	
21	-46	0.014717948								0.0	1	
22	-45	0.018546602								- (0	
23	-44	0.022879227		-70	-60	-50	-40	-30	-20	-10	0	
24	-43	0.027629835					r	2				
25	-42	0.032664436										



End of Tutorial



Appendix



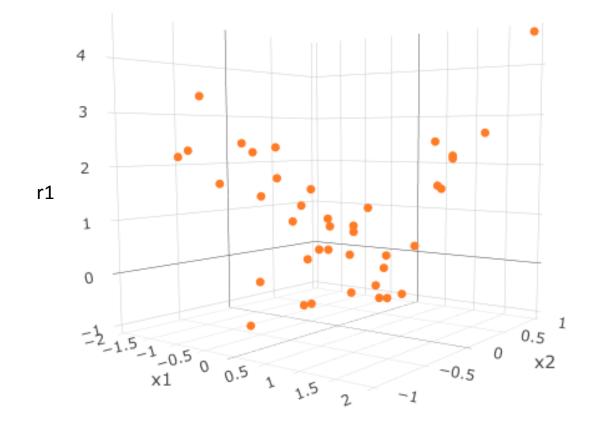
Appendix Contents

- What is a projection?
- What is Pearson correlation coefficient?
- What is Spearman's correlation coefficient?
- What is skewness?
- What is kurtosis?
- What is a 95% confidence interval?



What is a projection?

Consider a response that is dependent on multiple parameters. In the example on the right, the response is dependent on 2 parameters x1 and x2.

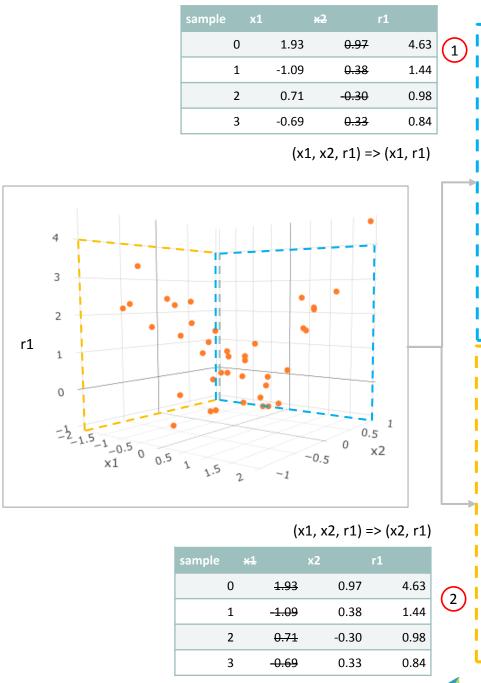


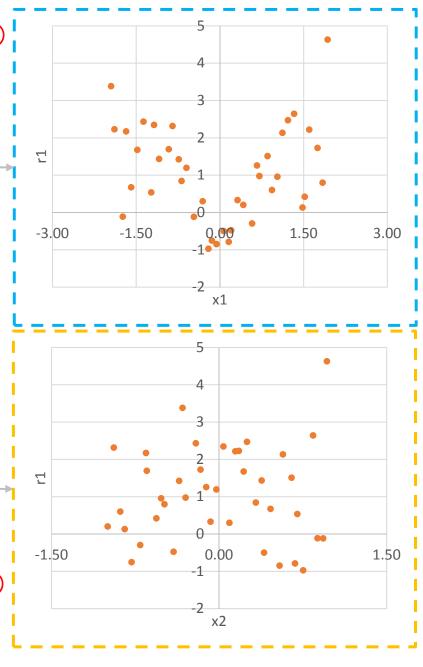


What is a projection?

An orthogonal projection is when N dimensional data is projected onto a 2D plane.

- 1. For the indicated plot, the 3D data is visualized on the x1, r1 plane.
- 2. For the indicated plot, the 3D data is visualized on the x2, r1 plane.





HEXAGON Technology Partner



What is Pearson Correlation Coefficient?

- Dakota lists Pearson correlation coefficients under the table titled Simple Correlation Matrix among all inputs and outputs.
- Another form of Pearson correlation coefficients are listed in the table titled Partial Correlation Matrix between input and output.

Visit

https://www.scribbr.com/statistics/pearson-correlation-coefficient/#visualize



What is Spearman's Correlation Coefficient?

- Dakota lists Spearman's correlation coefficients under the table titled Simple Rank Correlation Matrix among all inputs and outputs.
- Another form of Spearman's correlation coefficients are listed in the table titled Partial Rank Correlation Matrix between input and output.

Visit

https://www.scribbr.com/statistics/correlation-coefficient/#spearmans-rho



What is Skewness?

Visit

https://www.scribbr.com/statistics/skewness/



What is Kurtosis?

Visit

https://www.scribbr.com/statistics/kurtosis/



What is a confidence interval?

A confidence interval is NOT a probability or chance.

NOT OK

- There is a 95% probability the quantity of interest is within the interval.
- There is a 95% chance the quantity of interest is within the interval.

A confidence interval is confidence.

ОК

- There is 95% CONFIDENCE the quantity of interest is within the interval.
- After repeated sampling, 95% of confidence intervals will contain the true quantity of interest.

Visit

https://en.wikipedia.org/wiki/Confidence interval

