מוסד שמואל נאמן
למחקר מדיניות לאומית

אנליטיקה ותעשייה 4.0

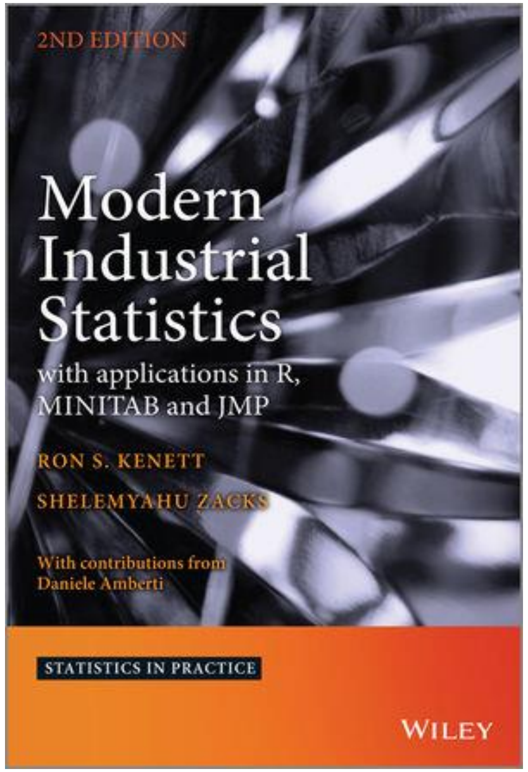
https://www.aeai.org.il/activity/smart-factory-num7-webinar

פרופ' רון קנת וד"ר אביגדור זוננשיין

Technion
Israel Institute of Technology

תעשייה 4.0

תעשייה 4.0




מוסד שמואל נאמן
למחקר מדיניות לאומית

קידום תשתיות ייצור מתקדמות
בעזרת אנליטיקה:
סקירת כלים ויישומים

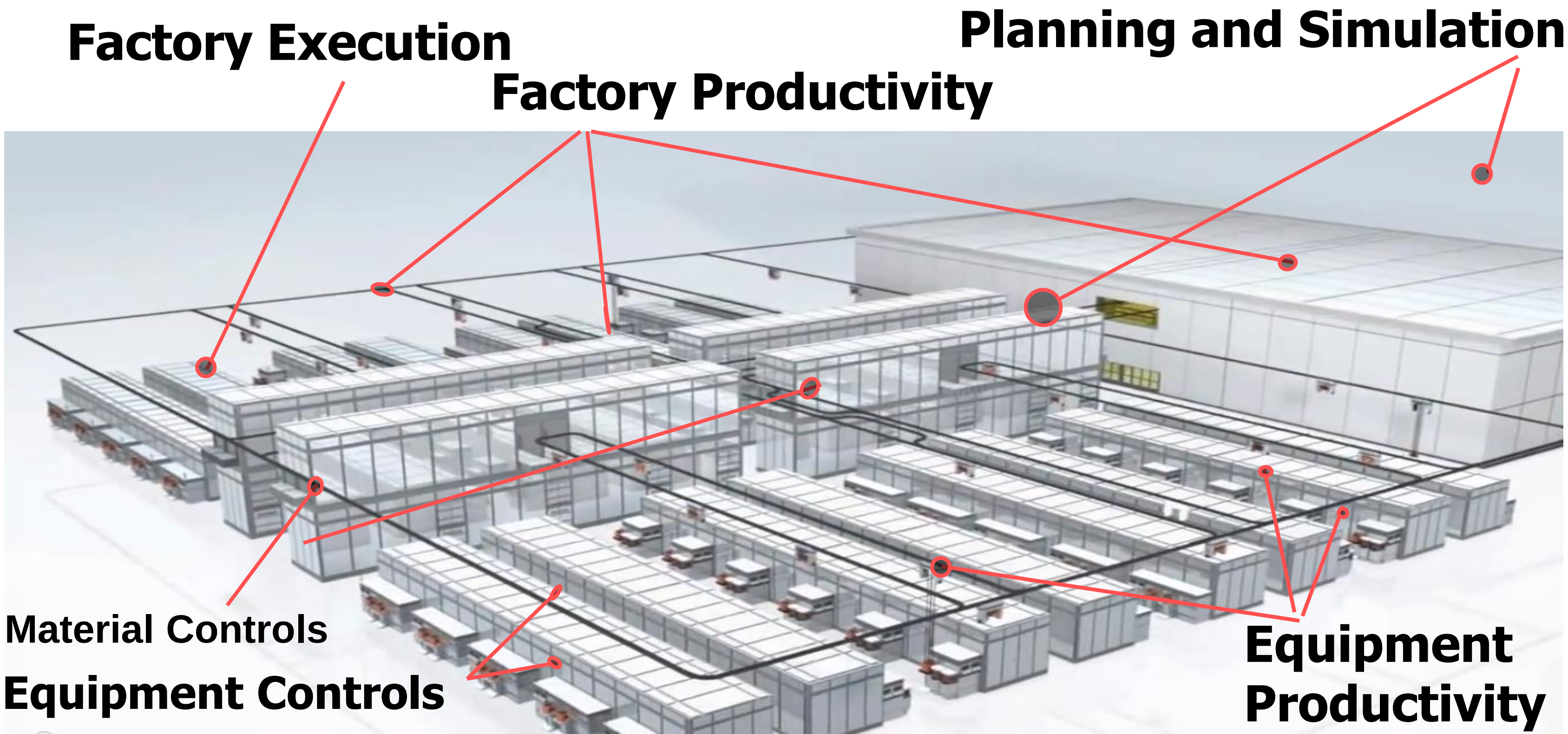
דו"ח ביניים

חוקרים:
פרופ' רון קנת
ד"ר ענבל יהב
ד"ר אביגדור זוננשיין

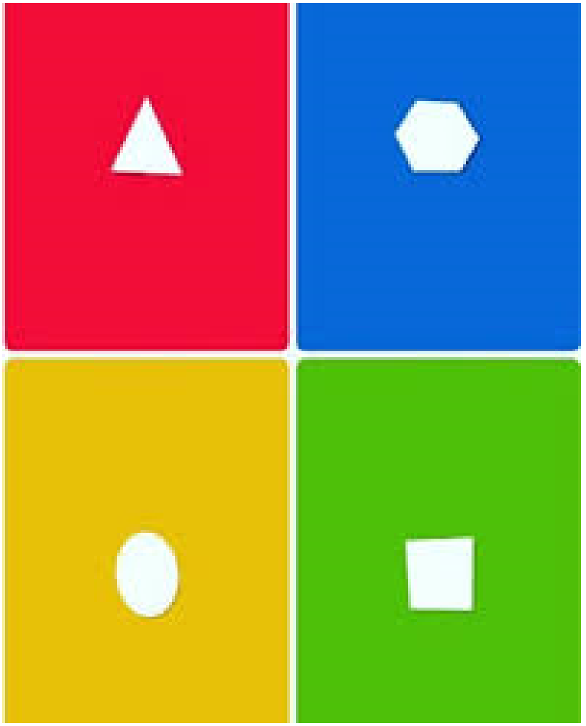
https://www.neaman.org.il/EN/Files/Data-Analytics-approaches-and-tools-survey-for-promoting-advanced-manufacturing.pdf

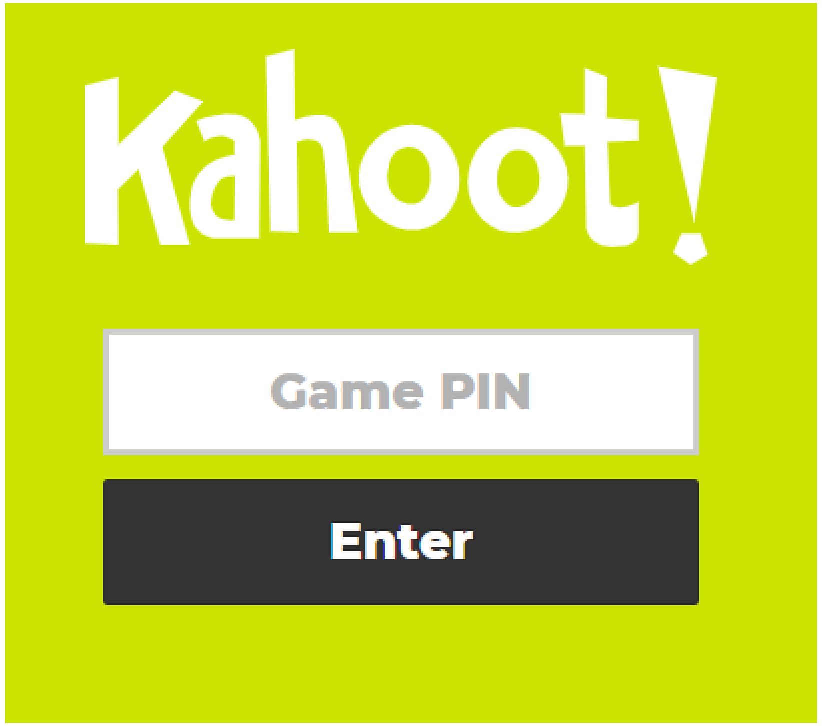
Monitoring – ניטור
Diagnostics – אבחון
Prognostics – חיזוי
Prescriptive - הנחיה

התחום האנליטי בייצור מתקדם



Kahoot.it





Kahoot.it

חידון מספר 1

מוסד שמואל נאמן
למחקר מדיניות לאומית

בחן את המשמעות מאחורי התמונות ובחר את התמונה עם משמעות דומה ל **א** ברמה המושגית.

סמן אותה בעזרת הצבע המתאים בטלפון החכם שלך.

א

ב

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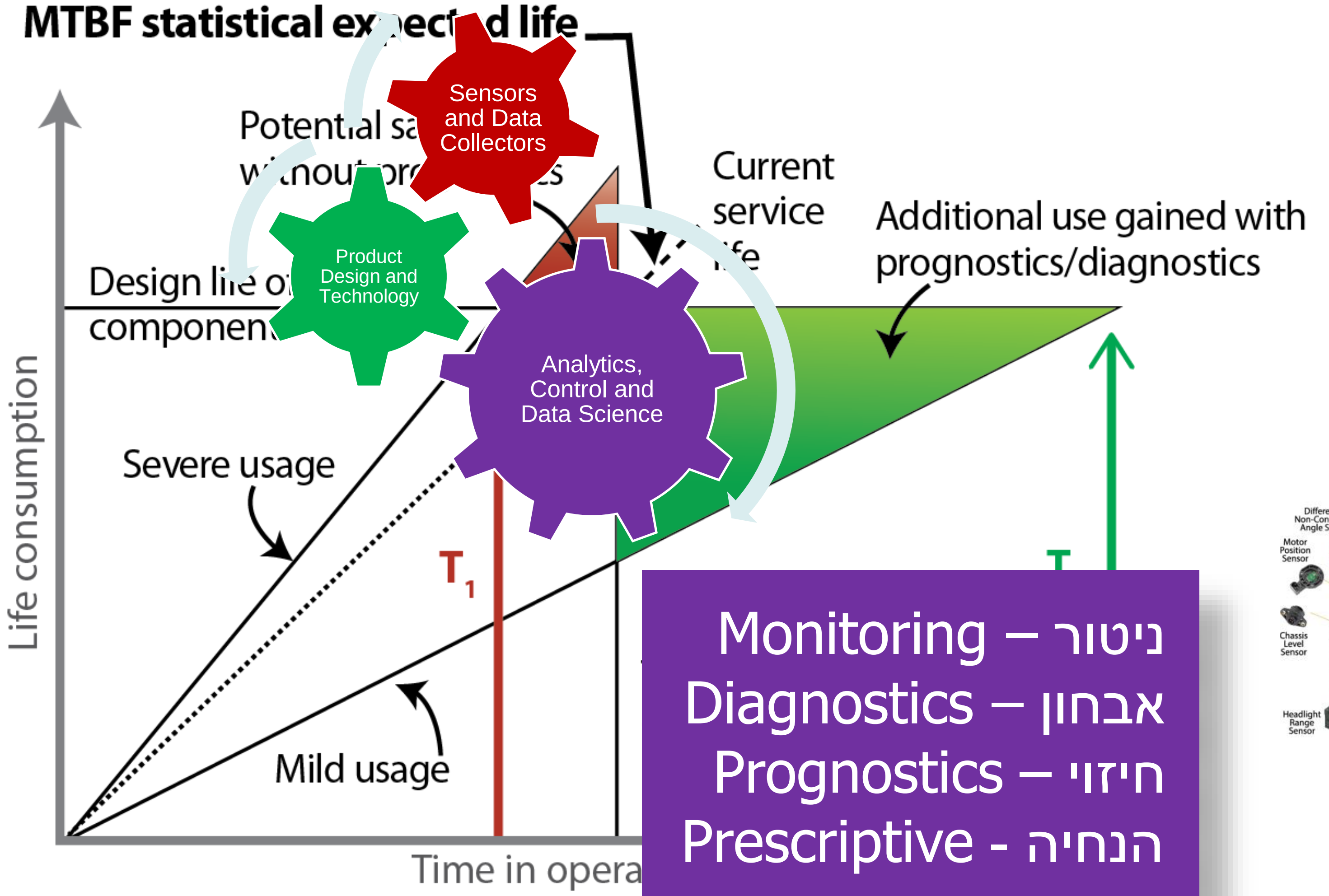
ה

הטכניון
מכון טכנולוגי לישראל

6

Condition Based Maintenance (CBM)
Health and Usage Monitoring Systems (HUMS)
Prognostics and Health Monitoring (PHM)

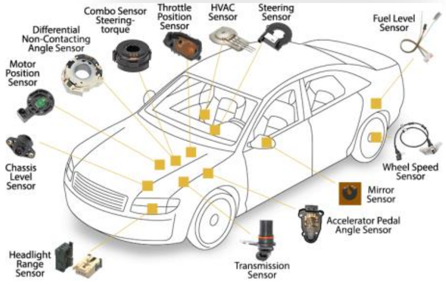


Monitoring – ניטור
Diagnostics – אבחון
Prognostics – חיזוי
Prescriptive - הנחיה

Source: Economic and Safety Benefits of Diagnostics & Prognostics (Romero et al. 1996)

Analytics

Sensor technology



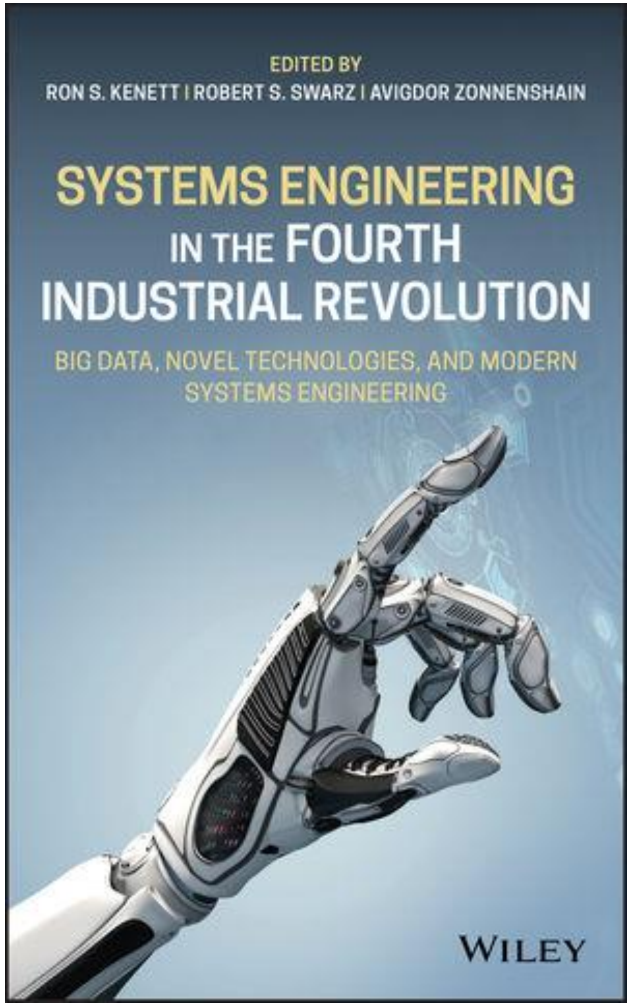
00514

מוסד שמואל נאמן
למחקר מדיניות לאומית

הטכניון
מכון טכנולוגי לישראל

7

https://www.wiley.com/en-us/Systems+Engineering+in+the+Fourth+Industrial+Revolution%3A+Big+Data%2C+Novel+Technologies%2C+and+Modern+Systems+Engineering-p-9781119513926



1. Engineering design
2. Manufacturing systems
3. Decision support systems
4. Shop floor control and layout
5. Fault detection and quality improvement
6. Condition-based maintenance
7. Customer and supplier relationship management
8. Energy and infrastructure management
9. Cybersecurity and security related issues

מוסד שמואל נאמן
למחקר מדיניות לאומית

הטכניון
מכון טכנולוגי
לישראל

8

Domain Space

Analytic Space

Goals

Information Quality

4 רכיבים

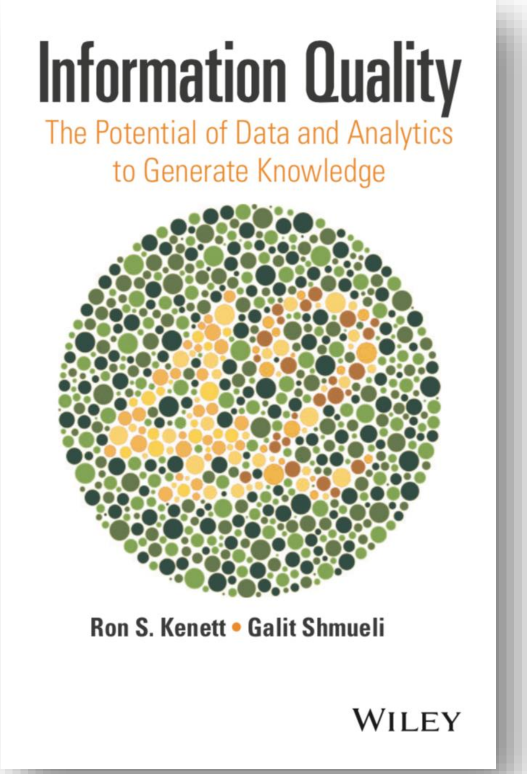
What

$$InfoQ(U,f,X,g) = U(f(X|g))$$

8 ממדים

How

1. Data resolution
2. Data structure
3. Data integration
4. Temporal relevance
5. Chronology of data and goal
6. Generalizability
7. Operationalization
8. Communication



An historical perspective

From product quality to information quality

מוסד שמואל נאמן
למחקר מדיניות לאומית

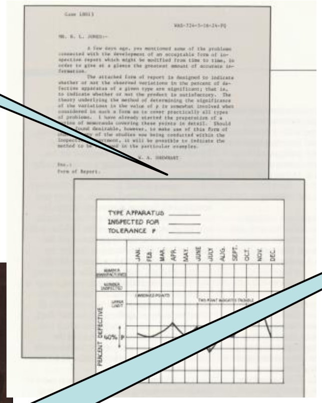
Product Quality	Process Quality	Service Quality	Management Quality	Design Quality	Information Quality
1800	1900	1950	1960	1980	2010

בקרת תהליכים

דגימת קבלה

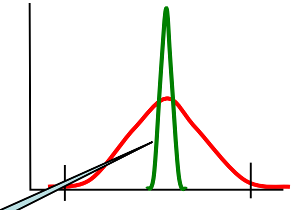
Specifications

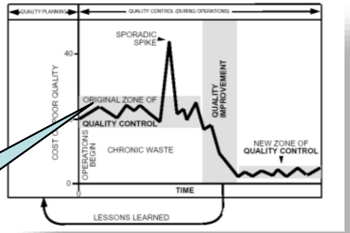
Inspecti



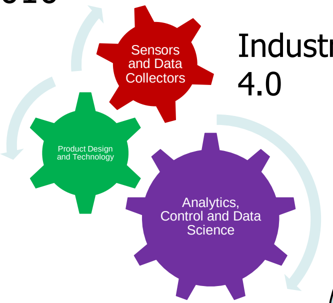
Control Charts

Robust Design





- Control
- Design
- Improvement



Industry 4.0

שיפור בקרה תיכנון

תכן חסין

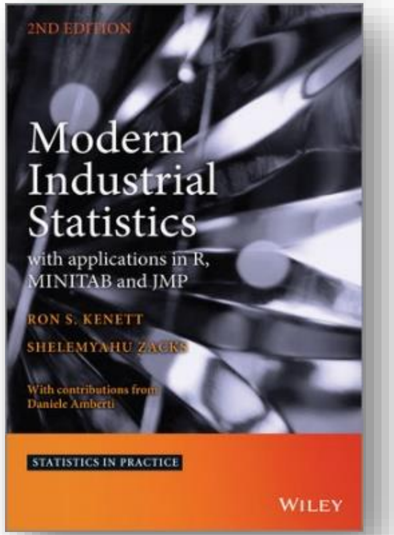
Overcontrol
Undercontrol

הטכניון
מכון טכנולוגי
לישראל

An historical perspective

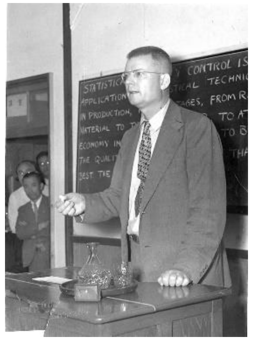
From product quality to information quality

Product Quality	Process Quality	Service Quality	Management Quality	Design Quality	Information Quality
1800	1900	1950	1960	1980	2010



Eli Whitney
(1765 – 1825)

Walter Shewhart
(1891 – 1961)

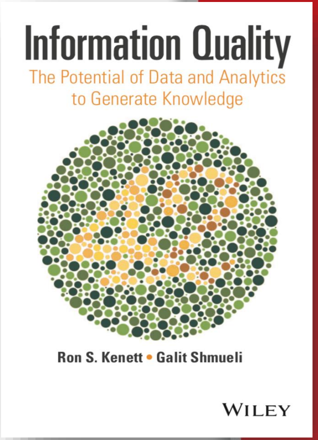


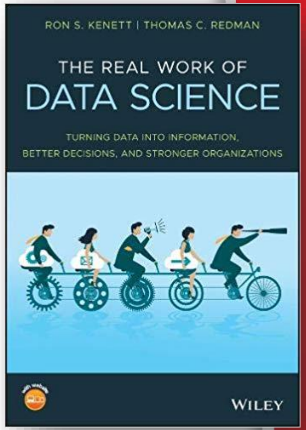
Edwards Deming
(1900 – 1993)

Joseph Juran
(1904 - 2008)

George Box
(1919 – 2013)

Genichi Taguchi
(1924 – 2012)





מוסד שמואל נאמן
למחקר מדיניות לאומית

הטכניון
מכון טכנולוגי
לישראל

Kahoot.it

חידון מספר 2

בחן את המשמעות מאחורי התמונות ובחר את התמונה עם משמעות דומה ל **א** ברמה המושגית.

סמן אותה בעזרת הצבע המתאים בטלפון החכם שלך.

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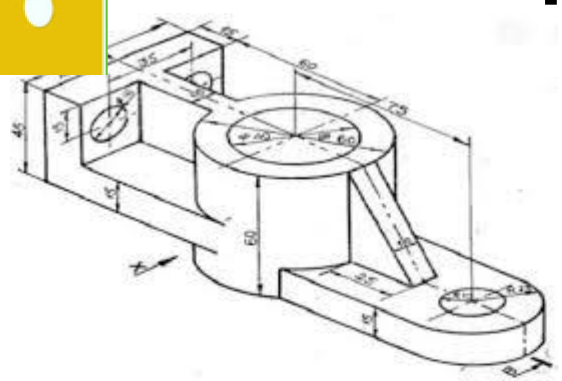
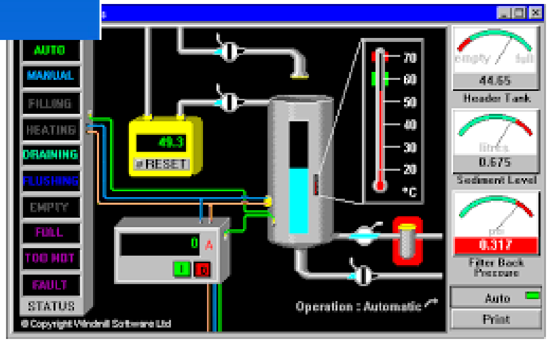


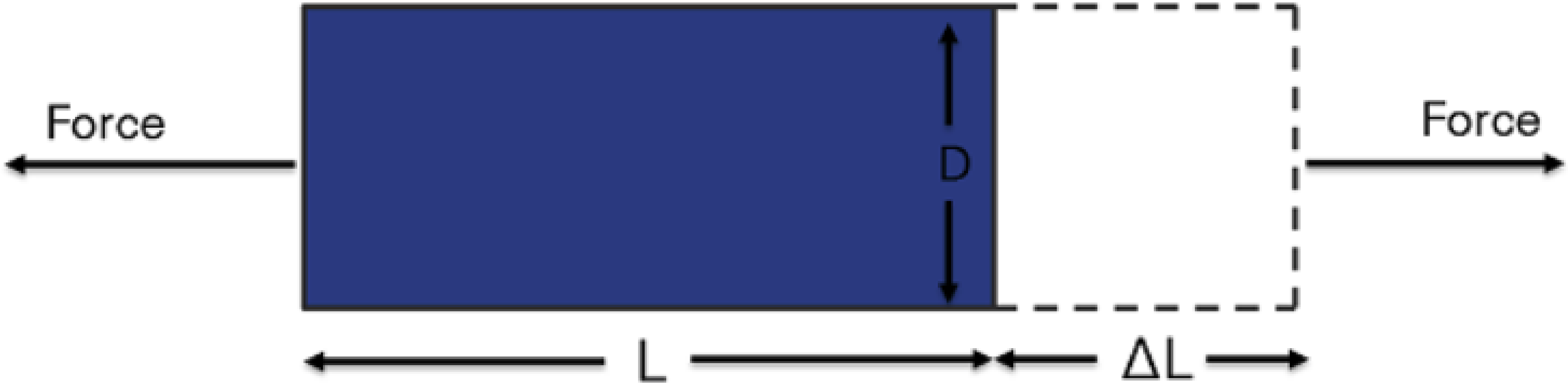
ה



מוסד שמואל נאמן למחקר מדיניות לאומית
הטכניון מכון טכנולוגי לישראל

דוגמא
מספר 1

Strain measurement



$$\varepsilon = \frac{\Delta L}{L}$$

Monitor structure deformation due to changes in pressure or temperature using strain measurement sensors.

Strain gauge

From Wikipedia, the free encyclopedia

A **strain gauge** is a device used to measure strain on an object. Invented by Edward E. Simmons and Arthur C. Ruge in 1938, the most common type of strain gauge consists of an insulating flexible backing which supports a metallic foil pattern. The gauge is attached to the object by a suitable adhesive, such as cyanoacrylate.[1] As the object is deformed, the foil is deformed, causing its electrical resistance to change. This resistance change, usually measured using a Wheatstone bridge, is related to the strain by the quantity known as the *gauge factor*.

הוצג בכנס PHM
בהרצליה 28.6.2018

Monitoring – ניטור
Diagnostics – אבחון
Prognostics – חיזוי
Prescriptive - הנחיה

Fiber Bragg grating sensors [edit source]

As well as being sensitive to strain, the Bragg wavelength is also sensitive to temperature. This means that fiber Bragg gratings can be used as sensing elements in optical fiber sensors. In a FBG sensor, the measurand causes a shift in the Bragg wavelength, $\Delta\lambda_B$. The relative shift in the Bragg wavelength, $\Delta\lambda_B/\lambda_B$, due to an applied strain (ϵ) and a change in temperature (ΔT) is approximately given by,

$$\left[\frac{\Delta\lambda_B}{\lambda_B}\right] = C_S\epsilon + C_T\Delta T$$

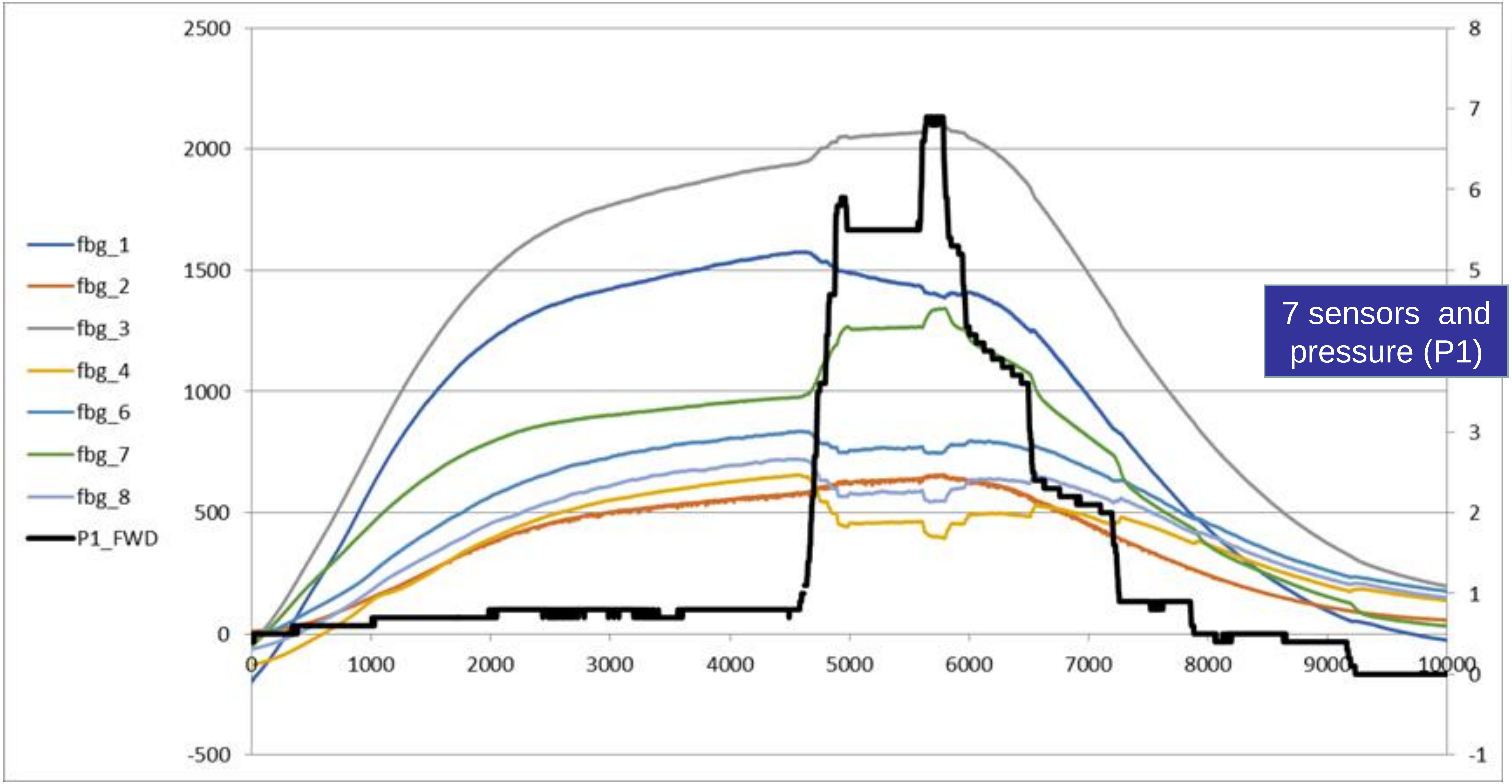
or,

$$\left[\frac{\Delta\lambda_B}{\lambda_B}\right] = (1 - p_e)\epsilon + (\alpha_\Lambda + \alpha_n)\Delta T$$

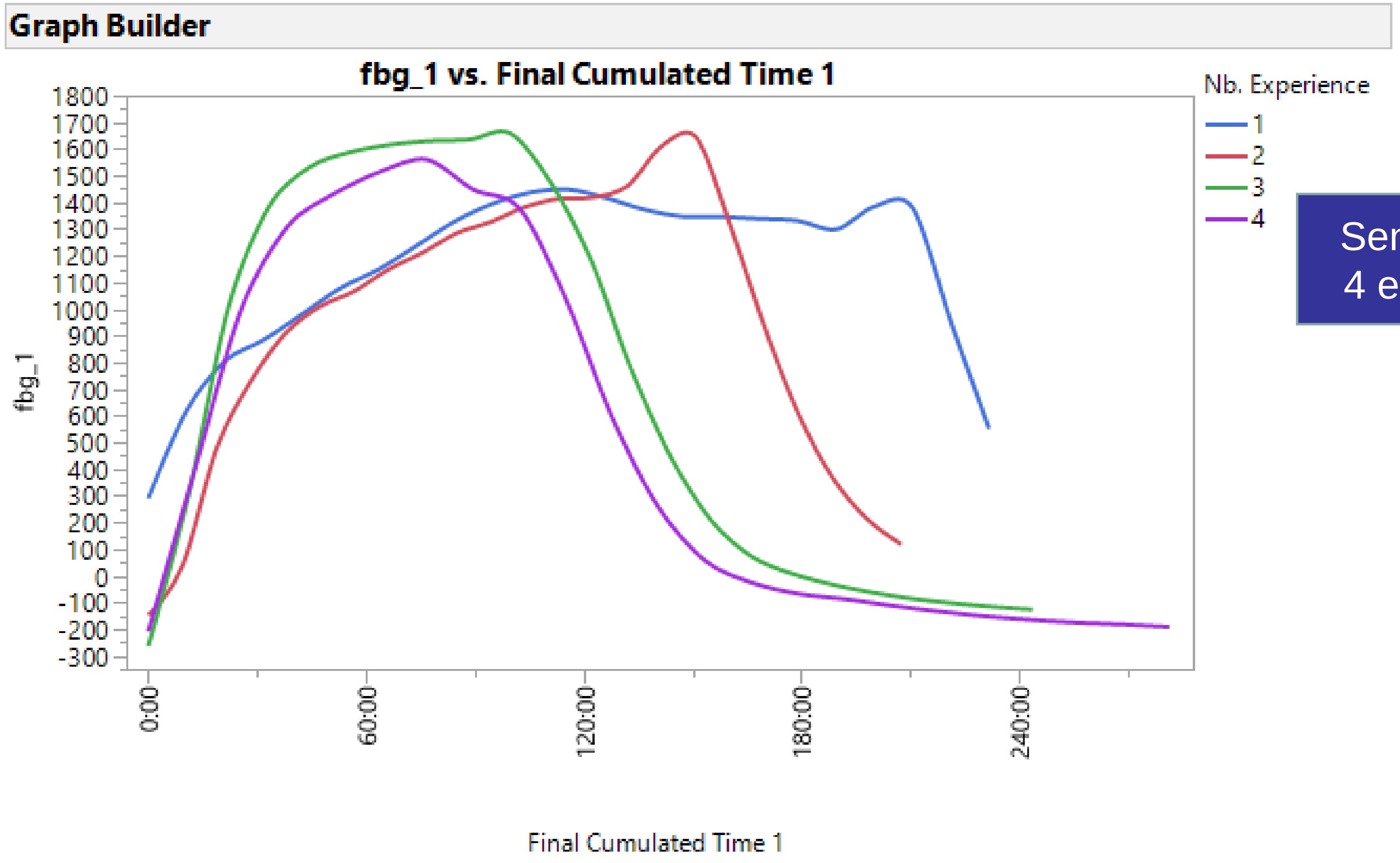
Here, C_S is the *coefficient of strain*, which is related to the *strain optic coefficient* p_e. Also, C_T is the *coefficient of temperature*, which is made up of the *thermal expansion coefficient* of the optical fiber, α_Λ, and the *thermo-optic coefficient*, α_n.[22]

Fiber Bragg gratings can then be used as direct sensing elements for strain and temperature. They can also be used as transduction elements, converting the output of another sensor, which generates a strain or temperature change from the measurand, for example fiber Bragg grating gas sensors use an absorbent coating, which in the presence of a gas expands generating a strain, which is measurable by the grating. Technically, the absorbent material is the sensing element, converting the amount of gas to a strain. The Bragg grating then transduces the strain to the change in wavelength.

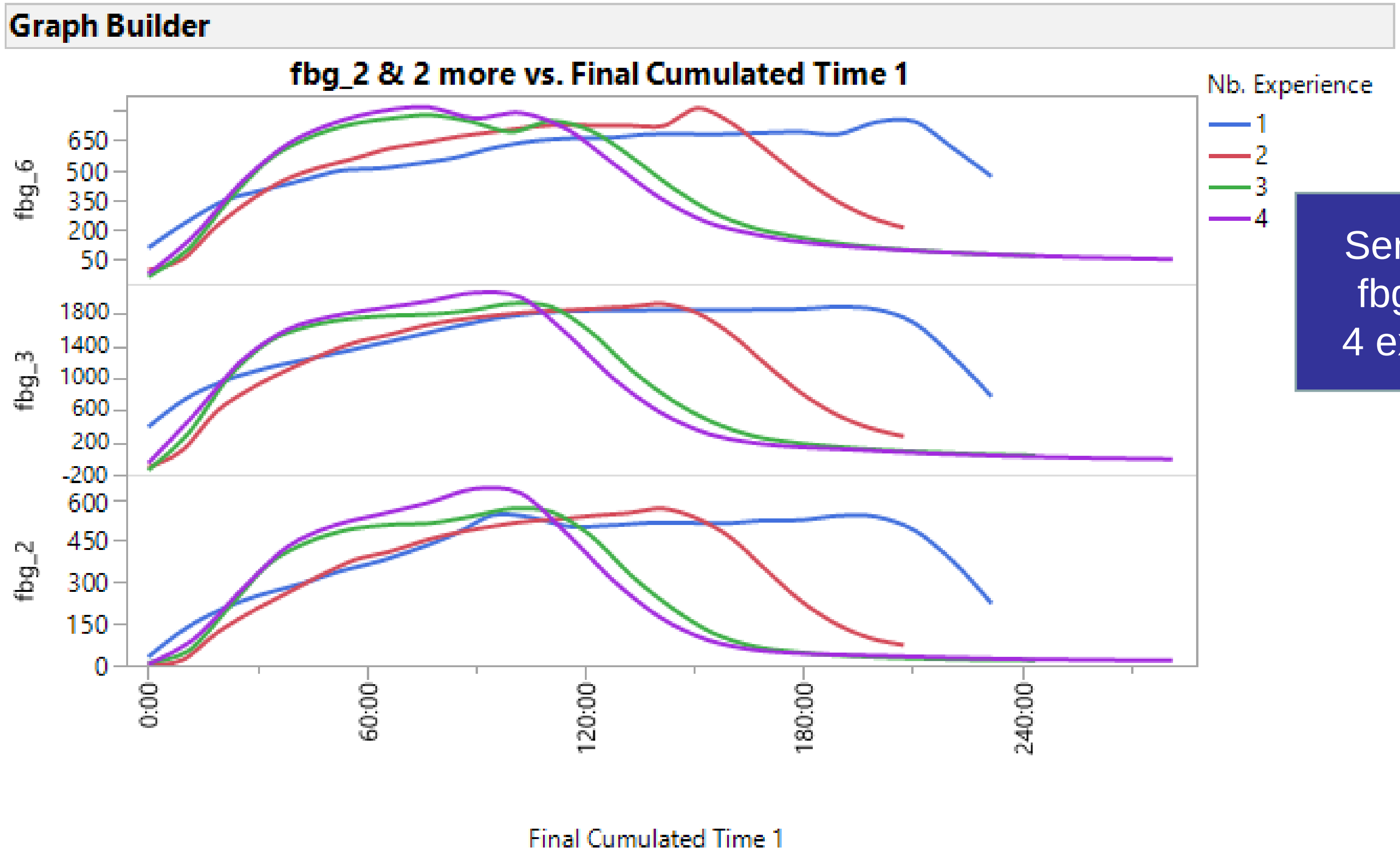
Specifically, fiber Bragg gratings are finding uses in instrumentation applications such as seismology,[23] pressure sensors for extremely harsh environments, and as downhole sensors in oil and gas wells for measurement of the effects of external pressure, temperature, seismic vibrations and inline flow measurement. As such they offer a significant advantage over traditional electronic gauges used for these applications in that they are less sensitive to vibration or heat and consequently are far more reliable. In the 1990s, investigations were conducted for measuring strain and temperature in composite materials for aircraft and helicopter structures.[24][25]



7 sensors and pressure (P1)

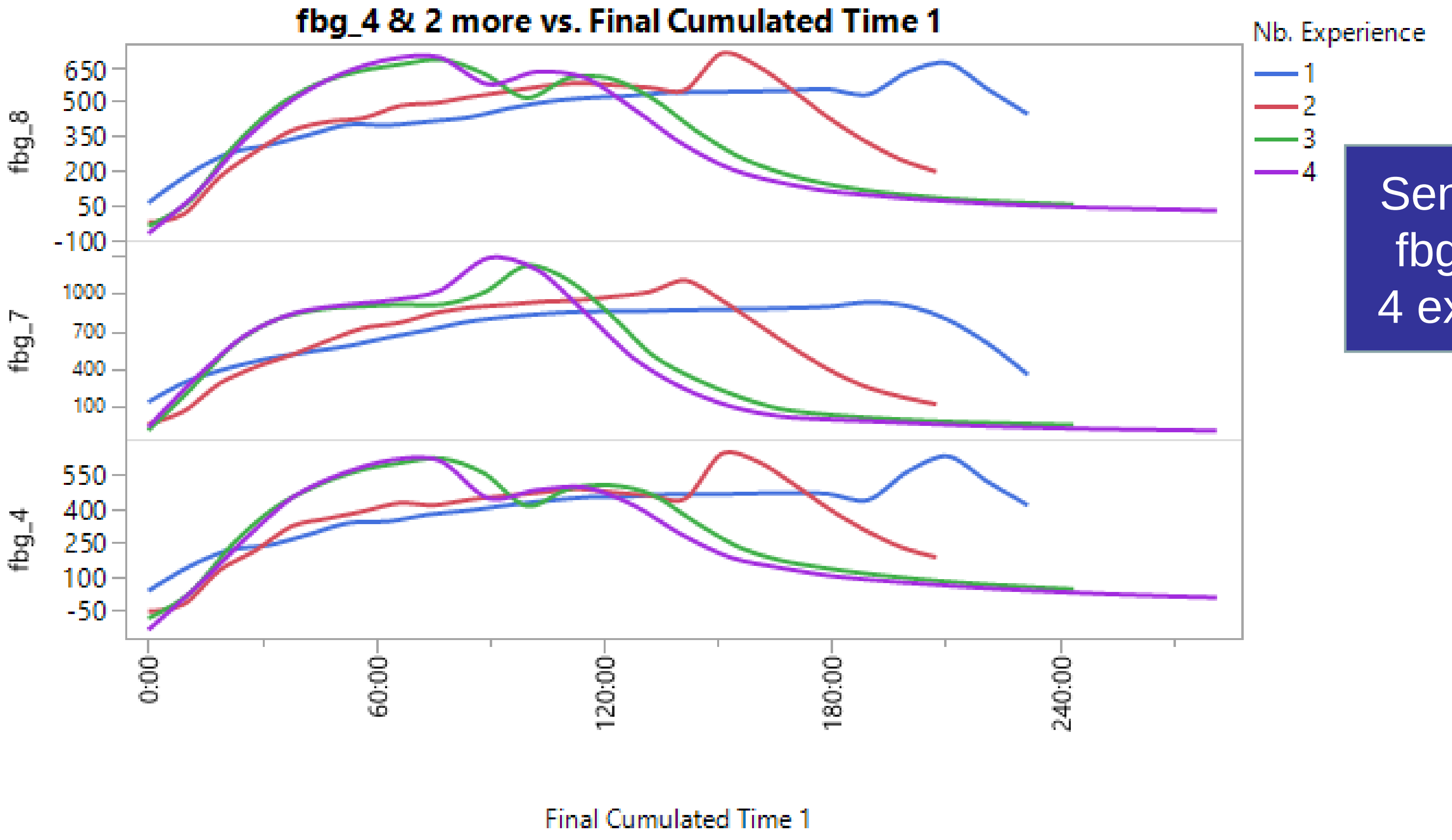


Sensor fbg1 in 4 experiments



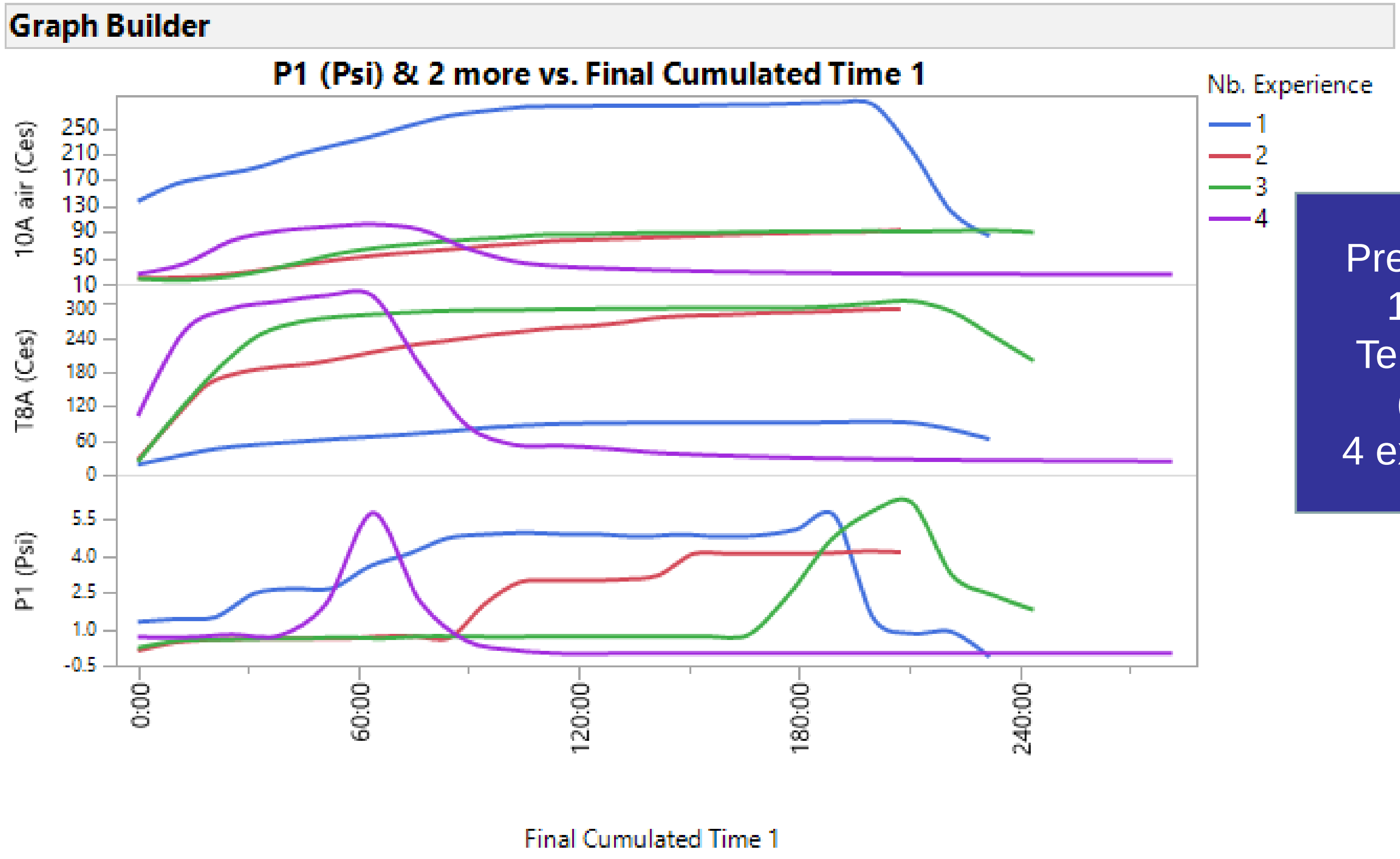
Sensors fbg2, fbg3, fbg6 in 4 experiments

Graph Builder



Sensors fbg4, fbg7, fbg8 in 4 experiments

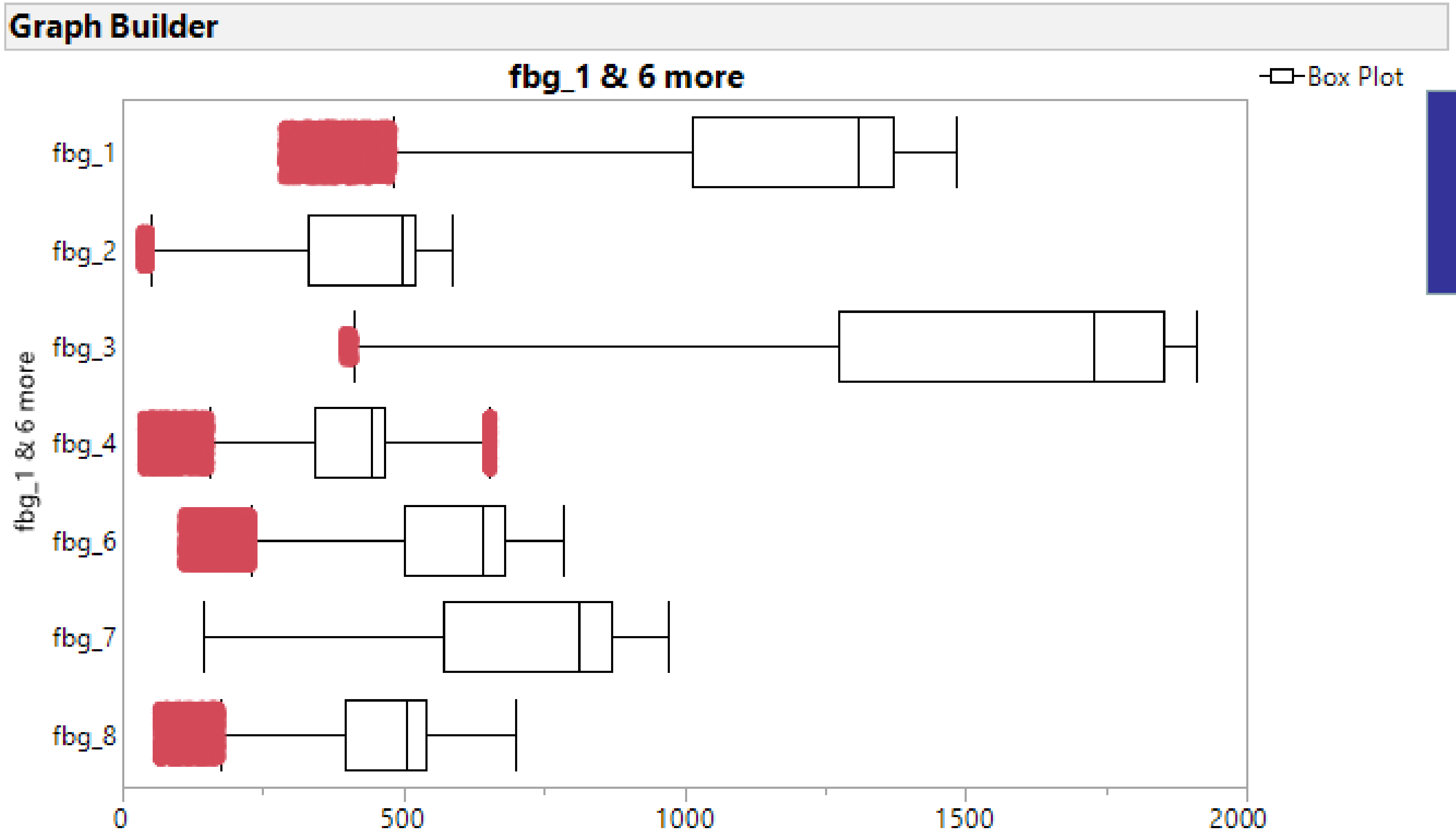
מוסד שמואל נאמן
למחקר מדיניות לאומית



Pressure (P1, 10A) and Temperature (T8A) in 4 experiments

הטכניון
מכון טכנולוגי
לישראל

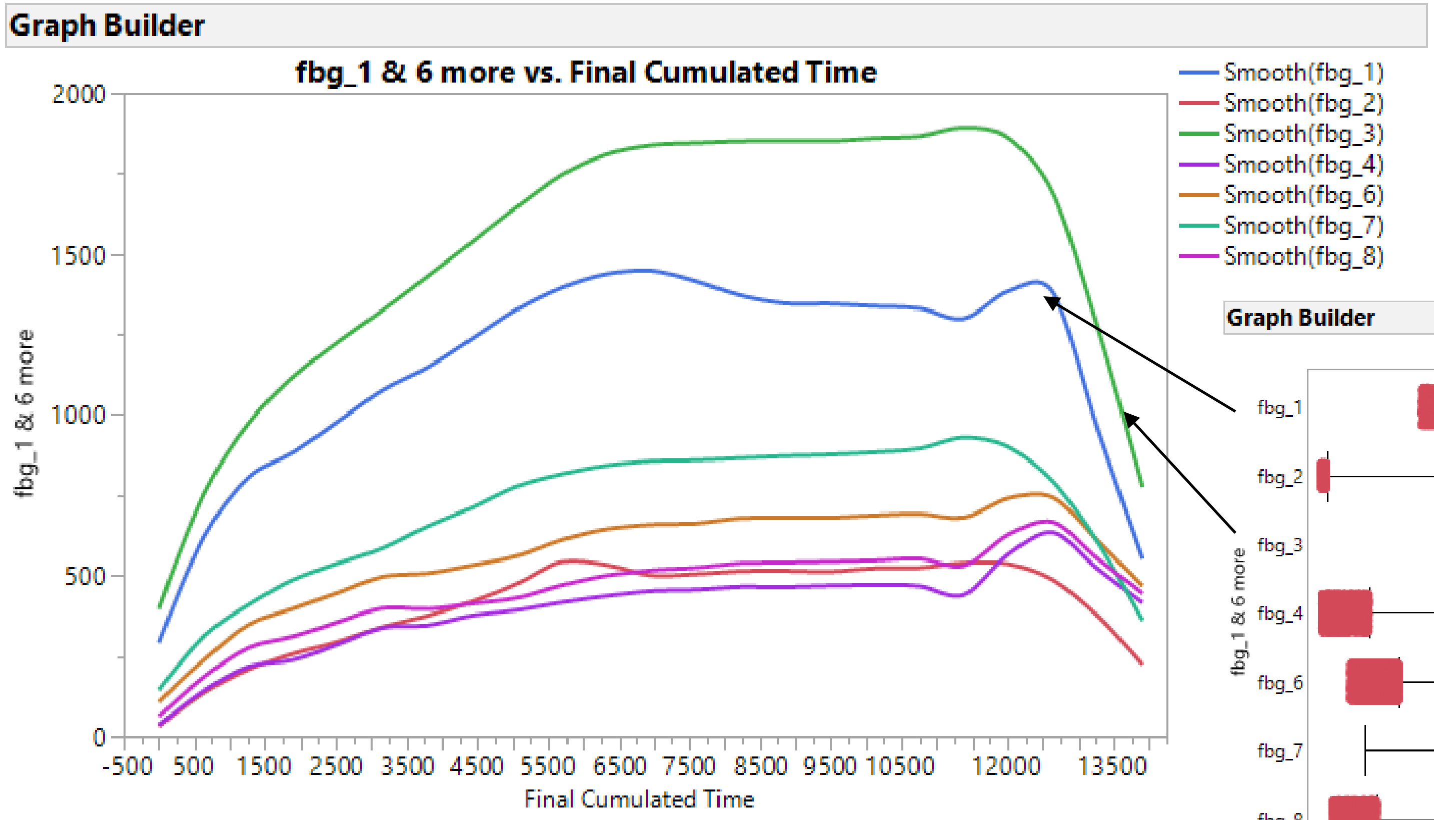
Seven sensors in experiment 1 (baseline)

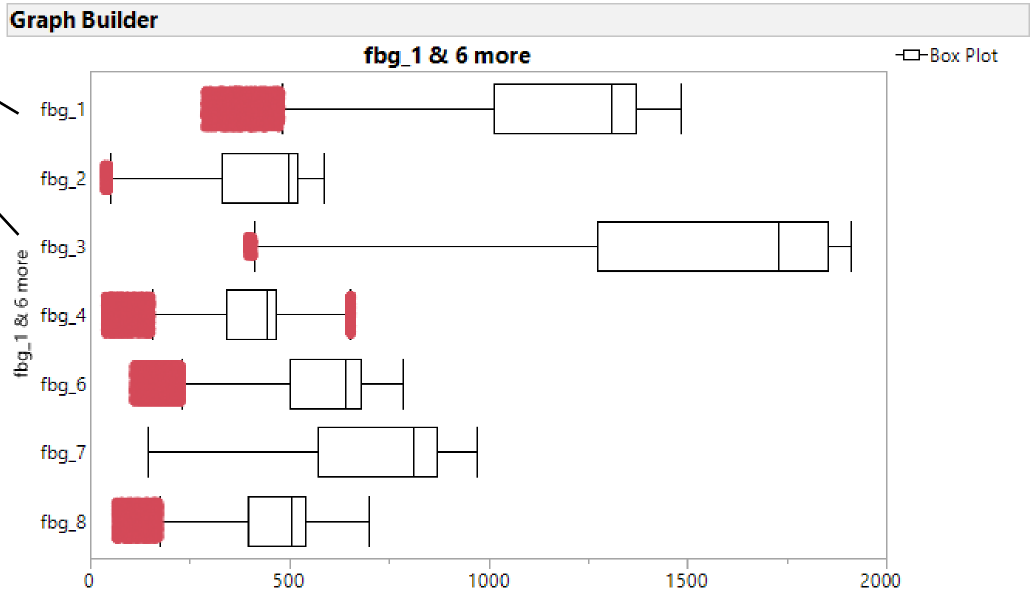


התפלגות ערכי הסנסורים בניסוי מספר 1

Seven sensors in experiment 1 (baseline)

התפלגות ערכי
הסנסורים בניסוי
מספר 1





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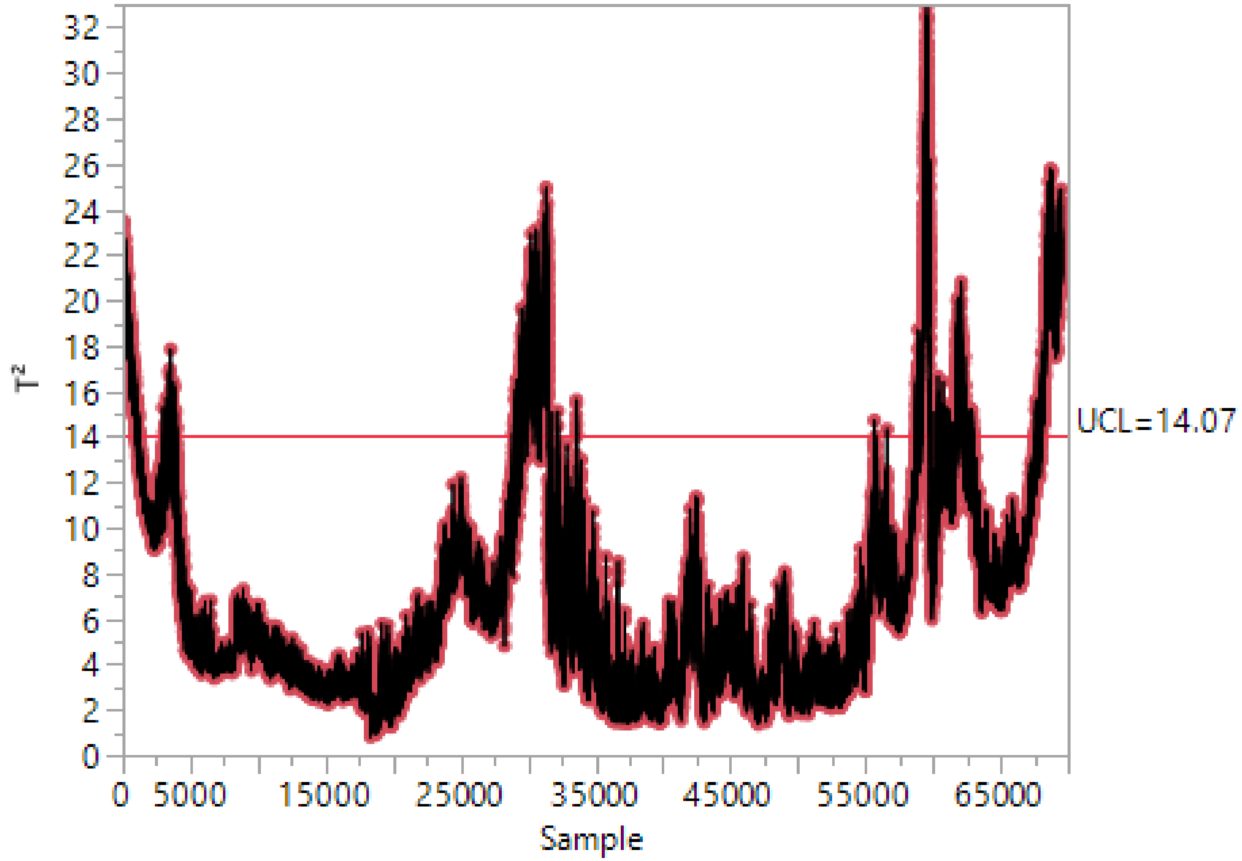
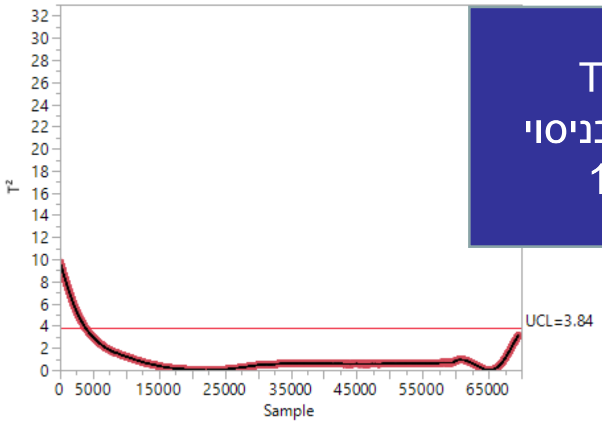
Mahalanobis T^2 analysis with experiment 1 as baseline

T Square with All Principal Components



Note: UCL is calculated based on Alpha=0.05

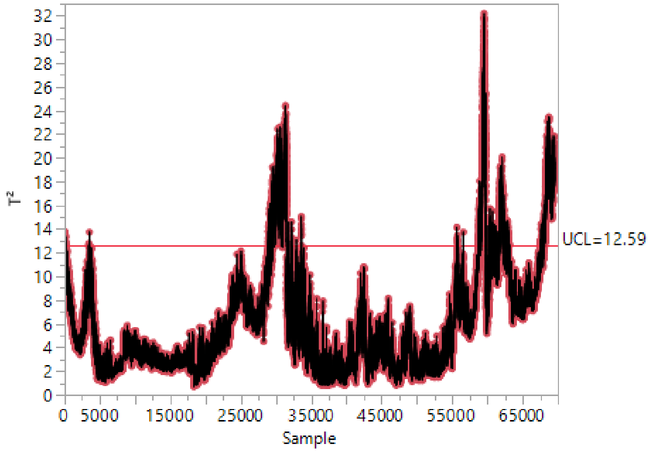
T Square with Big Principal Components



ערכי T2
לסנסורים בניסוי
מספר 1

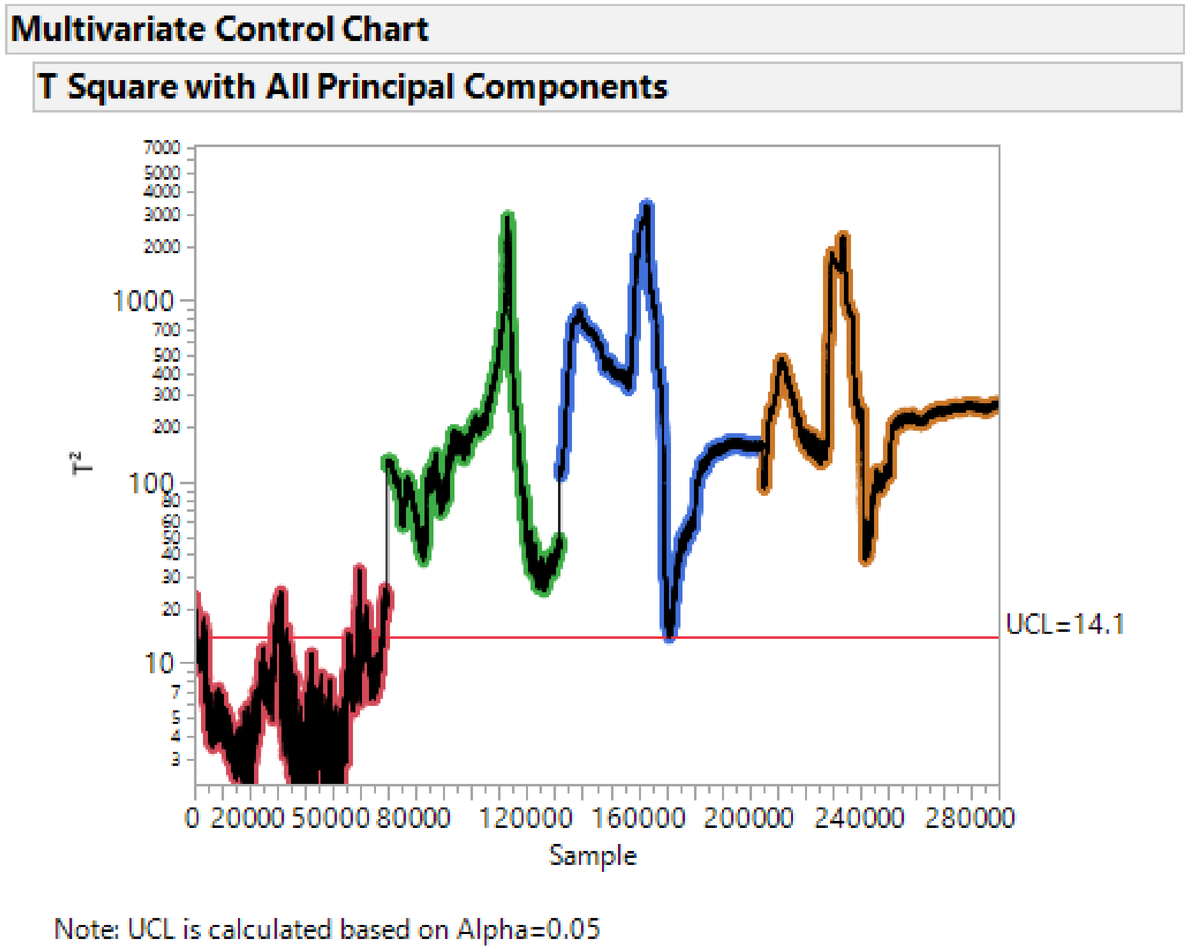
Note: UCL is calculated based on Alpha=0.05

T Square with Small Principal Components



Note: UCL is calculated based on Alpha=0.05

Mahalanobis T^2 analysis with experiment 1 as baseline



ערכי T2
לסנסורים בניסוי
מספר 1-4

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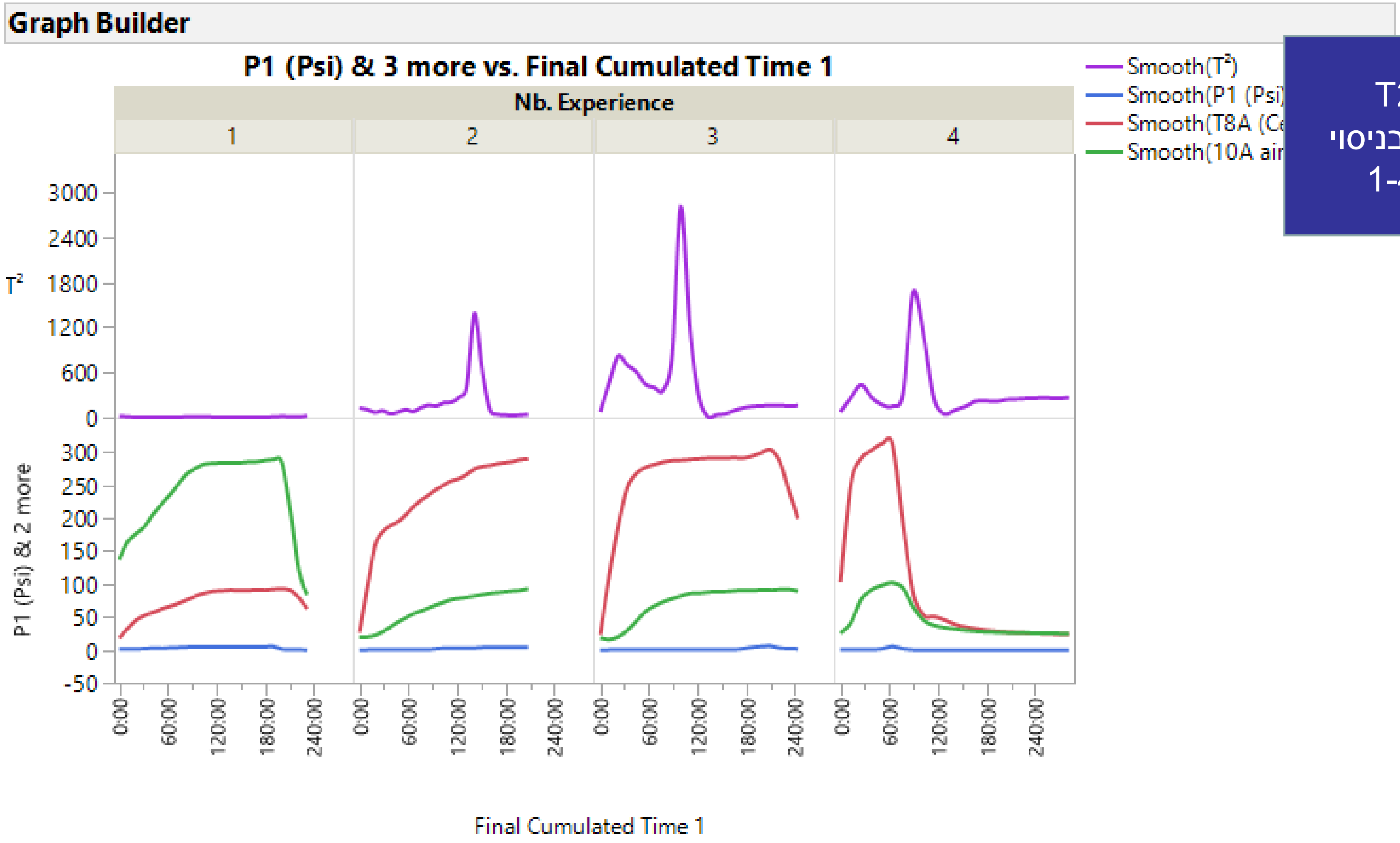
Mahalanobis T^2 analysis with covariates P1, 10A and T8A



ערכי T2
לסנסורים בניסוי
מספר 1-4

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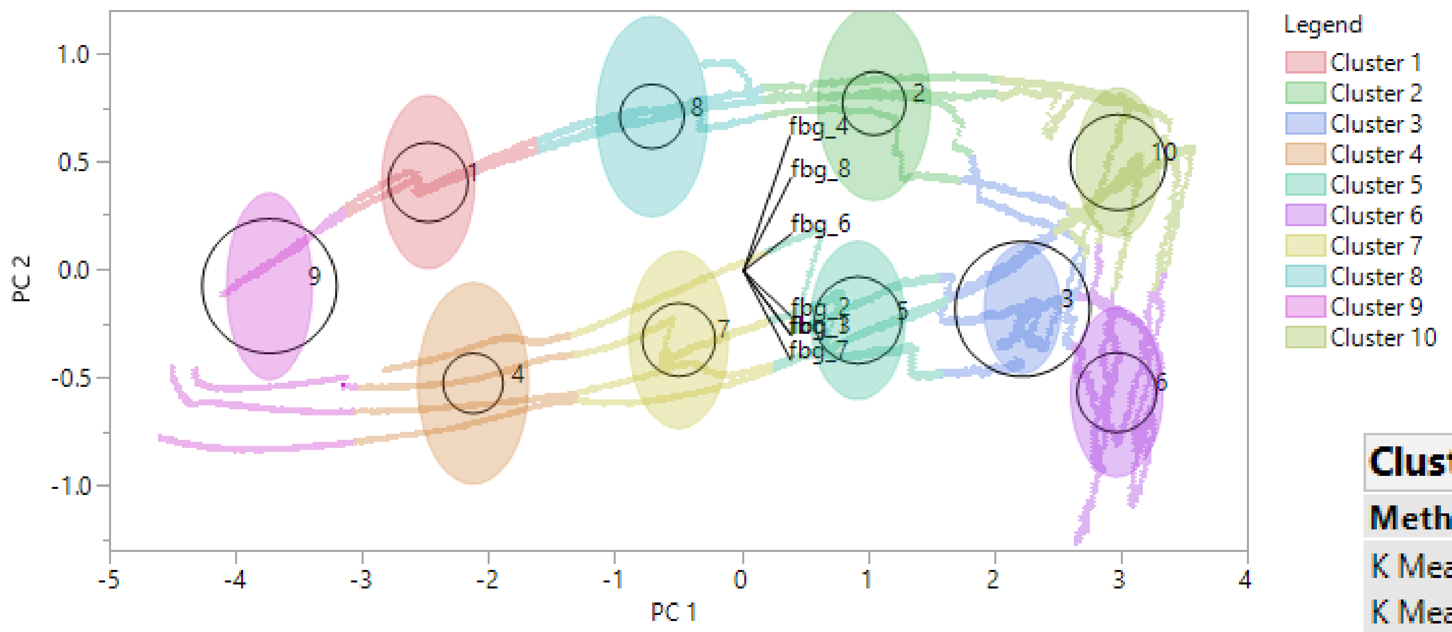
K-Means clustering

Biplot



Select principal components PC 1 PC 2

Eigenvalues
6.7497547 0.1926711 0.0360916 0.0151744 0.004292 0.0015399 0.0004763

10 clusters is optimal

Cluster Comparison

Method	NCluster	CCC	Best
K Means Cluster	3	173.323	
K Means Cluster	4	129.969	
K Means Cluster	5	96.7711	
K Means Cluster	6	153.422	
K Means Cluster	7	159.274	
K Means Cluster	8	168.873	
K Means Cluster	9	178.63	
K Means Cluster	10	212.595	Optimal CCC

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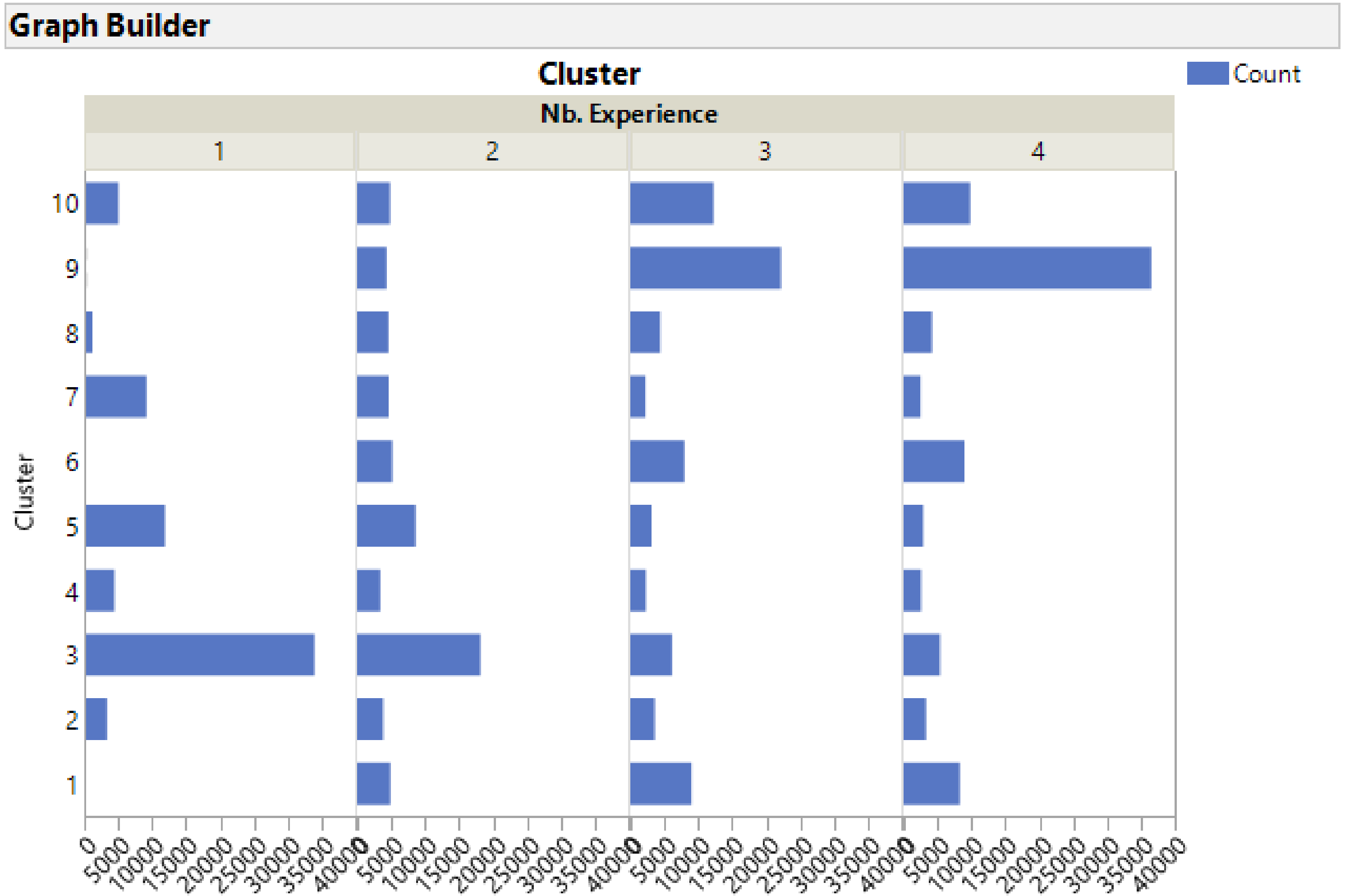
K-Means clustering by experiment



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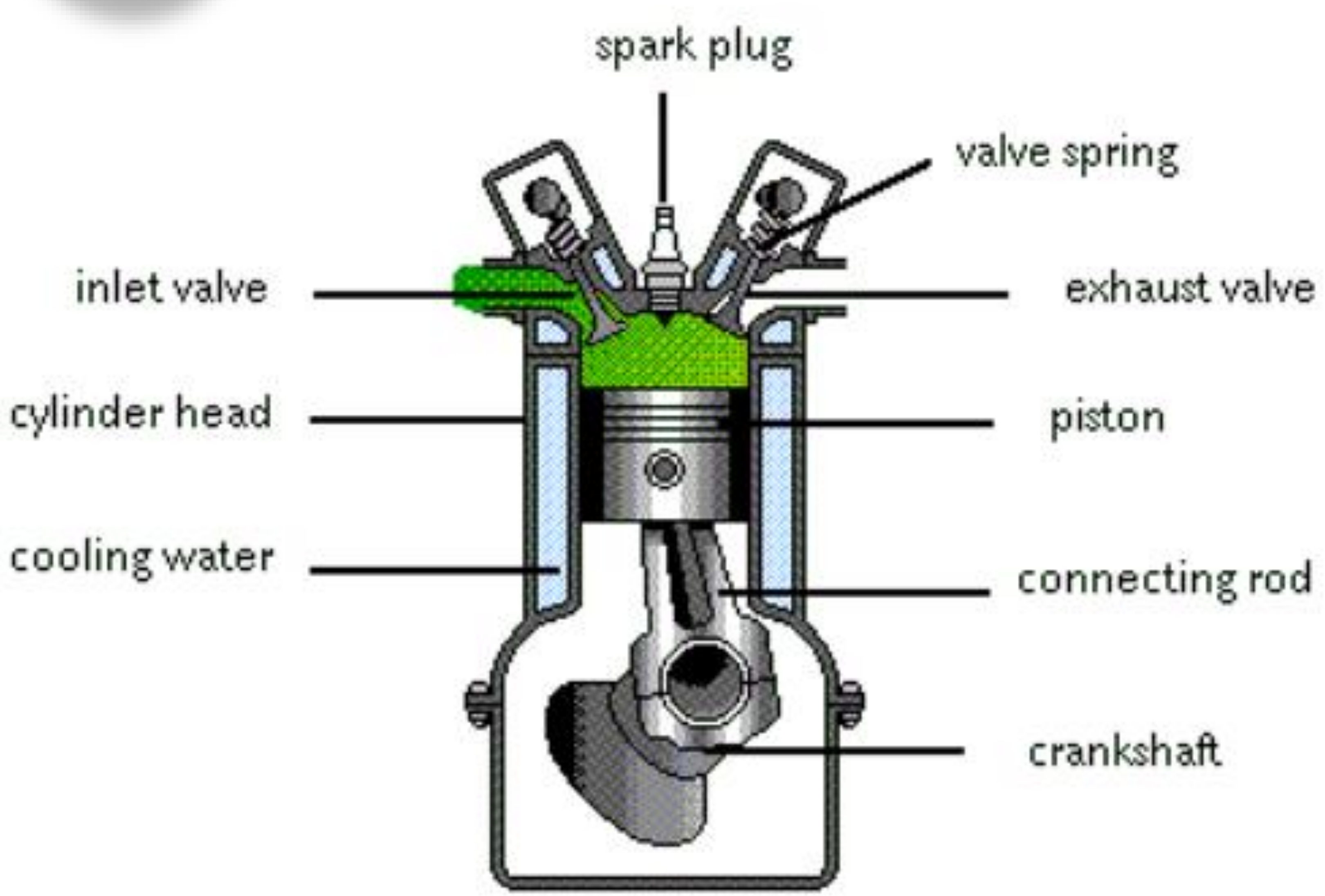
דוגמא
מספר 2

https://www.wiley.com/en-us/Modern+Industrial+Statistics%3A+with+applications+in+R%2C+MINITAB+and+JMP%2C+2nd+Edition-p-9781118763698



DOWNLOADS

Appendix I

Appendix II

Appendix III

Appendix III R scripts

Appendix IV mistat

Appendix V csv Files

Appendix VI MINITAB macros

Appendix VII JMP scripts

Appendix VIII

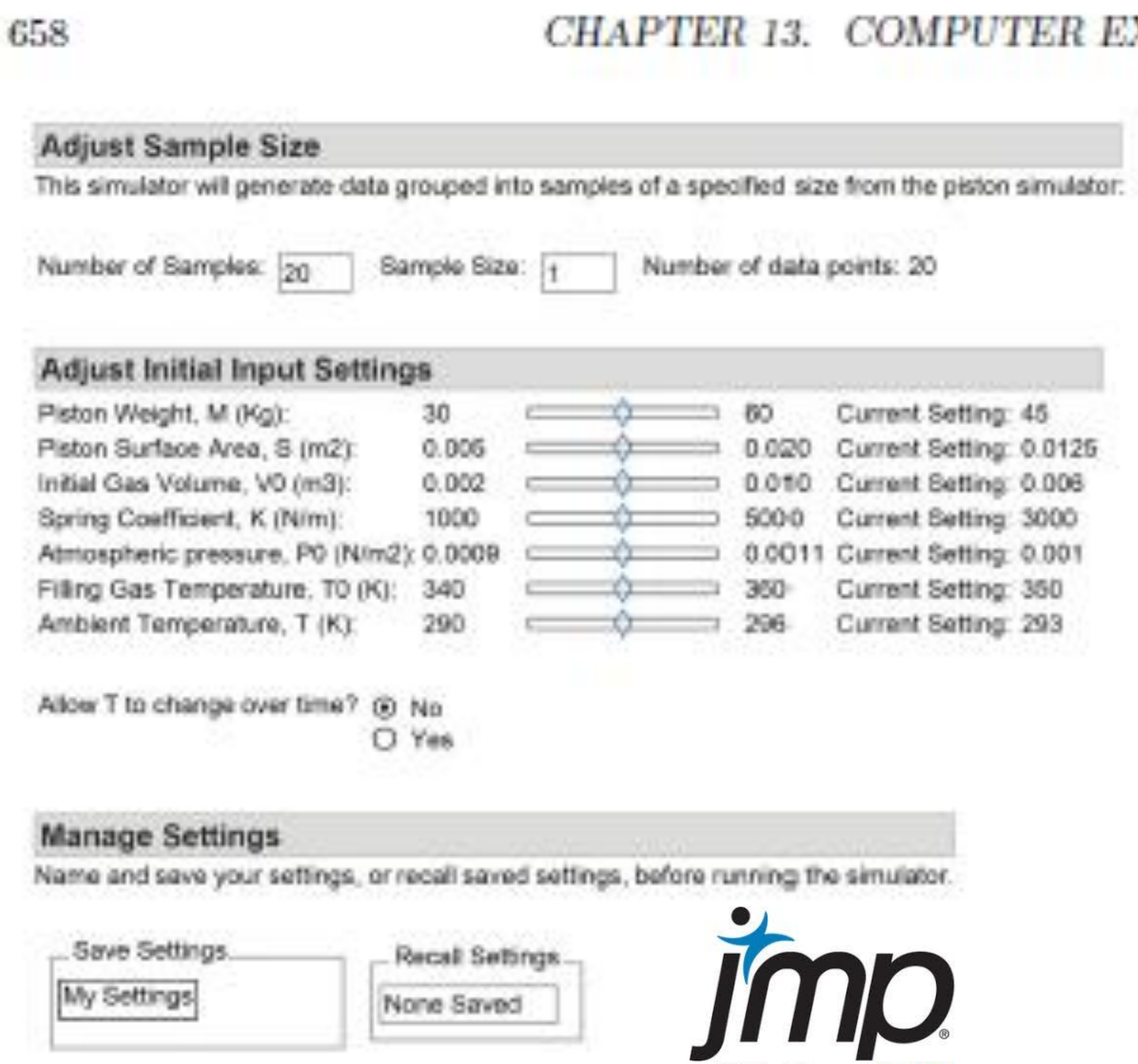
Table of Contents

Design robust piston to 0.5 sec.. cycle time

מוסד שמואל נאמן
למחקר מדיניות לאומית

הטכניון
מכון טכנולוגי
לישראל

- בדיקת השערות
- רגרסיה
- בקרה סטטיסטית
- תכנון ניסויים


658 CHAPTER 13. COMPUTER EXPERIMENTS

Adjust Sample Size

This simulator will generate data grouped into samples of a specified size from the piston simulator.

Number of Samples: 20 Sample Size: 1 Number of data points: 20

Adjust Initial Input Settings

Piston Weight, M (Kg):	30	60	Current Setting: 45
Piston Surface Area, S (m2):	0.005	0.020	Current Setting: 0.0125
Initial Gas Volume, V0 (m3):	0.002	0.010	Current Setting: 0.006
Spring Coefficient, K (N/m):	1000	5000	Current Setting: 3000
Atmospheric pressure, P0 (N/m2):	0.0009	0.0011	Current Setting: 0.001
Filling Gas Temperature, T0 (K):	340	360	Current Setting: 350
Ambient Temperature, T (K):	290	296	Current Setting: 293

Allow T to change over time? No / Yes

Manage Settings

Name and save your settings, or recall saved settings, before running the simulator.

Save Settings: My Settings

Recall Settings: None Saved

- S = Piston surface area (m^2), 0.005-0.020
- V_0 = Initial gas volume (m^3), 0.002-0.010
- k = Spring coefficient (N/m), 1000-5000
- P_0 = Atmospheric pressure (N/m^2), $9 \times 10^4 - 11 \times 10^4$
- T = Ambient temperature (K), 290-296
- T_0 = Filling gas temperature (K), 340-360

These factors affect the Cycle Time via a chain of nonlinear equations:

$$\text{Cycle Time} = 2\pi\sqrt{\frac{M}{k + S^2\frac{P_0V_0}{T_0}\frac{T}{V^2}}} \tag{13.1.3}$$

where

$$V = \frac{S}{2k}\left(\sqrt{A^2 + 4k\frac{P_0V_0}{T_0}T} - A\right) \quad \text{and} \quad A = P_0S + 19.62M - \frac{kV_0}{S}. \tag{13.1.4}$$

Randomness in Cycle Time is induced by generating observations for factors set up around design points with noise added to the nominal values. Figure 13.1 shows the operating panel of the piston simulator add-in within the JMP application. To change the factor level combinations simply move the sliders left or right. To install it, after installing JMP, download the file **com.jmp.cox.ian.piston.jmpaddin** from the book website and double click on. This will open up a "Piston Simulator" Add-In on the JMP top ruler.

we discuss Statistical Process Control (Chapters 8, 9 and 10) and the Design of Experiments (Chapters 11, 12 and 13). We continue at a pedestrian pace by recreating Table 2.1 using R. All the R applications referred to in this book are contained in a package called **mistat** available in Appendix III. The following R commands will install the **mistat** package, read the cycle time data and print them on your monitor:

```
> # This is a comment
> install.packages("mistat",          # Install mistat package
                   dependencies=TRUE) # and its dependencies
>                  #
> library(mistat)  # A command to make our datasets
>                  # and functions available
>                  #
> data(CYCLT)      # Load specified data set
>                  # CYCLT is a vector of values
>                  #
> help(CYCLT)      # Read the help page about CYCLT
>                  #
> CYCLT            # Print CYCLT to Console
```

Notice that functions in R have parenthesis. The library() function loads an additional package to extend R functionalities and CYCLT is an object containing a simple vector of values.
The differences in cycle times values is quite apparent and we can make the statement "cycle times are varying". Such a statement, in spite of being true, is not very useful. We have only established the existence of variability – we have not yet characterized it and are unable to predict and control future behavior of the piston.

Table 2.1. Cycle Times of Piston (in seconds) with control factors set at minimum levels

1.008	1.117	1.141	0.449	0.215
1.098	1.080	0.662	1.057	1.107
1.120	0.206	0.531	0.437	0.348
0.423	0.330	0.280	0.175	0.213
1.021	0.314	0.489	0.482	0.200
1.069	1.132	1.080	0.275	0.187
0.271	0.586	0.628	1.084	0.339
0.431	1.118	0.302	0.287	0.224
1.095	0.319	0.179	1.068	1.009
1.088	0.664	1.056	1.069	0.560

Example 2.2. Consider an experiment in which a coin is flipped once. Suppose the coin is fair in the sense that it is equally likely to fall on either one of its

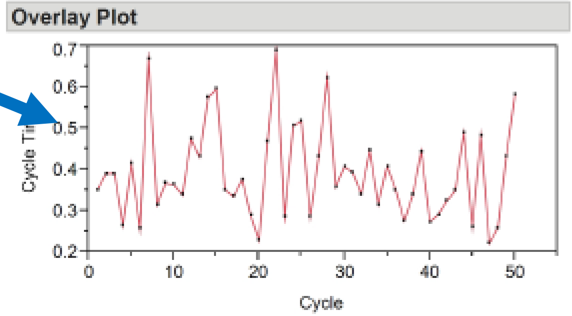


Figure 8.2. Run Chart or Connected Line Plot (JMP)) of 50 Piston Cycle Times, [sec]

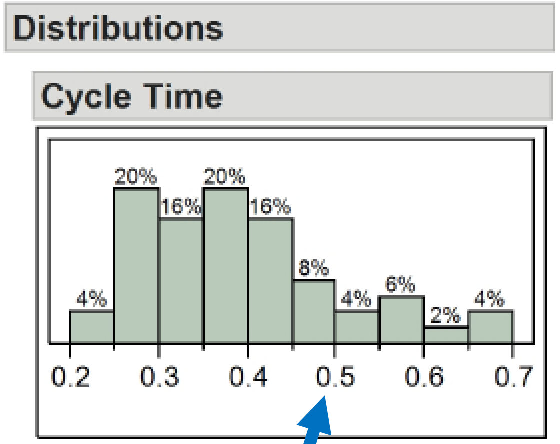


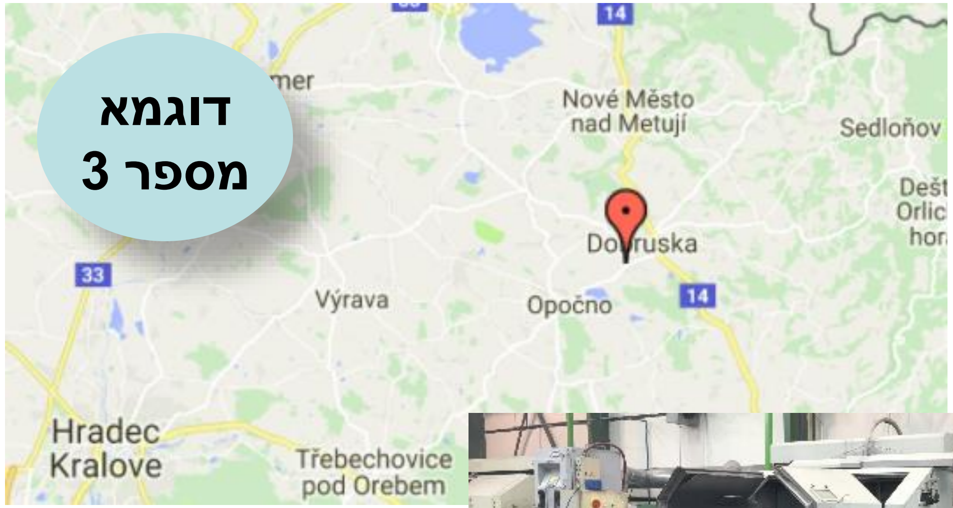
Figure 8.3. Histogram of 50 Piston Cycle Times (JMP)

Even though no changes occurred in the operating conditions of the piston we observe variability in the cycle times. From Figure 8.2 we note that cycle times vary between 0.22 and 0.69 seconds. The histogram in Figure 8.3 indicates some skewness in the data. The normal probability plot of the 50 cycle times (Figure 8.4) also leads to the conclusion that the cycle time distribution is not normal, but skewed.

- אופטימיזציה
- רגרסיה
- בקרה סטטיסטית
- תכנון ניסויים

Statistical Discovery.™ From SAS.

דוגמא
מספר 3



Work orders, critical parameters, machine parts, actions

ET.3120.A.038-P_REV.03_long			
5/9/2012 7:14			
(mm)	ACTUAL	NOMINAL	LO-TOL
Temperature Compensation: OFF			
Temperature Compensation: OFF			
Temperature Compensation: OFF			
==			
==			
===================CAGE CRITICAL DIMENSI			
================== Datum Planes Definition			
Plane B =================================			
Plane:PLNB			
Flatness	0.0484	0.1	
Perpendicular	0.0489	0.1	DAT(datA)
Plane C =================================			
Plane:PLNC			
Perpendicular	0.002	0.05	DAT(datA)
Flatness	0.0019	0.03	
Perpendicular	0.0055	0.05	DAT(datB)
Plane D =================================			
Plane:PLND			
Flatness	0.0586	0.1	
Perpendicular	0.0592	0.1	DAT(datA)
Parallelism	0.0903	0.15	DAT(datB)

Parser

Work Order: Manage | Select active work order
Part Specification: Part Specifications | Upload | Export
Information Settings: Settings | Causes and Actions

Work Order: > Part: P5178M7 HA > Critical param: CP4 > **Raw Data**

Batch	Revision	Measuring date	Value	Valid
1	1	09-23-2012 05:35	9.05	Included
1	1	09-23-2012 07:35	9.3	Included
1	1	09-23-2012 08:35	8.65	Included
1	1	09-23-2012 09:35	8.95	Included
1	1	09-23-2012 10:35	9.05	Included
1	1	09-23-2012 11:35	8.85	Included
1	1	09-24-2012 05:35	8.9	Included
1	1	09-24-2012 07:35	9.3	Included
1	1	09-24-2012 08:35	9.15	Included
1	1	09-24-2012 09:35	9.1	Included
1	1	09-24-2012 10:35	9.2	Included
1	1	09-24-2012 11:35	9.15	Included
1	1	09-25-2012 05:35	9.25	Included
1	1	09-25-2012 07:35	8.6	Included
1	1	09-25-2012 08:35	9.05	Included
1	1	09-25-2012 09:35	9.25	Included
1	1	09-25-2012 10:35	9.25	Included
1	1	09-25-2012 11:35	9.05	Included
1	1	09-25-2012 12:35	9.15	Included
1	1	09-25-2012 13:35	9.3	Included

מוסד שמואל נאמן
למחקר מדיניות לאומית

הטכניון
מכון טכנולוגי
לישראל

דוגמא מספר 3

Monitoring – ניטור
Diagnostics – אבחון
Prognostics – חיזוי
Prescriptive - הנחיה

https://www.youtube.com/watch?v=E7W99sCYYos&fbclid=IwAR3jjFfv640YJn8RipksFhEWWQVfdVlrPb4EpgbmCpInPng6x6EEGI2C8RU

מוסד שמואל נאמן
למחקר מדיניות לאומית

SPC Operator Panel

Work Order / Part Number Selection

Work Order: AV 3 12 T1
Part Number: P5178M5 AV

Select

Add Row | Clear the Table

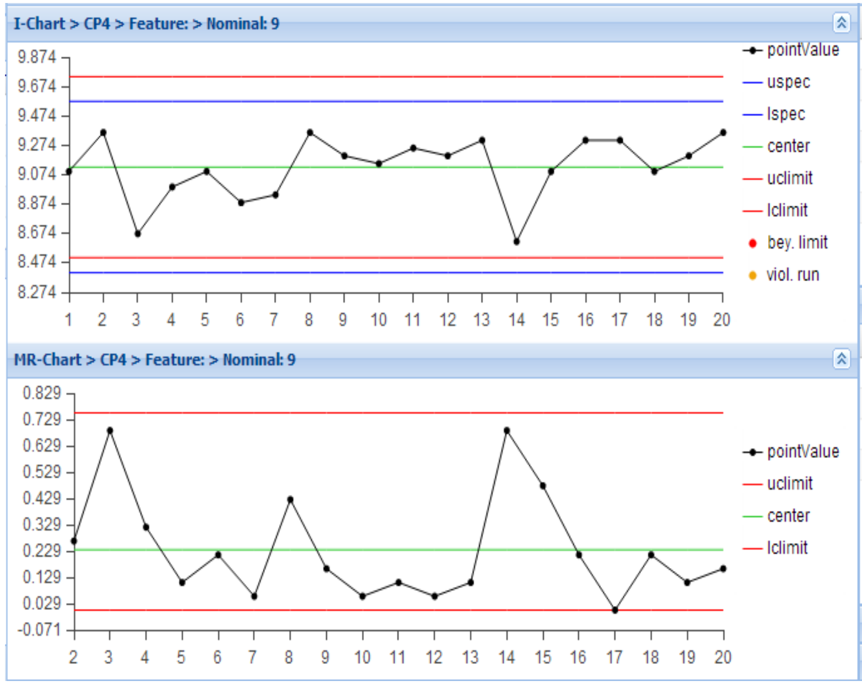
Serial	CP1 - Z	CP2 - X	CP2 - Y	CP2 - Z
	0.5	0.03	0.03	0.03
	0.55	0.025	0.026	0.028

Details selection

Batch: 1
Manufacturing Machine: Machine 1
Operator: Operator 1
Shift: Morning
Inspection Tool: INP_TOOL 1
Production: Production

Save Raw Data Values

Control Chart



Name	Value
Total observations	20
Mean	9.078
Min	8.600
Max	9.300
Standard Deviation	0.203
Average Range	0.218

Process Capability

Name	Value
Pp	0.903
Ppk	0.694
Cp	0.947
Cpk	0.727

Beyond Limits

Violating Runs

הטכניון
מכון טכנולוגי
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דוגמא
מספר 3

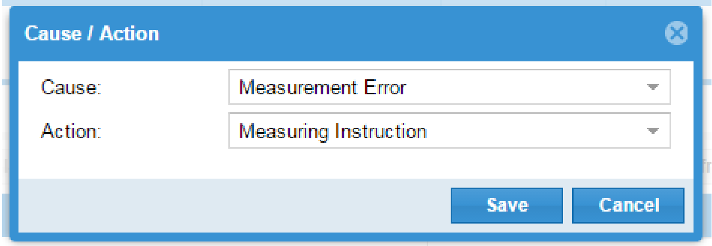
https://www.youtube.com/watch?v=2V1vG9UGHFs

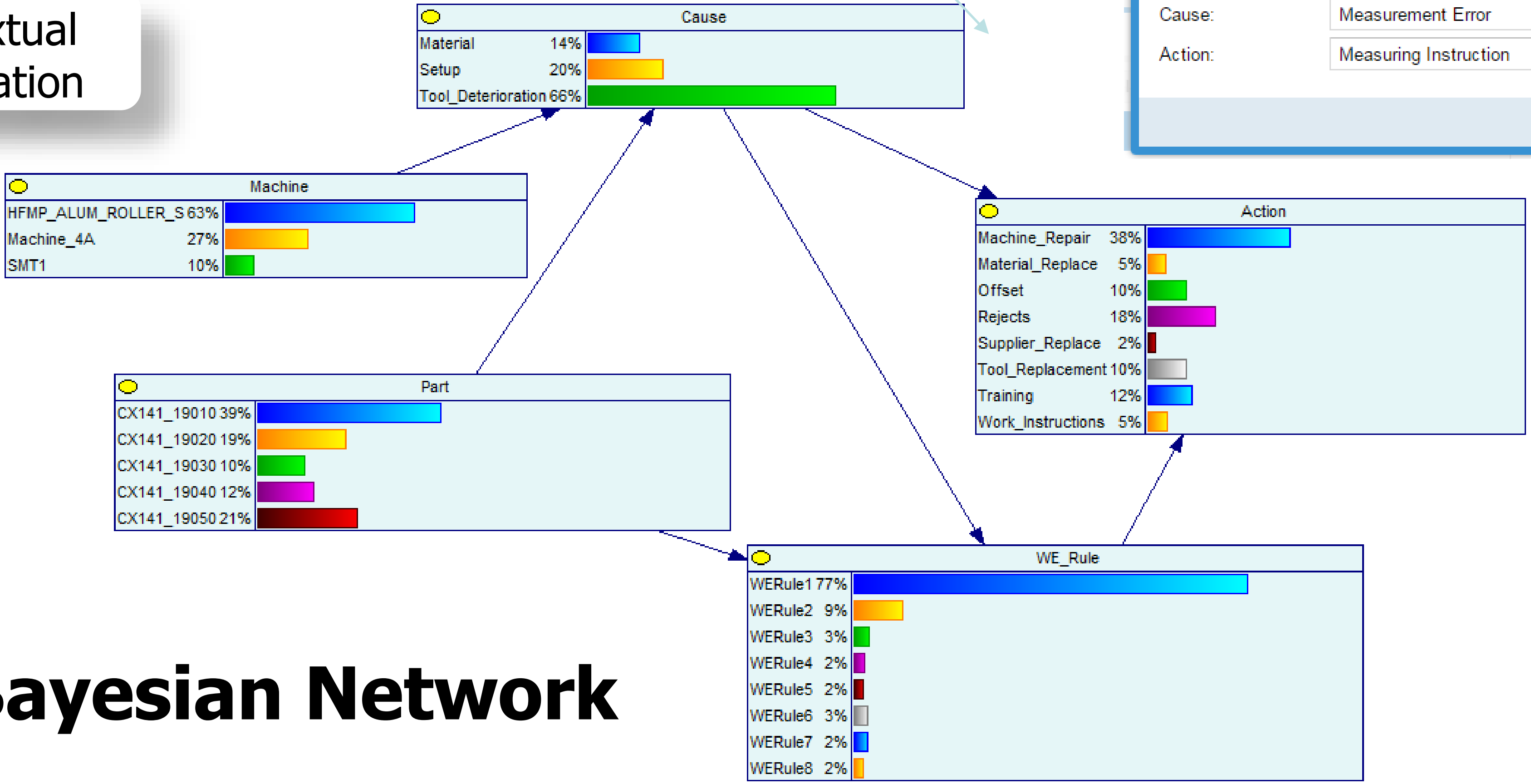
https://vimeo.com/285180512

Cause & Action annotation of out of trend data points

Contextual information

Action Log





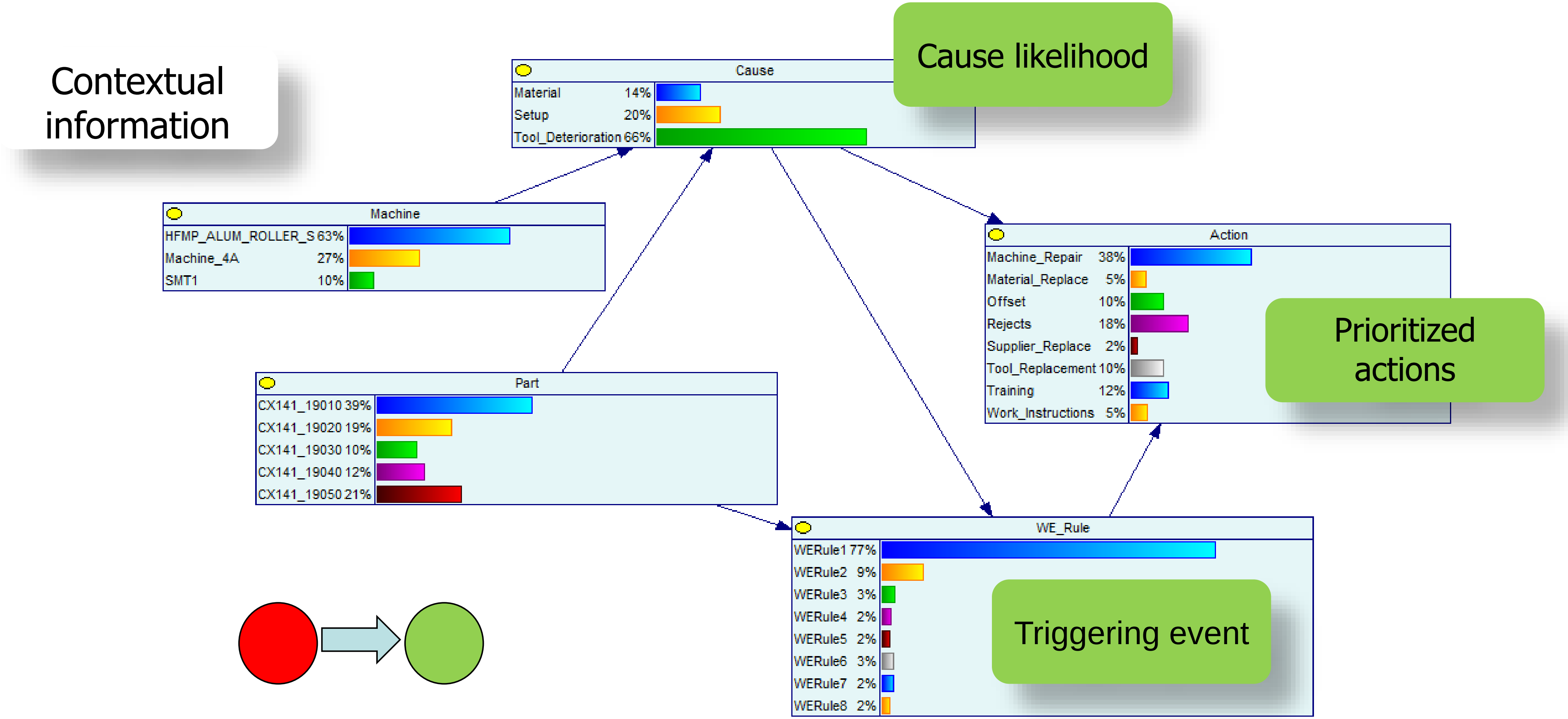
Bayesian Network

מוסד שמואל נאמן
למחקר מדיניות לאומית

הטכניון
מכון טכנולוגי
לישראל

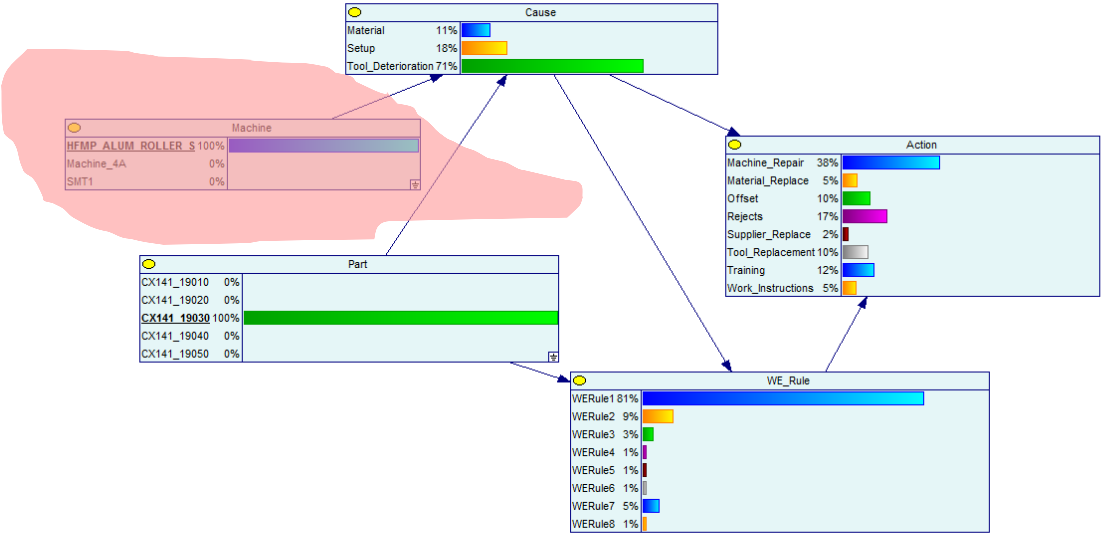
Predictive Analysis (Proactive, What-If)

Prognostics for machine/part planning



Predictive Analysis (Proactive, What-If)

Prognostics for machine/part planning

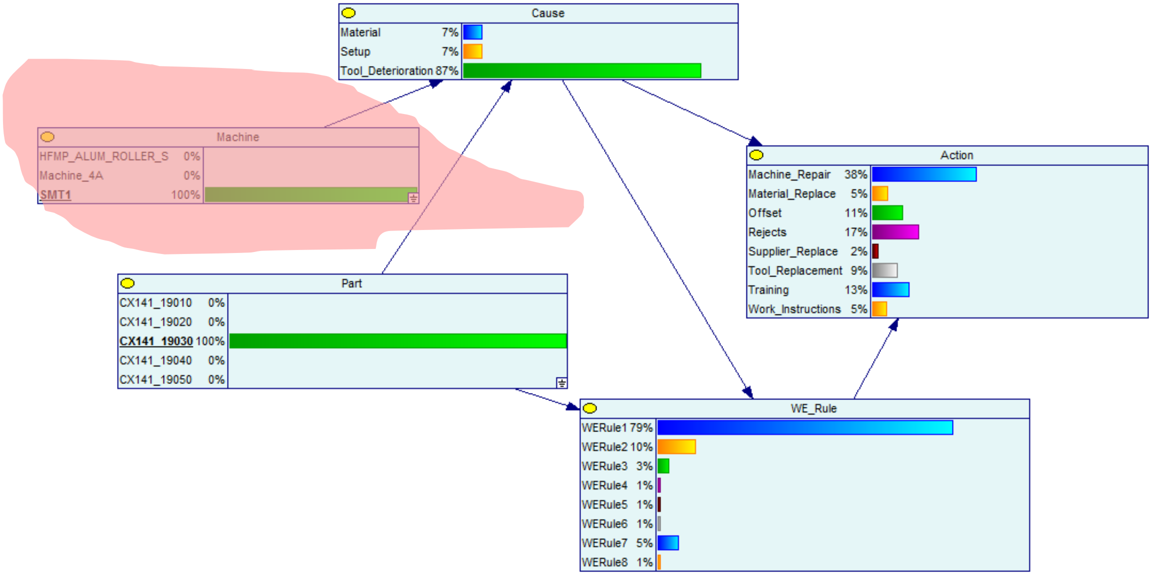


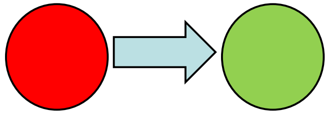
Machine SMT1
Part CX141 19030

- Setup issues 7% probability
- Tool issues 87% probability

Machine HFMP ALUM ROLLER S
Part CX141 19030

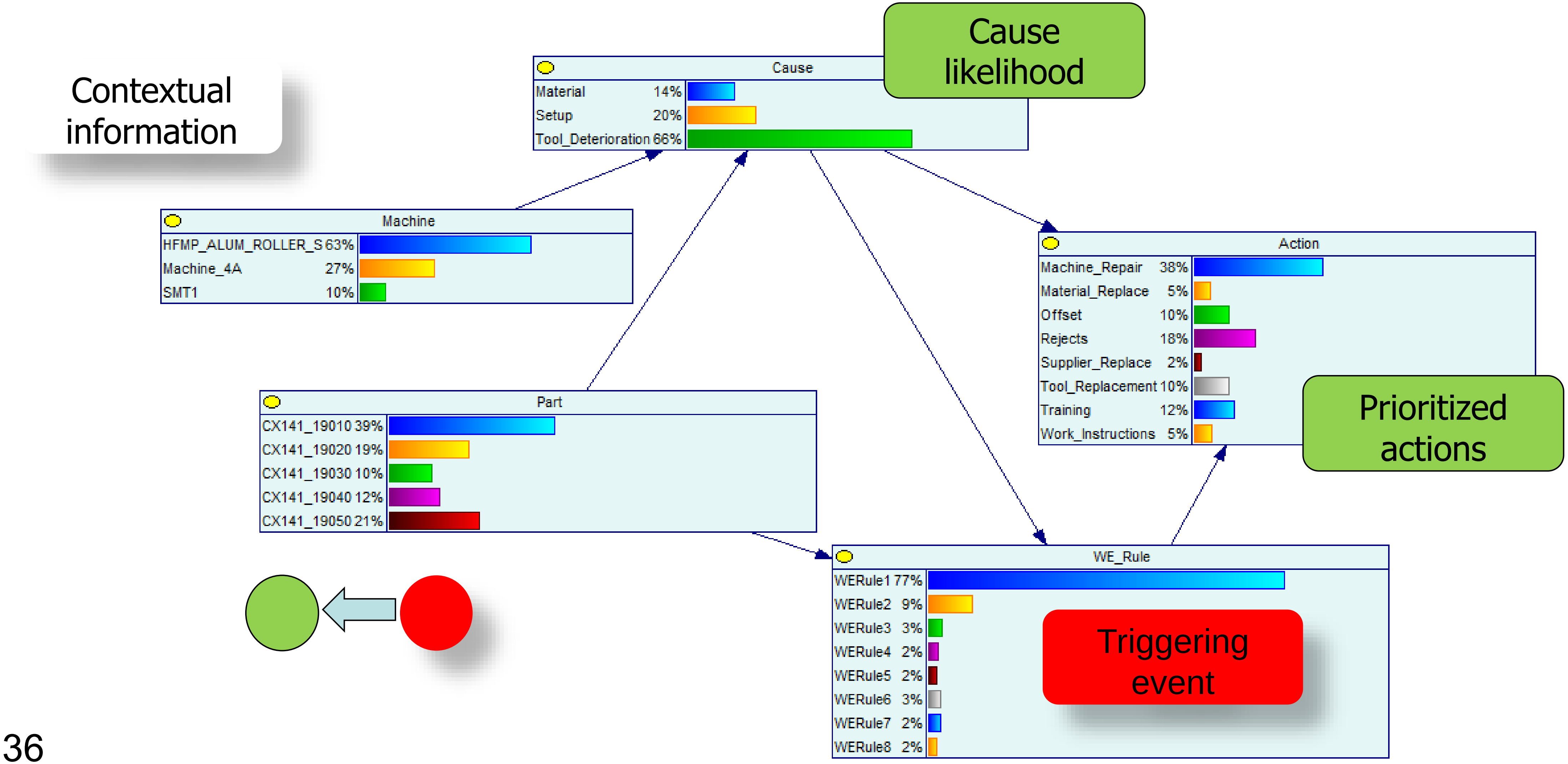
- Setup issues 18% probability
- Tool issues 71% probability





Diagnostics (Reactive, If-then)

Diagnostics following alarm



מוסד שמואל נאמן
למחקר מדיניות לאומית

הטכניון
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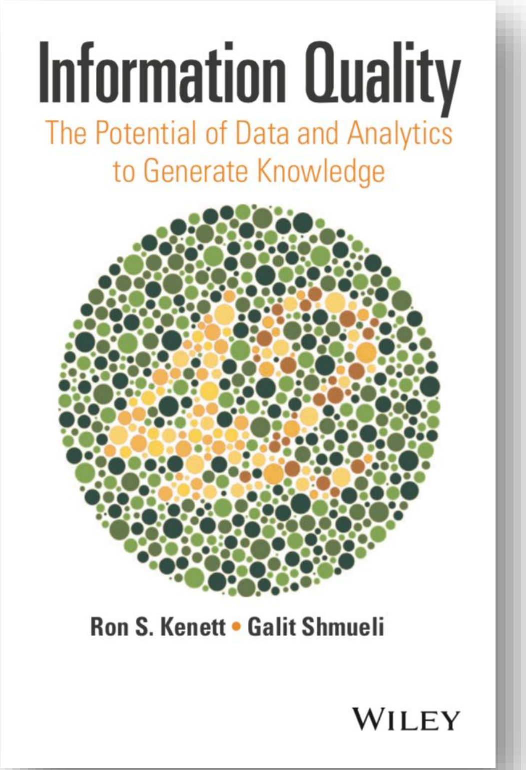
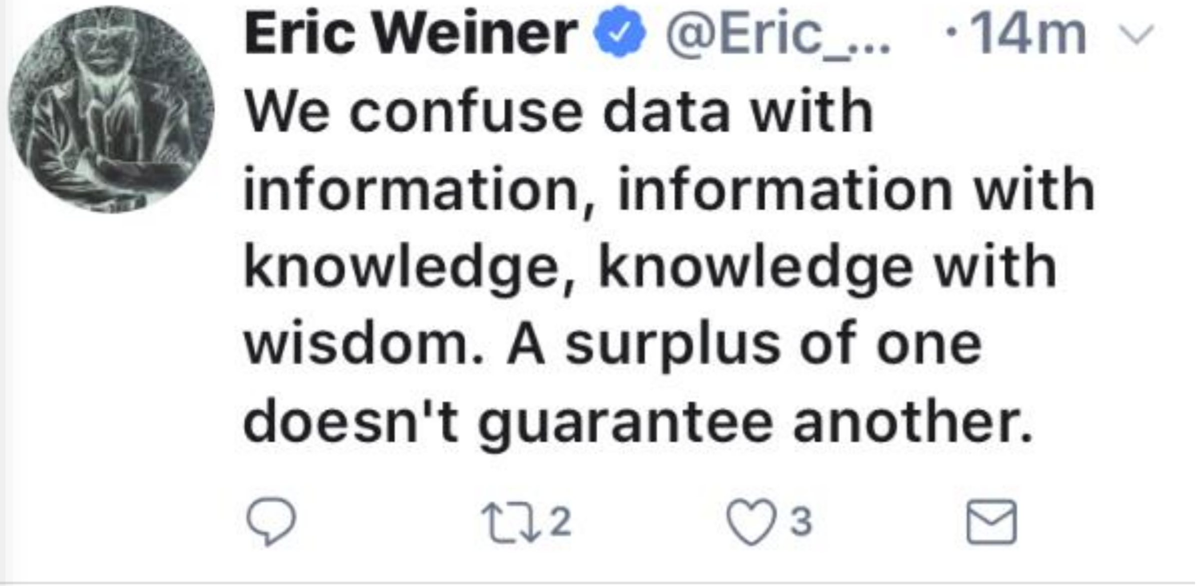
לישראל


Information Quality
The Potential of Data and Analytics
to Generate Knowledge
Ron S. Kenett • Galit Shmueli
WILEY


Eric Weiner @Eric_... · 14m
We confuse data with information, information with knowledge, knowledge with wisdom. A surplus of one doesn't guarantee another.
2
3

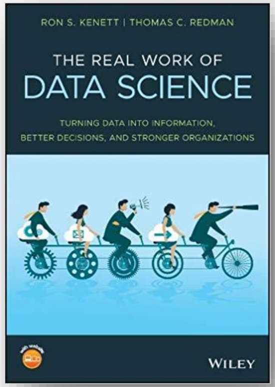
Level 5: *Learning and discovery* - This is where attention is paid to information quality. Data from different sources is integrated. Chronology of Data and Goal and Generalization is a serious consideration in designing analytic platforms. **Leverage causality models.**

Level 4: *Quality by Design* - Experimental thinking is introduced. The data scientist suggests experiments, like A/B testing, to help determine which website is better. **Develop causality analysis**.

Level 3: *Process focus* - Probability distributions are part of the game. The idea that changes are statistically significant, or not, is introduced. Some attention is given to model fitting. **Introduce causality analysis.**

Level 2: *Descriptive statistics level* – Management asks to see histograms, bar charts and averages. **Models are not used, data is analyzed in rather basic ways.**

Level 1: *Random demand for reports driven by firefighting* - New reports address questions such as: How many components of type X did we replace last month or how many people in region Y applied for a loan?



מוסד שמואל נאמן
למחקר מדיניות לאומית

https://soundcloud.com/crm-buzz/vztiidywcnye/s-0cEZ3

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https://www.youtube.com/watch?v=Z_hcmxYH8Ng&list=PLOQ4CAjSlhKm8WrhWVfLi1S2EonR0riaQ&index=4&t=0s

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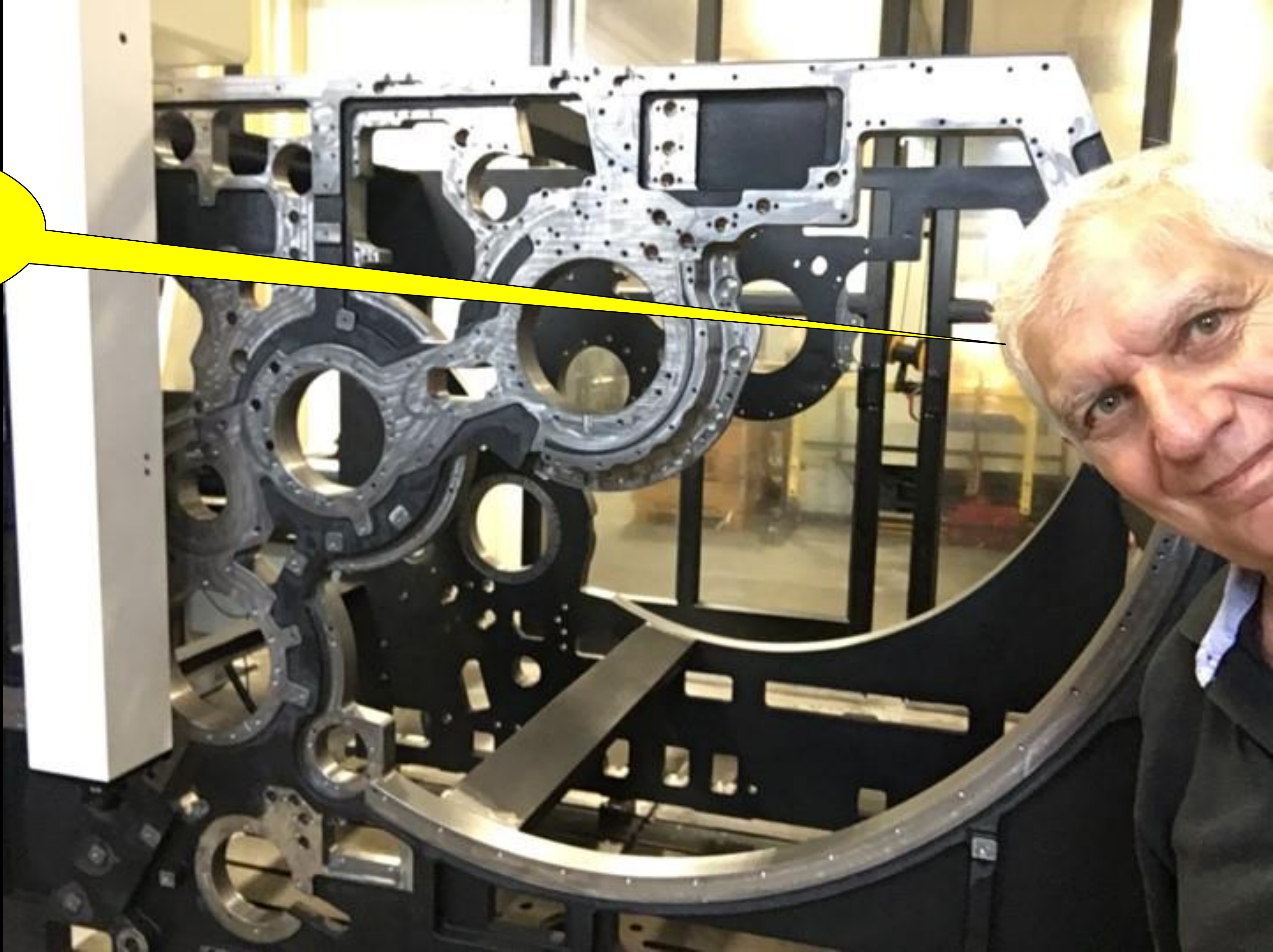
לישראל

https://www.youtube.com/watch?v=GX3F6Zy-Vwk&list=PLOQ4CAjSlhKm8WrhWVfLi1S2EonR0riaQ&index=1


שאלות?