Module 9

RUN CHART

What is a Run Chart?

A Run Chart is the most basic tool used to display how a process performs over time. It is a line graph of data points plotted in chronological order—that is, the sequence in which process events occurred. These data points represent measurements, counts, or percentages of process output. Run Charts are used to assess and achieve process stability by highlighting signals of special causes of variation (Viewgraph 1).

Why should teams use Run Charts?

Using Run Charts can help you determine whether your process is stable (free of special causes), consistent, and predictable. Unlike other tools, such as Pareto Charts or Histograms, Run Charts display data in the sequence in which they occurred. This enables you to visualize how your process is performing and helps you to detect signals of special causes of variation.

A Run Chart also allows you to present some simple statistics related to the process:

Median: The middle value of the data presented.
You will use it as the Centerline on your Run Chart.

Range: The difference between the largest and smallest values in the data.
You will use it in constructing the Y-axis of your Run Chart.

You can benefit from using a Run Chart whenever you need a graphical tool to help you (Viewgraph 2)

- Understand variation in process performance so you can improve it.
- Analyze data for patterns that are not easily seen in tables or spreadsheets.
- Monitor process performance over time to detect signals of changes.
- Communicate how a process performed during a specific time period.

What is a Run Chart?

A line graph of data points plotted in chronological order that helps detect special causes of variation.

RUN CHART VIEWGRAPH 1

Why Use Run Charts?

- Understand process variation
- Analyze data for patterns
- Monitor process performance
- Communicate process performance

RUN CHART VIEWGRAPH 2

What are the parts of a Run Chart?

As you can see in Viewgraph 3, a Run Chart is made up of seven parts:

1. Title: The title briefly describes the information displayed in the Run Chart.

2. Vertical or Y-Axis: This axis is a scale which shows you the magnitude of the measurements represented by the data.

3. Horizontal or X-Axis: This axis shows you when the data were collected. It always represents the sequence in which the events of the process occurred.

4. Data Points: Each point represents an individual measurement.

5. Centerline: The line drawn at the median value on the Y-axis is called the Centerline. (Finding the median value is Step 3 in constructing a Run Chart.)

6. Legend: Additional information that documents how and when the data were collected should be entered as the legend.

7. Data Table: This is a sequential listing of the data being charted.

How is a Run Chart constructed?

Step 1 - List the data. List the data you have collected in the sequence in which it occurred. You may want to refer to the Data Collection module for information on defining the purpose for the data and collecting it.

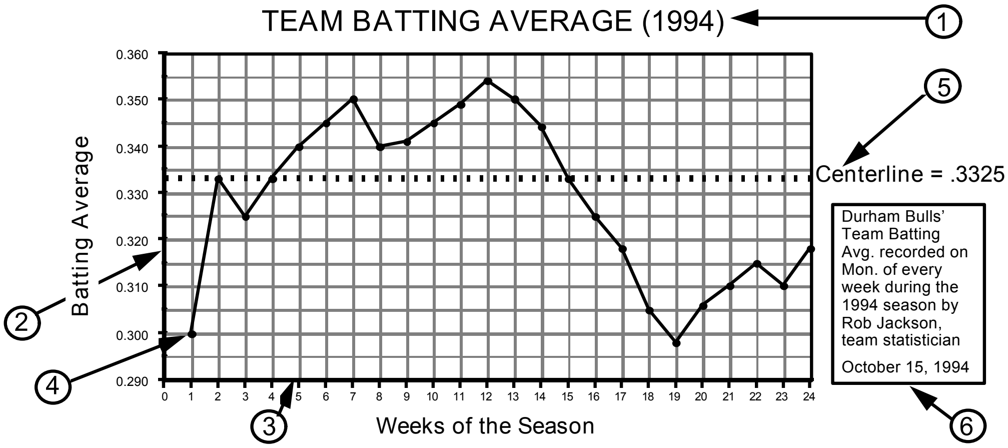
Step 2 - Order the data and determine the range (Viewgraph 4). To order the data, list it from the lowest value to the highest. Determine the range—the difference between the highest and lowest values.

Step 3 - Calculate the median (Viewgraph 4). Once the data have been listed from the lowest to the highest value, count off the data points and determine the middle point in the list of measurements—the point that divides the series of data in half.

- If the count is an odd number, the middle is an odd number with an equal number of points on either side of it. If you have nine measurements, for example, the median is the fifth value.

- If the count is an even number, average the two middle measurements to determine the median value. For example, for 10 measurements, the median is the average of the fifth and sixth values. To determine the average, just add them together and divide by two.

Parts of a Run Chart



WEEK	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
AVG	300	333	325	332	340	345	350	340	341	345	349	354	350	344	333	325	318	305	298	306	310	315	310	318

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1 TITLE
2 Y-AXIS
3 X-AXIS
4 DATA POINT
5 CENTERLINE
6 LEGEND
7 DATA TABLE

RUN CHART VIEWGRAPH 3

How to Construct a Run Chart
Step 2 - Order data & determine range
Step 3 - Calculate the median

RANK	AVG	RANK	AVG	RANK	AVG
1	.298	9	.318	17	.341
2	.300	10	.325	18	.344
3	.305	11	.325	19	.345
4	.306	12	.332	20	.345
5	.310	13	.333	21	.349
6	.310	14	.333	22	.350
7	.315	15	.340	23	.350
8	.318	16	.340	24	.354

MEDIAN:
(.332 + .333) / 2
= .3325

RANGE: .354 - .298 = 0.56

RUN CHART VIEWGRAPH 4

Now let's continue with the remaining steps (Viewgraph 5).

Step 4 - Construct the Y-Axis. Center the Y-Axis at the median. Make the Y-axis scale 1.5 to 2 times the range.

Step 5 - Draw the Centerline. Draw a horizontal line at the median value and label it as the Centerline with its value. The median is used as the Centerline, rather than the mean, to neutralize the effect of any very large or very small values.

Step 6 - Construct the X-axis. Draw the X-axis 2 to 3 times as long as the Y-axis to provide enough space for plotting all of the data points. Enter all relevant measurements and use the full width of the X-axis.

NOTE: One of the strengths of a Run Chart is its readability, so don't risk making it harder to interpret by putting too many measurements on one sheet. If you have more than 40 measurements, consider continuing the chart on another page.

Step 7 - Plot the data points and connect them with straight lines.

Step 8 - Provide a Title and a Legend. Give the chart a title that identifies the process you are investigating and compose a legend that tells:

- The period of time when the data were collected
- The location where the data were collected
- The person or team who collected the data

How do we interpret a Run Chart?

Interpreting a Run Chart requires you to apply some of the theory of variation. You are looking for trends, runs, or cycles that indicate the presence of special causes. But before we examine those features of Run Charts, a word about variation. Expect to see it. Just remember that process improvement activities are expected to produce positive results, and these sometimes cause trends or runs, so the presence of special causes of variation is not always a bad sign.

- A Trend signals a special cause when there is a sequence of seven or more data points steadily increasing or decreasing with no change in direction. When a value repeats, the trend stops. The example in Viewgraph 6 shows a decreasing trend in lower back injuries, possibly resulting from a new "Stretch and Flex" exercise program.

    When your Run Chart shows seven or more consecutive ascending or descending data points, it is a signal that a special cause may be at work and the trend must be investigated.

How to Construct a Run Chart

Step 4 - Construct the Y-axis

Step 5 - Draw the Centerline

Step 6 - Construct the X-axis

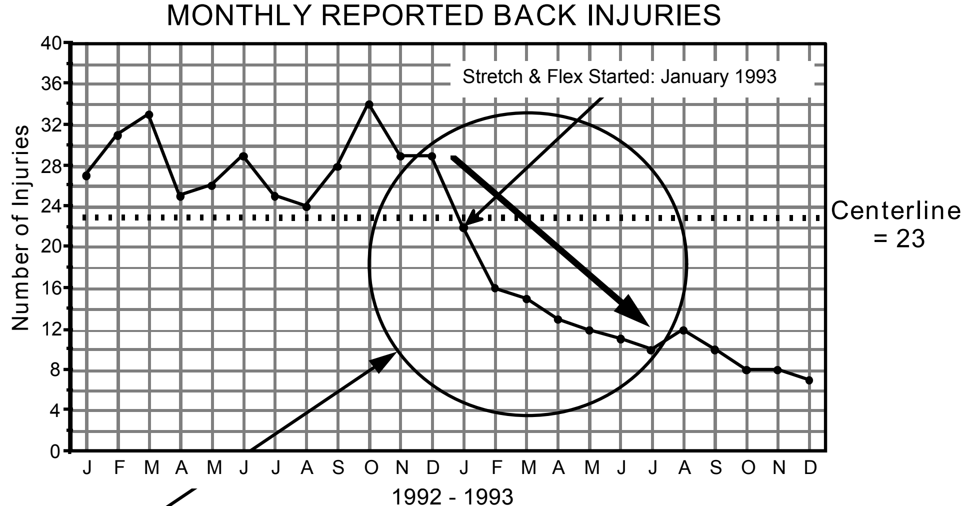
Step 7 - Plot and connect the data points

Step 8 - Provide a title and a legend

RUN CHART VIEWGRAPH 5

Trend Example

MONTHLY REPORTED BACK INJURIES



Signal of special cause variation: 7 or more consecutive ascending or descending points

Data taken from OSHA Reports and CA-1 forms by Bob Kopiske. Compiled and charted on 15 January 1994.

RUN CHART VIEWGRAPH 6

- A Run consists of two or more consecutive data points on one side of the centerline. A run that signals a special cause is one that shows nine or more consecutive data points on one side of the centerline. In the example in Viewgraph 7, you can see such a run occurring between 15 and 28 March. Investigation revealed that new software was responsible for the increase in duplication. This was corrected on 29 March with the introduction of a software "patch." Whenever a data point touches or crosses the centerline, a run stops and a new one starts.

    When your Run Chart shows nine or more consecutive data points on one side of the centerline, it is an unusual event and should always be investigated.

- A Cycle, or repeating pattern, is the third indication of a possible special cause. A cycle must be interpreted in the context of the process that produced it. In the example in Viewgraph 8, a housing office charted data on personnel moving out of base housing during a four-year period and determined that there was an annual cycle. Looking at the 1992-1993 data, it's evident that there were peaks during the summer months and valleys during the winter months. Clearly, understanding the underlying reasons why a cycle occurred in your process enables you to predict process results more accurately.

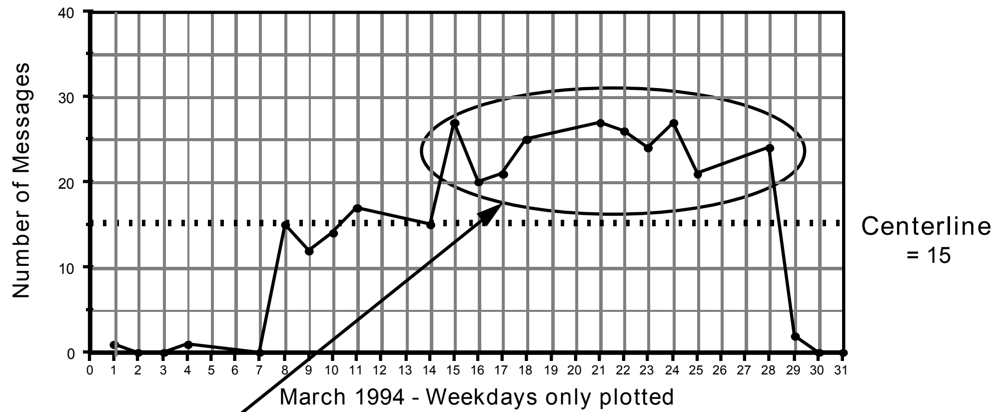
    A cycle must recur at least eight times before it can be interpreted as a signal of a special cause of variation.

  When interpreting a cycle, remember that trends or runs might also be present, signaling other special causes of variation.

NOTE: The absence of signals of special causes does not necessarily mean that a process is stable. Dr. Walter Shewhart suggested that a minimum of 100 observations without a signal is required before you can say that a process is in statistical control. Refer to the Control Chart module for more information on this subject.

Run Example

DUPLICATE MESSAGES



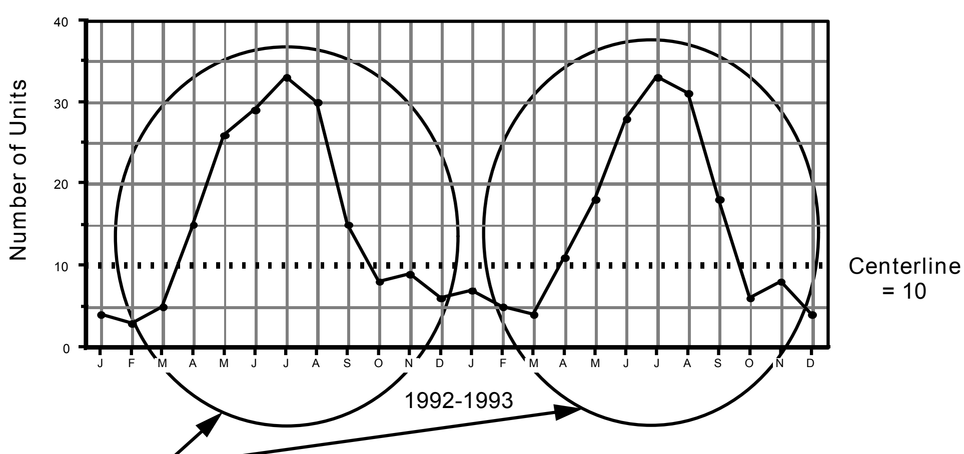
Signal of special cause variation:
9 or more consecutive data points on the same side of the centerline

Data taken from manual daily count of incoming messages, entered on checksheet by L. Zinke, NAVEUR Fleet Quality Office.

RUN CHART | VIEWGRAPH 7

Cycle Example

HOUSING MOVE-OUTS



Signal of special cause variation:
Repeating patterns

Data from Housing Office records for 1992-93. Compiled and charted on 1 FEB 94 by Gail Wylie.

RUN CHART | VIEWGRAPH 8

How can we practice what we've learned?

The following exercises are provided to help you sharpen your skills in constructing and interpreting Run Charts.

EXERCISE 1 has two parts based on this scenario:

> Maintenance personnel in a helicopter squadron were receiving complaints from within the squadron and from its external customers because of valve overhaul backlogs which kept some aircraft grounded. To overcome the complaints and satisfy their customers, they realized they needed to reduce valve overhaul time without lessening reliability.

EXERCISE 1 - PART A: They collected data from their process for 14 days, placing their measurements in a table (Viewgraph 9). The table told them that it took them between 170 and 200 minutes to complete one valve overhaul. Although the workload assignment for the 14-day period was 20 overhauls, their process allowed them to complete only 1 per day. This meant that they were adding 6 valves to the backlog every 2 weeks.

They decided to display their data in a Run Chart which they could analyze for signals of special cause variation. To do this, they put their data in numerical order and calculated the centerline as follows:

1	200
2	191
3	190
4	190
5	187
6	185
7	184
Centerline (184 + 183) / 2 = 183.5	
8	183
9	175
10	175
11	175
12	174
13	173
14	170

Draw a Run Chart of the overhaul time for the 14 valves shown in Viewgraph 9. Viewgraph 10 is an answer key.

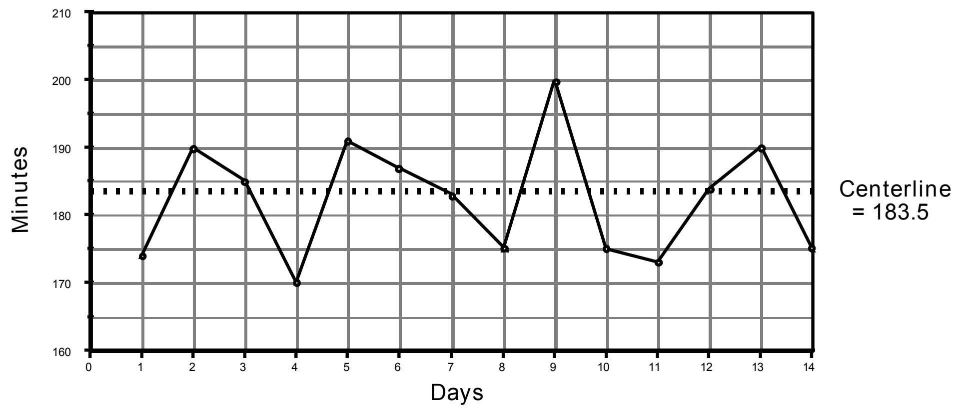
EXERCISE 1A DATA
Overhaul Times
First 14 Valves

VALVE	1st	2nd	3rd	4th	5th	6th	7th
TIME	174	190	185	170	191	187	183
DAY	1	2	3	4	5	6	7

VALVE	8th	9th	10th	11th	12th	13th	14th
TIME	175	200	175	173	184	190	175
DAY	8	9	10	11	12	13	14

RUN CHART VIEWGRAPH 9

EXERCISE 1A RUN CHART
First 14 Valves



Valve	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th	14th
Time	174	190	185	170	191	187	183	175	200	175	173	184	190	175
Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14

RUN CHART VIEWGRAPH 10

In the Run Chart constructed from the data in Part A of Exercise 1 (Viewgraph 10), there are no patterns or indications of special causes of variation. However, it appears that the process is not meeting customers' expectations in terms of the number of valves that can be repaired within a given period of time.

The helicopter maintenance team realized that they needed to decrease the time required to overhaul each valve so that they could increase the number of overhauled valves produced. Using tools such as Flowcharts, Pareto Charts, and Cause-and-Effect Diagrams, they analyzed their process and made some changes.

EXERCISE 1 - PART B: The team collected data from the overhaul of the next 14 valves and placed them in a table (Viewgraph 11). The table told them that the new range of the overhaul process was 95 to 165 minutes.

Perform the centerline calculation for the two sets of data. Viewgraph 12 is an answer key.

Draw a new Run Chart showing the overhaul times for all 28 valves. Viewgraph 13 is an answer key.

Interpret the Run Chart. As you plot the data for all 28 valves, answer these questions:

What can we tell about the performance of this process?

What has occurred?

How do we know?

EXERCISE 1B DATA
Overhaul Times
Second 14 Valves

VALVE	15th	16th	17th	18th	19th	20th	21st
TIME	165	140	125	110	108	105	100
DAY	15	16	17	18	19	20	21

VALVE	22nd	23rd	24th	25th	26th	27th	28th
TIME	95	108	115	120	105	100	95
DAY	22	23	24	25	26	27	28

RUN CHART VIEWGRAPH 11

EXERCISE 1B
Centerline Calculations

Old Process

Starts … Ends

1	2	3	4	5	6	7	8	9	10	11	12	13	14
200	191	190	190	187	185	184	183	175	175	175	174	173	170

Centerline (184 + 183)/2 = 183.5

New Process

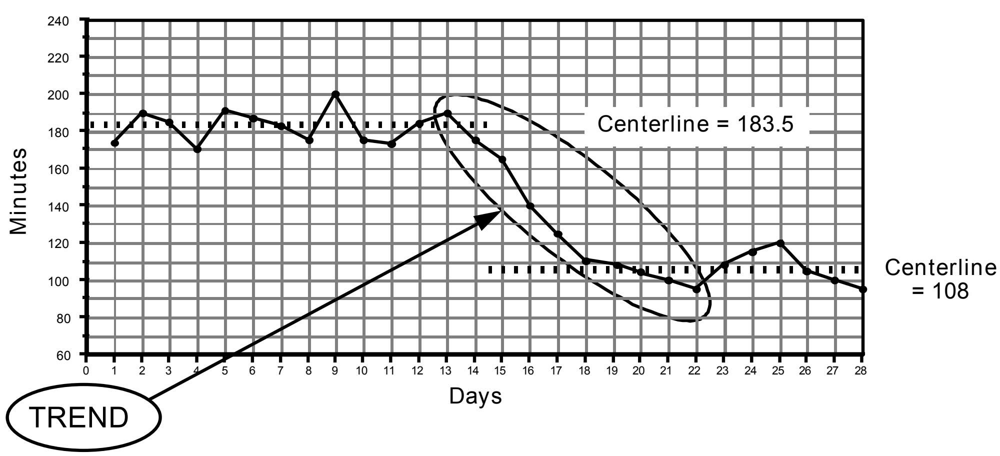
Starts … Ends

15	16	17	18	19	20	21	22	23	24	25	26	27	28
165	140	125	120	115	110	108	108	105	105	100	100	95	95

Centerline (108 + 108)/2 = 108

RUN CHART VIEWGRAPH 12

EXERCISE 1B RUN CHART
All 28 Valves



Valve	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th	14th	15th	16th	17th	18th	19th	20th	21st	22nd	23rd	24th	25th	26th	27th	28th
Time	174	190	185	170	191	187	183	175	200	175	173	184	190	175	165	140	125	110	108	105	100	95	108	115	120	105	100	95
Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28

RUN CHART VIEWGRAPH 13

Looking at Viewgraph 12, you can see that there are now two distinct processes, each with its own centerline. The Run Chart plotted in Viewgraph 13 clearly shows that the new process has significantly improved the throughput by reducing the valve overhaul time.

EXERCISE 2: A team was tasked with reducing the time required to launch the ship's motor whaleboat during man-overboard drills. Their analysis identified starting the motor as the factor having the greatest affect on time to launch. The team collected data on the time, measured in minutes, required to start the motor during 10 drills using the current process. The data table they prepared is shown in Viewgraph 14.

The team then brainstormed factors that might contribute to the amount of time it took the engine to start. Fuel injector fouling was cited numerous times. The team investigated and learned that the engine started promptly on four earlier occasions when the injectors were removed and cleaned or completely replaced. They then used a technique know as “the five whys” to investigate further:

Q: Why were the injectors getting fouled?
A: There was oil in the cylinders.

> Q: Why was there oil in the cylinders?
> A: The piston rings were worn.
>
> > Q: Why were the piston rings worn?
> > A: They were old and needed replacement.
> >
> > > Q: Why weren't they replaced?
> > > A: Spare parts were not readily available.
> > >
> > > > Q: Why weren't spare parts readily available?
> > > > A: The engine manufacturer recently lost all stock of spare parts in a devastating fire. Parts will be available in about two months.

The team was able to develop a plan for improvement based on the answers this method of inquiry produced. To deal with the fouling problem, they (1) initiated a schedule for cleaning or replacing the fuel injectors, (2) made long-term plans to replace the worn piston rings, and (3) reviewed the maintenance schedule to ensure that the rings would be replaced routinely at particular maintenance intervals. After these changes in the process were instituted, the team collected data on the next 10 drills. The data table they prepared is shown in Viewgraph 15.

Draw a Run Chart of the data from the 20 drills. Don’t forget to perform the centerline calculations. An answer key is provided in Viewgraph 16.

Interpret your Run Chart.

Are there any signals of special cause variation?

If so, what are they?

EXERCISE 2 DATA
Minutes to Start Engine
First 10 Drills

DRILL	1st	2nd	3rd	4th	5th
TIME	15.3	12.1	14.4	16.8	17.3

DRILL	6th	7th	8th	9th	10th
TIME	16.6	14.2	12.0	11.3	13.9

RUN CHART VIEWGRAPH 14

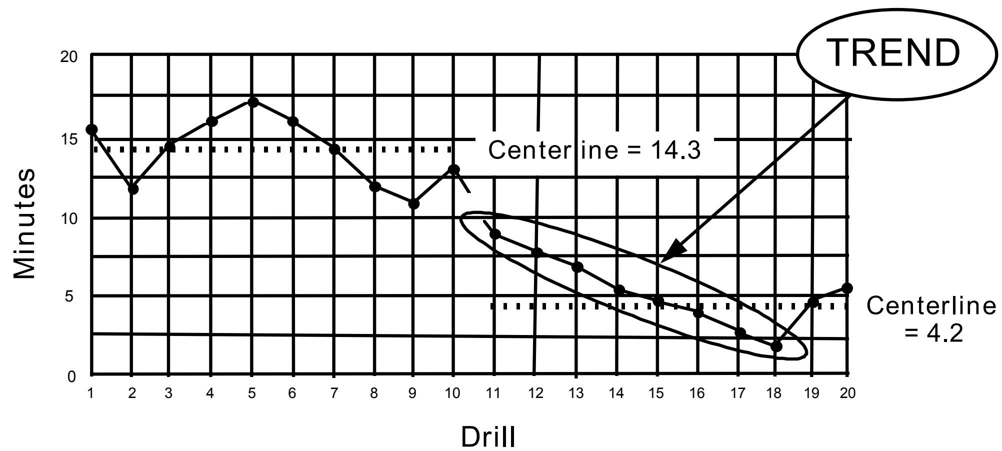
EXERCISE 2 DATA
Minutes to Start Engine
Second 10 Drills

DRILL	11th	12th	13th	14th	15th
TIME	8.1	7.6	7.2	5.1	4.4

DRILL	16th	17th	18th	19th	20th
TIME	4.0	2.6	2.2	4.5	5.3

RUN CHART VIEWGRAPH 15

EXERCISE 2 RUN CHART
Minutes to Start Engine



Drill	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Time	15.3	12.1	14.4	16.8	17.3	16.6	14.2	12.0	11.3	13.9	8.1	7.6	7.2	5.1	4.4	4.0	2.6	2.2	4.5	5.3

RUN CHART VIEWGRAPH 16

When you interpret the Run Chart in Viewgraph 16, you'll see that there is indeed a signal of a special cause of variation—a trend. This trend charts the dramatic reduction in the number of minutes required to start the engine during the second ten drills. The efforts of the team described in Exercise 2 were rewarded with an improvement in the process.

REFERENCES:

1. Brassard, M. (1988). The Memory Jogger, A Pocket Guide of Tools for Continuous Improvement, pp. 30 - 35. Methuen, MA: GOAL/QPC.

2. Department of the Navy (November 1992). Fundamentals of Total Quality Leadership (Instructor Guide), pp. 6-52 - 6-56. San Diego, CA: Navy Personnel Research and Development Center.

3. Department of the Navy (September 1993). Systems Approach to Process Improvement (Instructor Guide), pp. 7-13 - 7-43. San Diego, CA: OUSN Total Quality Leadership Office and Navy Personnel Research and Development Center.

4. U.S. Air Force (Undated). Process Improvement Guide - Total Quality Tools for Teams and Individuals, pp. 52 - 53. Air Force Electronic Systems Center, Air Force Materiel Command.

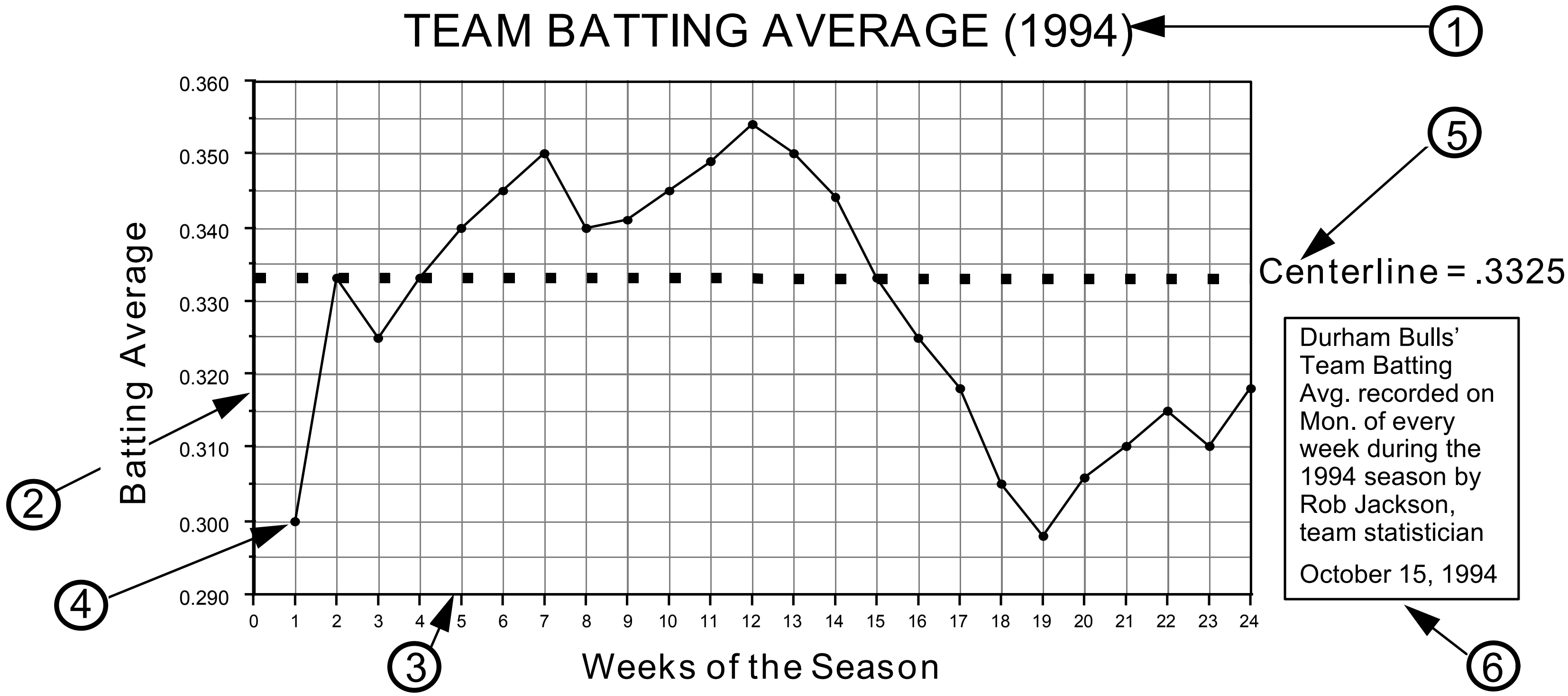
What is a Run Chart?

A line graph of data points plotted in chronological order that helps detect special causes of variation.

Why Use Run Charts?

- Understand process variation
- Analyze data for patterns
- Monitor process performance
- Communicate process performance

Parts of a Run Chart



WEEK	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
AVG	300	333	325	332	340	345	350	340	341	345	349	354	350	344	333	325	318	305	298	306	310	315	310	318

7

1 TITLE
2 Y-AXIS
3 X-AXIS
4 DATA POINT
5 CENTERLINE
6 LEGEND
7 DATA TABLE

How to Construct a Run Chart

Step 2 - Order data & determine range
Step 3 - Calculate the median

RANK	AVG	RANK	AVG	RANK	AVG
1	.298	9	.318	17	.341
2	.300	10	.325	18	.344
3	.305	11	.325	19	.345
4	.306	12	.332	20	.345
5	.310	13	.333	21	.349
6	.310	14	.333	22	.350
7	.315	15	.340	23	.350
8	.318	16	.340	24	.354

MEDIAN:
(.332 + .333) / 2
= .3325

RANGE: .354 - .298 = 0.56

How to Construct a Run Chart

Step 4 - Construct the Y-axis

Step 5 - Draw the Centerline

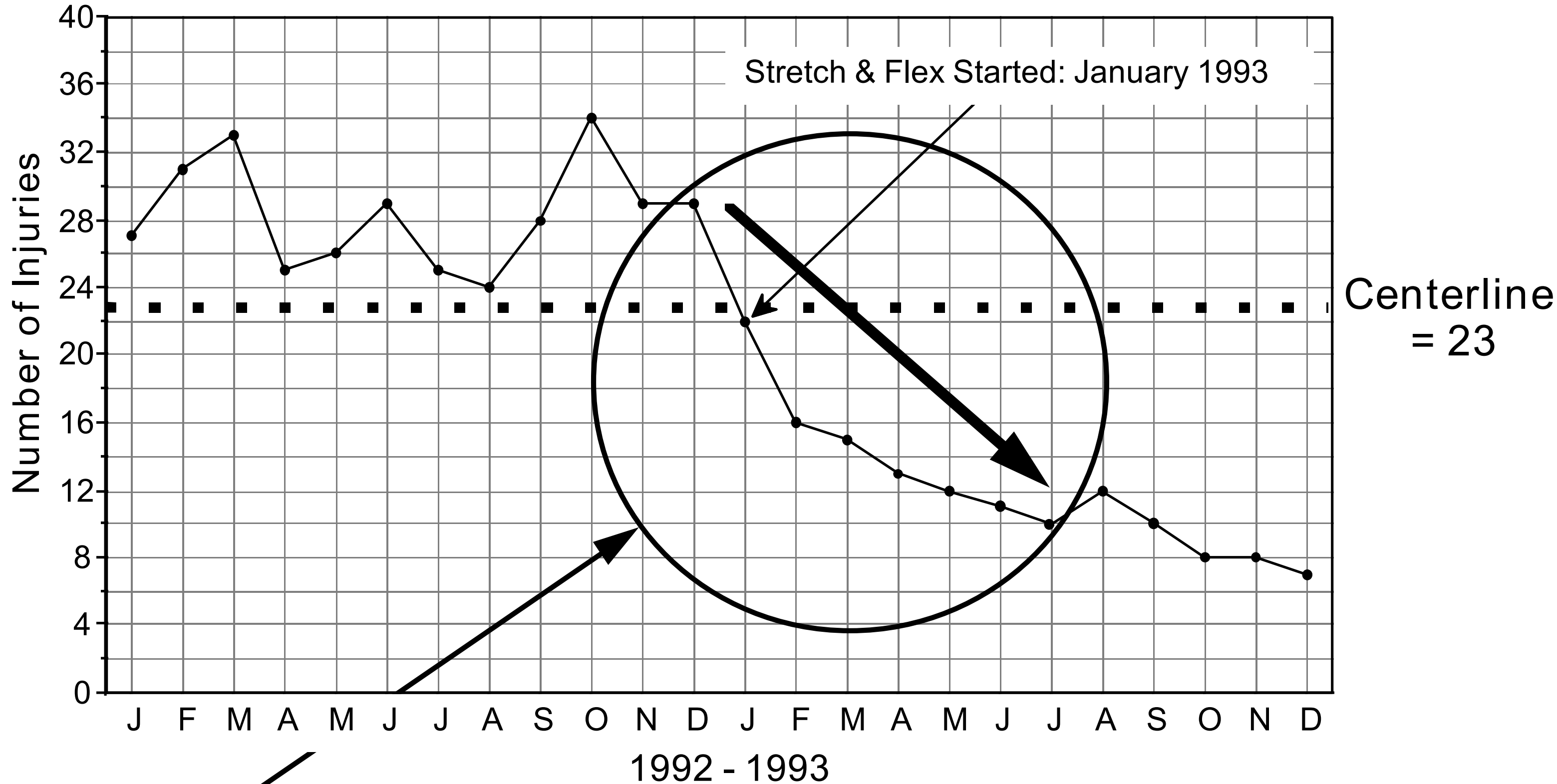
Step 6 - Construct the X-axis

Step 7 - Plot and connect the data points

Step 8 - Provide a title and a legend

Trend Example

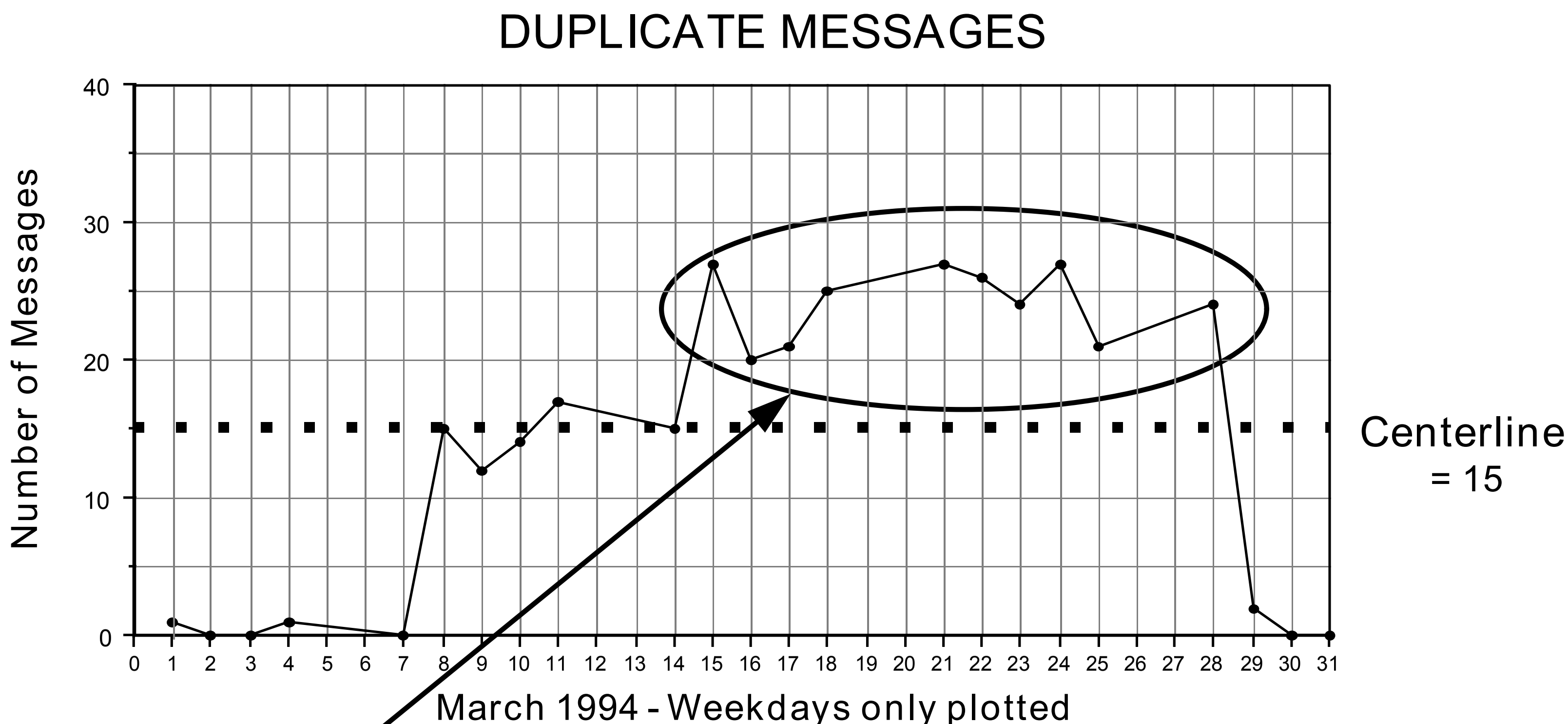
MONTHLY REPORTED BACK INJURIES



Signal of special cause variation: 7 or more consecutive ascending or descending points

Data taken from OSHA Reports and CA-1 forms by Bob Kopiske. Compiled and charted on 15 January 1994.

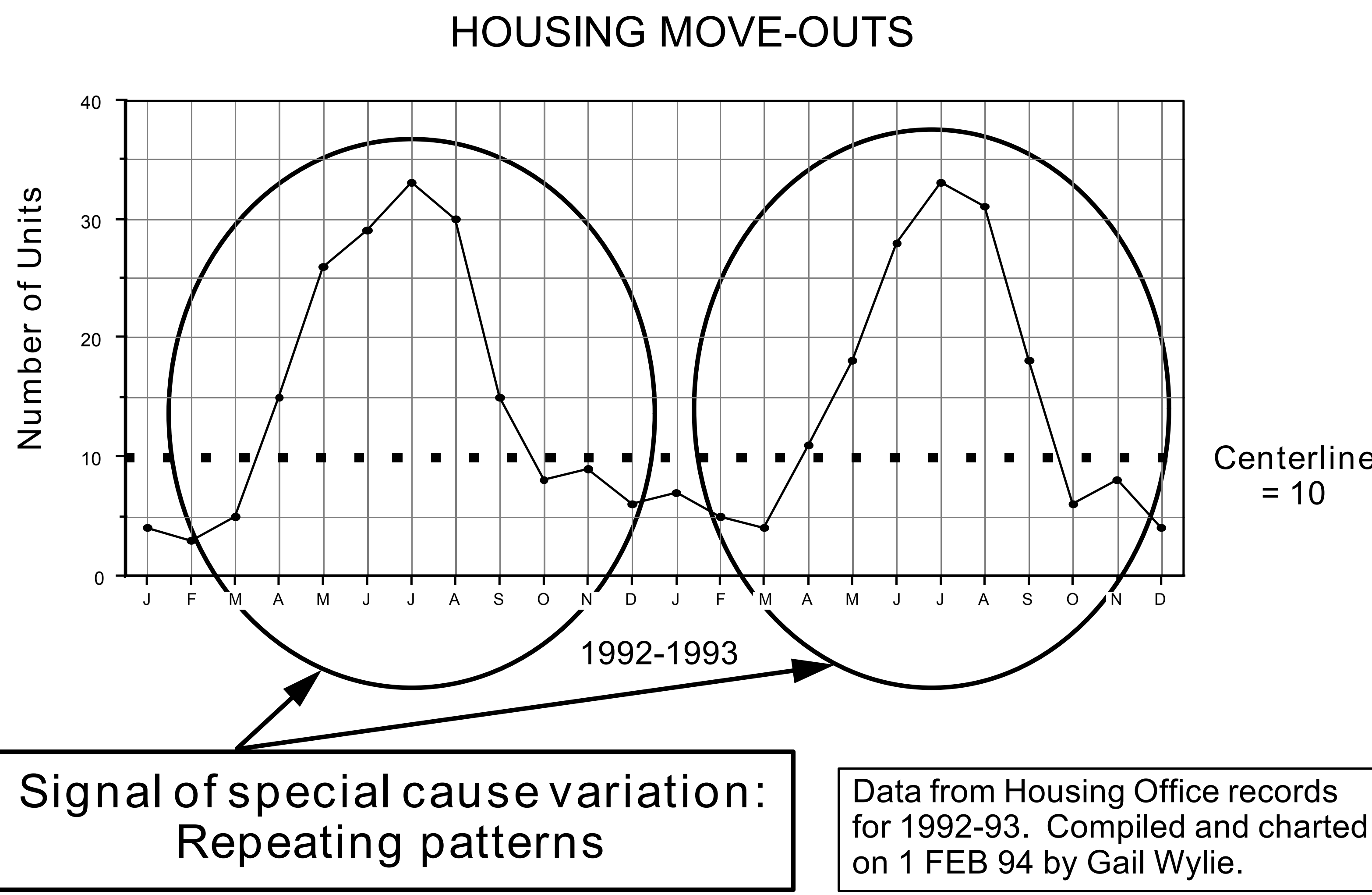
Run Example



Signal of special cause variation: 9 or more consecutive data points on the same side of the centerline

Data taken from manual daily count of incoming messages, entered on checksheet by L. Zinke, NAVEUR Fleet Quality Office.

Cycle Example



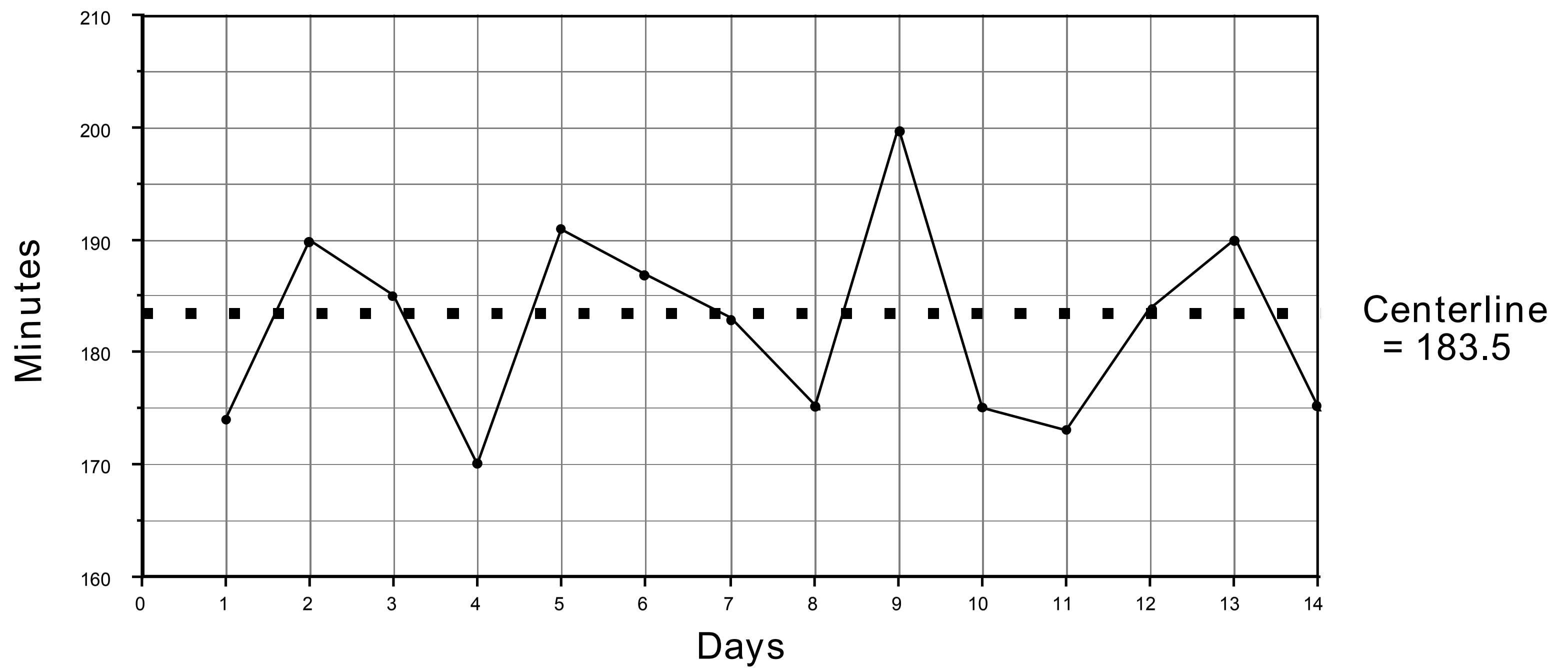
Data from Housing Office records for 1992-93. Compiled and charted on 1 FEB 94 by Gail Wylie.

EXERCISE 1A DATA
Overhaul Times
First 14 Valves

VALVE	1st	2nd	3rd	4th	5th	6th	7th
TIME	174	190	185	170	191	187	183
DAY	1	2	3	4	5	6	7

VALVE	8th	9th	10th	11th	12th	13th	14th
TIME	175	200	175	173	184	190	175
DAY	8	9	10	11	12	13	14

EXERCISE 1A RUN CHART
First 14 Valves



Valve	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th	14th
Time	174	190	185	170	191	187	183	175	200	175	173	184	190	175
Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14

EXERCISE 1B DATA
Overhaul Times
Second 14 Valves

VALVE	15th	16th	17th	18th	19th	20th	21st
TIME	165	140	125	110	108	105	100
DAY	15	16	17	18	19	20	21

VALVE	22nd	23rd	24th	25th	26th	27th	28th
TIME	95	108	115	120	105	100	95
DAY	22	23	24	25	26	27	28

EXERCISE 1B
Centerline Calculations

Old Process

Starts … Ends

1	2	3	4	5	6	7	8	9	10	11	12	13	14
200	191	190	190	187	185	184	183	175	175	175	174	173	170

Centerline $(184 + 183)/2 = 183.5$

New Process

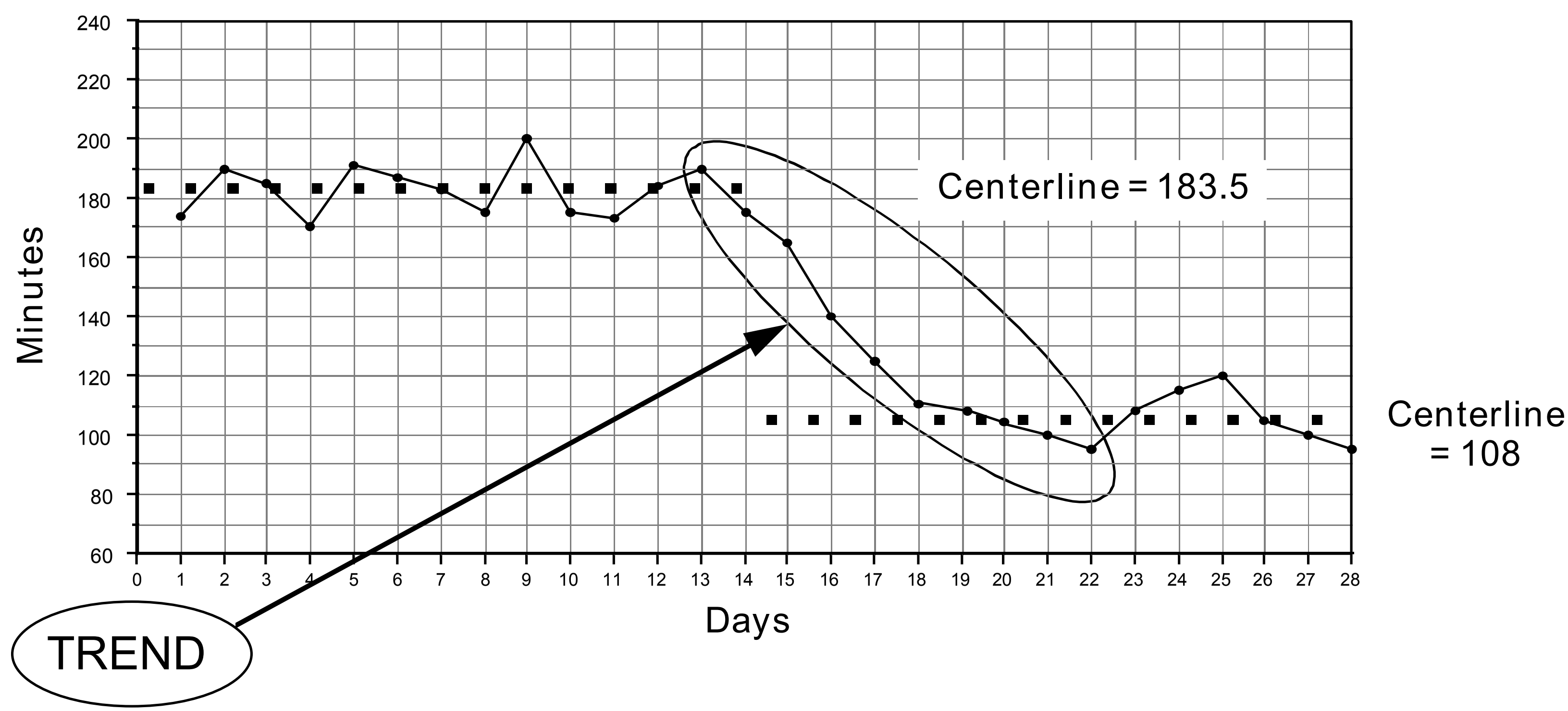
Starts … Ends

15	16	17	18	19	20	21	22	23	24	25	26	27	28
165	140	125	120	115	110	108	108	105	105	100	100	95	95

Centerline $(108 + 108)/2 = 108$

EXERCISE 1B RUN CHART

All 28 Valves



Valve	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th	14th
Time	174	190	185	170	191	187	183	175	200	175	173	184	190	175
Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14

Valve	15th	16th	17th	18th	19th	20th	21st	22nd	23rd	24th	25th	26th	27th	28th
Time	165	140	125	110	108	105	100	95	108	115	120	105	100	95
Day	15	16	17	18	19	20	21	22	23	24	25	26	27	28

EXERCISE 2 DATA
Minutes to Start Engine
First 10 Drills

DRILL	1st	2nd	3rd	4th	5th
TIME	15.3	12.1	14.4	16.8	17.3

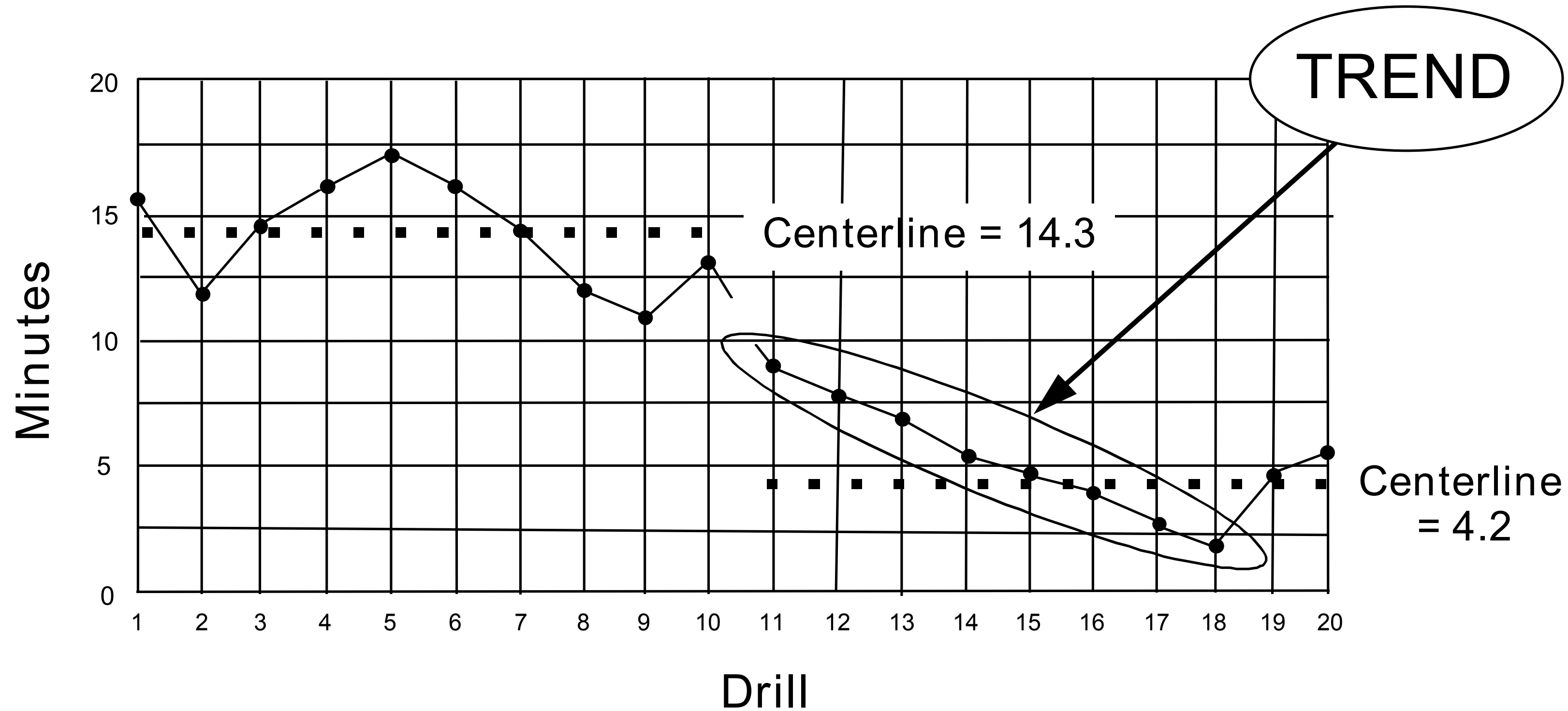
DRILL	6th	7th	8th	9th	10th
TIME	16.6	14.2	12.0	11.3	13.9

EXERCISE 2 DATA
Minutes to Start Engine
Second 10 Drills

DRILL	11th	12th	13th	14th	15th
TIME	8.1	7.6	7.2	5.1	4.4

DRILL	16th	17th	18th	19th	20th
TIME	4.0	2.6	2.2	4.5	5.3

EXERCISE 2 RUN CHART
Minutes to Start Engine



Drill	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Time	15 .3	12 .1	14 .4	16 .8	17.3	16 .6	14.2	12 .0	11.3	13 .9	8 .1	7.6	7.2	5 .1	4 .4	4.0	2.6	2.2	4.5	5.3