The Space Shuttle Flight into Space
STS-113 Ascent Timeline 24/11/2002

STS-113 Ascent Events			SpaceCalc
EVENTS	**Eastern**	**L-HH:MM**	**Pre-Launch Events**
Shuttle Endeavour 19th flight Inc.: 51.6 Throttle: 104 A/P: 137/36 sm OMS: 143/121	10:24:48 AM	L-08:55	Fueling begins
	3:59:48 PM	L-03:55	Crew Walkout
	6:34:48 PM	L-01:15	**T-20 and holding**
	6:44:48 PM	L-01:05	Resume countdown
		L-MM:SS	**Terminal Countdown**
Launch 11/24/02 7:49 Win Close 11/24/02 7:54 -34:49:43 SLF Max Wind: 18 Wind Direction: 300 SLF Crosswind: **8.52** **Xwind OK**	6:55:48 PM	L-49:00	**T-9 hold begins**
	7:40:47 AM	L-09:00	Resume countdown
	7:42:17 AM	L-07:30	Orbiter access arm retraction
	7:44:47 AM	L-05:00	Auxilliary power unit start
	7:44:52 AM	L-04:55	Liquid oxygen drainback begins
	7:45:52 AM	L-03:55	Purge sequence 4 hydraulic test
	7:46:52 AM	L-02:55	Oxygen tank at flight pressure
	7:46:52 AM	L-02:55	Gaseous oxygen vent arm retraction
	7:47:12 AM	L-02:35	Fuel cells to internal
	7:47:50 AM	L-01:57	Hydrogen tank at flight pressure
	7:48:57 AM	L-00:50	Orbiter to internal power
	7:49:16 AM	L-00:31	Shuttle computers control countdown
	7:49:26 AM	L-00:21	Booster steering test
	7:49:40 AM	L-00:06.6	Main engine ignition

Abort Data		L+MM:SS	Ascent Events	MPH
0:02:25 RTLS ONLY	7:49:47 AM	T+00:00	**Launch**	**(Yi)**
	7:49:58 AM	T+00:11	Start roll program	927
	7:50:05 AM	T+00:18	End roll program	1,002
	7:50:19 AM	T+00:32	Main engine throttle down	1,193
	7:50:35 AM	T+00:48	Main engine throttle up	1,418
	7:50:48 AM	T+01:01	Max Q (728 psf)	1,657
	7:51:50 AM	T+02:03	SRB separation	3,634
	7:52:00 AM	T+02:13	Start OMS assist	3,750
	7:52:12 AM	T+02:25	Last pre-TAL RTLS	3,887
0:02:37 TAL ONLY	7:52:13 AM	T+02:26	**TAL available**	3,887
	7:53:30 AM	T+03:43	End OMS assist	5,200
	7:53:39 AM	T+03:52	Negative return	5,523
	7:54:50 AM	T+05:03	Last pre-ATO TAL	7,501
0:03:20 ATO	7:54:51 AM	T+05:04	**Press to ATO**	7,501
	7:55:34 AM	T+05:47	Roll to heads up	9,001
	7:55:58 AM	T+06:11	Press to MECO	9,887
	7:56:41 AM	T+06:54	Single engine MECO	12,069
	7:57:09 AM	T+07:22	3G Limiting	13,638
	7:58:11 AM	T+08:24	**MECO command**	17,524
	8:34:47 AM	T+45:00	OMS-2 orbit circularization	
			Compiled by William Harwood	

The information above came from http://spaceflightnow.com/

The velocity given in the table is in miles per hour and includes the velocity of the Earth (since the Earth is spinning). At the Kennedy Space Centre, from where most NASA launches take place, the rotational velocity of the Earth is about 894 mph (1,430 kph). This is therefore the initial speed of the Space Shuttle before it has actually started moving relative to the Earth.

The space shuttle at launch has a mass of about 2 million kg and consists of 4 main parts.

1. The **orbiter**, the aeroplane-like spacecraft that carries the crew and the payload into space. It has three main engines which fire during the lift off and at various other times in the mission.

2. The **external fuel tank**, which supplies the hydrogen fuel and the oxygen for the orbiter's engines during the first eight minutes or so of the flight. It detaches from the orbiter when the fuel runs out and falls back towards the earth where it lands in the ocean. It is not recovered. The hydrogen fuel burns cleanly, leaving no smoke, and so it is difficult to see the thrust coming from the orbiter's main engines.

3. The **two Solid Rocket Boosters** (SRBs), which provide the extra force required at launch. These run out of fuel and fall away from the external fuel tank after about 2 minutes. They fall into the ocean and are recovered and reused. The fuel doesn't burn as cleanly, so lots of smoke is produced.

YOUR MISSION: To produce a speed vs time graph for the ascent stage of a Space Shuttle.

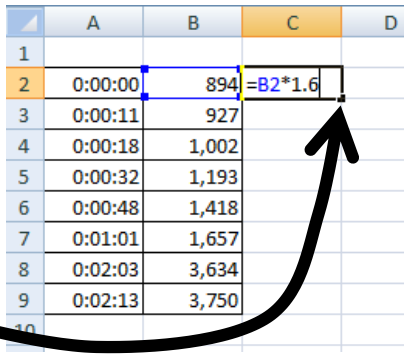
Using Excel and the data on Page 1 above (which has already been typed out for you below), you are to create an annotated **Speed vs Time graph** (with speed on the y-axis and time on the x-axis) for the **Space Shuttle's Ascent**, that is from Launch until its Main Engine Cut Off (MECO) when it has reached space about 8½ minutes later. You will **annotate** the graph with five text boxes which contain information about events that take place during the ascent; for example, SRB separation at 2 minutes and 3 seconds after launch. (See an example of an annotated graph on page 4.)

Time into mission	Speed in MPH
0:00:00	894
0:00:11	927
0:00:18	1,002
0:00:32	1,193
0:00:48	1,418
0:01:01	1,657
0:02:03	3,634
0:02:13	3,750
0:02:25	3,887
0:02:26	3,887
0:03:43	5,200
0:03:52	5,523
0:05:03	7,501
0:05:04	7,601
0:05:47	9,001
0:06:11	9,887
0:06:54	12,069
0:07:22	13,638
0:08:24	17,524

You will need to follow the instructions carefully.

1. Create a table in Excel showing
(i) Time into mission
(ii) Speed in Miles per Hour
(iii) Speed in Kilometres per hour (mph x 1.6).

To do this the easy way,
(a) click on the box next to the "894"
(b) type "=", click the 894 box (cell B2) and then type "*1.6".
When you press Enter, the value should appear.
(c) Click and hold the small elbow of the box and drag down the table. This performs a "fill down" operation (C2*1.6, D2*1.6 etc.) and all the values then appear automatically.



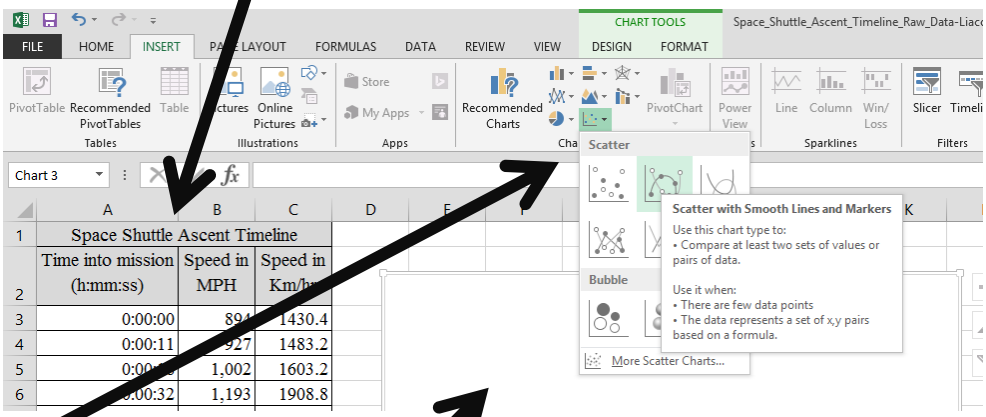
(d) Put a border around the table and highlight the headings. You may need to use the "Merge and Centre" button and the "Wrap Text" button (both on the Home Tab) to format the text.

The data in the time column <u>should</u> to be formatted to Hours:Minutes:Seconds. To do this…
Highlight the cells: Right click: Format Cells: Number Tab: Custom: h:mm:ss

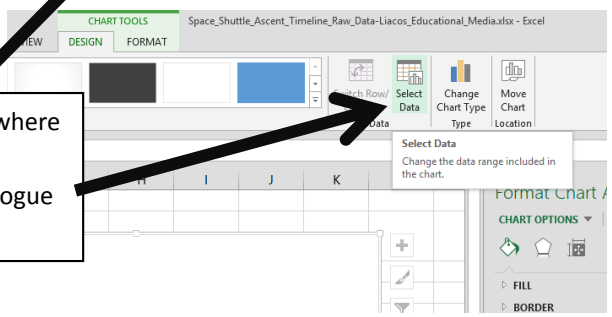
It should look something like this.

2. Draw a graph of the information with **time on the x axis (the horizontal axis)** and **speed in kilometres per hour on the y axis (the vertical axis)**. (See below for instructions)

To draw a graph…

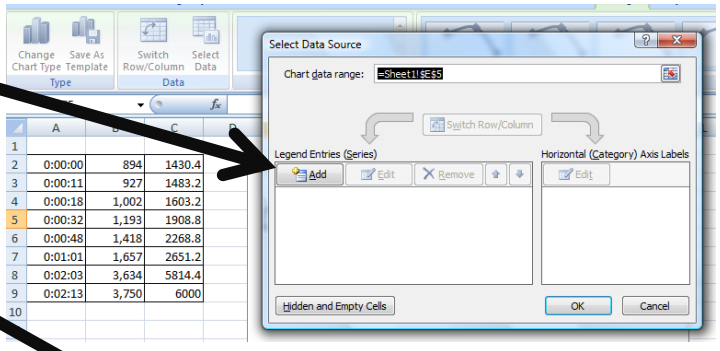


Step 1. Click on an **empty cell <u>at least two cells away</u>** from the table.
Step 2. Click Insert…Scatter… Scatter with Smooth Lines and Markers.

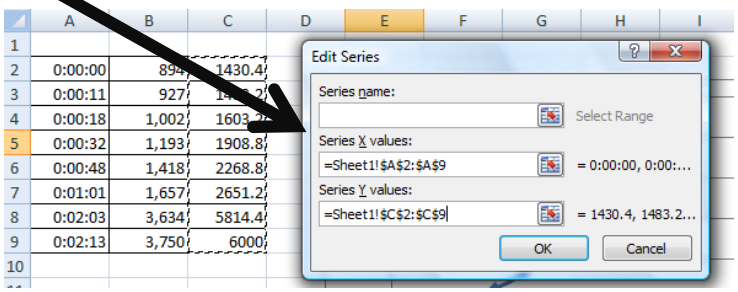


Step 3. You should see a **<u>blank area</u>** where the graph will go.
Click **Select Data** on the Menu. A dialogue box will open.

Step 4. Click the **Add** button.
This allows you to tell the computer what data you want on the x-axis and what data you want on the y-axis.

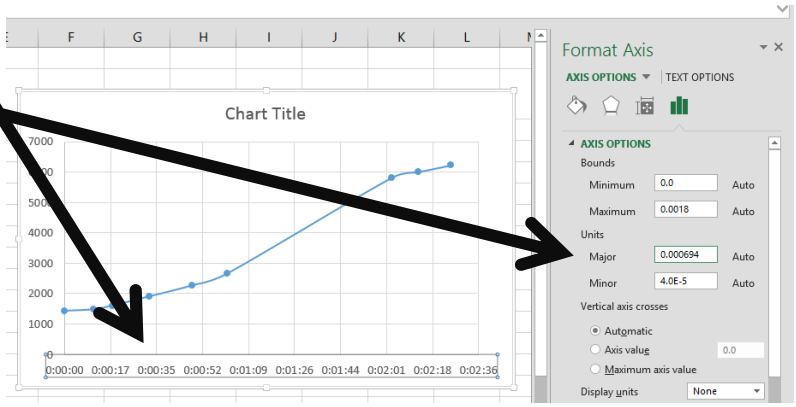


Step 4. Highlight the data you want to graph on the X axis **(in this case, TIME)**. You will see something like "=Sheet1!$A$1:$A$3" .
Highlight only the numbers, not the headings!
A similar operation is performed for the data you want on the Y axis **(in this case SPEED in KM/HR.)** (you need to delete the "={1}" that appears.

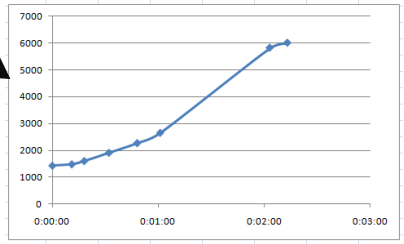


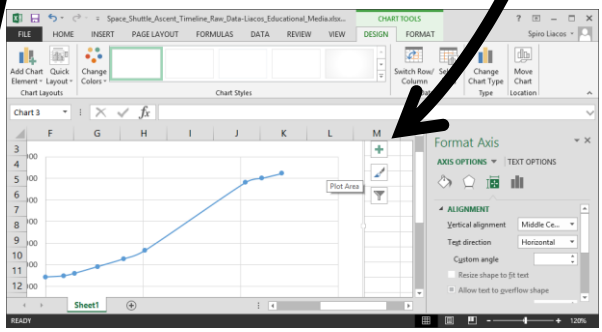
Step 5. If the time axis shows unusual numbers you will need to change the formatting so that the graph show **increments in minutes**. To do this,
(i) right click the numbers
(ii) click "Format Axis".
(iii) In "Axis Options", type 0.000694 in the "Major" Units box. This is the fraction that 1 minute takes up of one day: 1/(24x60).

(If your time was written, for example, as 8:24, Excel is likely to format the cell as HH:MM—hours and minutes—so you may need to type in 0.0416666, which is 1/24.)



Step 6. It should now look something like this. Click either, Add Chart Elements, or the + sign next to the graph and add a "Chart Title" and "Axis Titles".
Format the graph to taste.





Ensure the graph takes up **1 whole page**. Use **View: Page Layout**. You may like to copy the graph into Word and then re-size it.

3. Add some pictures and 5 small text boxes to the graph to provide information in your own words about some major events that occur on the shuttle's flight to space. The information below might be helpful. An example of an annotated graph is also shown below.

4. Answer the following questions in full sentences.
   (a) At what time (with respect to the launch) does the fuelling of the fuel tank begin?
   (b) At what time (with respect to the launch) does the access arm from the tower retract?
   (c) At what time (with respect to the launch) do the orbiter's main engines ignite?
   (d) At T+03:52, the shuttle is "Negative return". What does this mean?
   (e) How fast is the shuttle travelling when it reaches space and its engines are switched off?
   (f) Comment on the shape of the graph and what it shows.

(g) How fast is the shuttle travelling at the (i) 3-minute mark? (ii) 4-minute mark? (iii) 5-minute mark? (iv) 6-minute mark? (v) 7-minute mark? (vi) MECO command.
(h) What is the difference in speed between the 3-minute mark and the 4-minute mark?
(i) What is the difference in speed between the 6-minute mark and the 7-minute mark?
(j) The Space Shuttle's speed is obviously increasing. What is happening to the Shuttle's acceleration (which is the change in speed per unit of time)? Explain why.

5. Write your name on your work and submit it.

An explanation of some of the events that take occur during a shuttle's ascent.
(written by William Harwood http://spaceflightnow.com/)

T+0:11 **Start roll maneuver**
Endeavour begins a programmed roll maneuver to achieve a northeasterly track from KSC, heading toward a 51.6 degree inclination to the equator.

T+0:18 **End roll**
The shuttle completes the programmed roll maneuver and is now positioned heads down, wings level.

T+0:32 **Start throttle down**
The three liquid-fueled main engines are throttled down to ease the vehicle's flight through the dense lower atmosphere.

T+0:48 **Throttle up**
Endeavour's main engines begin throttling back up to about full thrust for the continued trek to space.

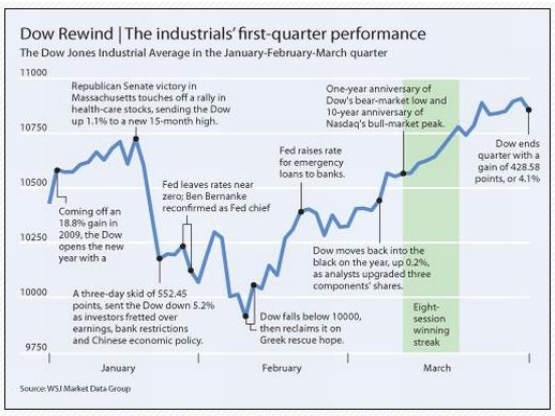
T+1:01 **Max-Q**
The shuttle passes through the area of maximum aerodynamic pressure that is experienced during its climb to orbit.

T+2:03 **SRB staging**
Having consumed all their propellant, the solid rocket boosters are jettisoned from the attachment points on the external fuel tank. The boosters parachute into the Atlantic Ocean for recovery and reuse.

T+3:52 **Negative return**
Endeavour is now too far downrange and traveling too fast to make an emergency Return-to-Launch-Site abort landing at Kennedy Space Center. A problem after this point during flight requiring an abort would lead to a Trans-Atlantic Abort Landing, Abort-to-Orbit or Abort-Once-Around.

T+5:47 **Rolls to heads up**
A programmed maneuver rolls Endeavour to a heads up position, placing the shuttle atop the external tank. This is done to improve communications between the shuttle and NASA's orbiting Tracking and Data Relay Satellite System.

T+8:24 **MECO command (Main Engine Cut Off)**
Endeavour's three main engines are shut down. The external fuel tank is jettisoned moments later. An upcoming firing at about T+45 minutes by the Orbital Maneuvering System (OMS) engines will boost the shuttle from its current sub-orbital trajectory to a safe altitude as the chase begins to rendezvous with the International Space Station.



(An annotated graph can look something like this)
Source: http://www.investmentpostcards.com/2010/04/01/q1-global-stock-market-performance-in-review/