Communiquer avec l'atterrisseur InSight

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Objectif : Montrer qu'il n'est pas simple de communiquer avec la Terre depuis Mars, puis regarder les solutions utilisées par insight

Préparatifs : Problèmes InSight 6 et 9 (en anglais) tirés de 'space math' (http://spacemath.gsfc.nasa.gov). L'activité proposée nécessite aussi Animation geogebra sur les trajectoires Terre-Mars.

Déroulement :

Step 1 - ***Matérialiser les voies de communication Terre-Mars***
Dessin à l'échelle des trajectoires Terre et Mars (1 cm pour 20 millions de km) en considérant les orbites circulaires (voir fig1) ou pas (voir fig2)
***Année martienne** = 687 jours*
Placer la Terre et Mars alignées au Soleil.
Placer les positions mensuelles de la Terre et de Mars pendant 24 mois.
(On appellera ces points T_1 , M_1 , T_2 , M_2 …)
Tracer [T_1 M_1] ; [T_2 M_2] ; …
Quels problèmes de communication vont se poser ?

Step 2 - **Angle Soleil Mars Terre en fonction des mois et communication avec la Terre.**
Répondre aux problèmes de la fiche 'Space Maths' InSight 6
Voir fig 3

Step 3 : ***Données transmises depuis Mars***
temps de communication et buffer nécessaire pour envoyer l'information :
une piste sur les données perdues.
Répondre aux problèmes de la fiche 'Space maths' InSight 9

Documentation complémentaire :

SpaceMath@NASA stimule les élèves à l'usage des mathématiques par le biais de l'exploration spatiale. A travers divers articles scientifiques, les élèves sont invités à résoudre des problèmes mathématiques.
https://spacemath.gsfc.nasa.gov/

Figure 1

PLANETES	*DIAMETRES (en km)*	*DISTANCES AU SOLEIL (en millions de km)*
Mercure	*4 900*	*58*
Vénus	*12 100*	*108*
Terre	*12 800*	*150*
Mars	*6 800*	*228*
Jupiter	*142 900*	*778*
Saturne	*12 500*	*1 427*
Uranus	*51 100*	*2 871*
Neptune	*50 500*	*4 497*
Pluton	*2 300*	*5 913*

Information : les orbites de ces planètes ne sont pas circulaires mais elliptiques.

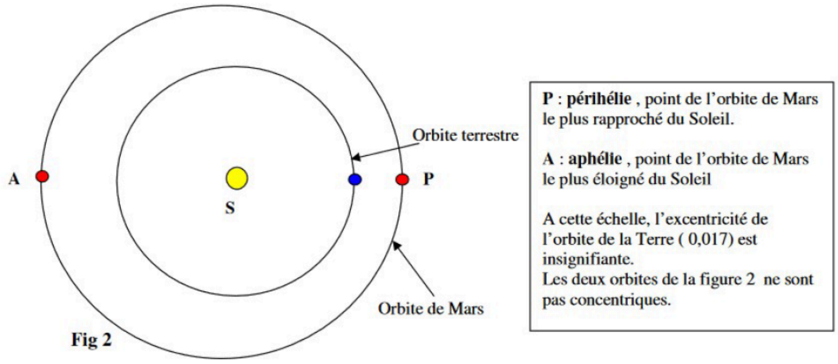
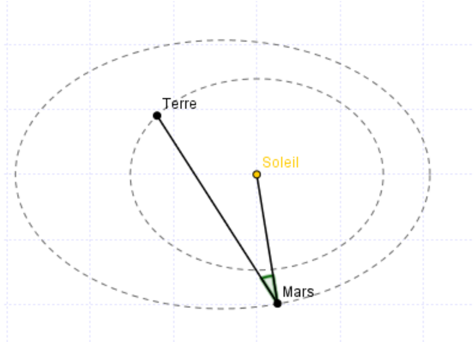


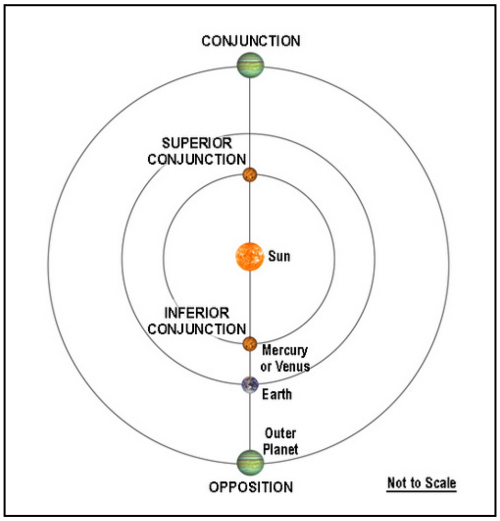
Fig 2

Fig. 3 : Angle Soleil Mars-Terre en fonction des mois



Problèmes de la fiche 'Space Maths' InSight 6 :
Aide au problème 1 > les conjonctions arrivent de manière périodique
Aide au problème 2 > il suffit de regarder dans le tableau les valeurs entre -10 et +10
Aide au problème 3 > il faut utiliser le tableur pour répondre aux questions

Problèmes de la fiche 'Space Maths' InSight 9 :
Aide au problème 1 > Mega est un préfixe qui correspond au million
Aide au problème 2 > facile
Aide au problème 3 > attention, on parle de 2h de données à envoyer
Aide au problème 4 > on veut connaître le maximum de données que l'on pourrait stocker si on envoyait les données pendant 2h en continu



The InSight Lander needs to be in constant communication with Earth every day the data it gathers can be sent back to Earth. As viewed from the surface of Mars, Earth never gets very far from the sun. Over the course of about 780 days, Earth travels from its farthest westward position in the sky (morning star) of 46^o W, to its farthest eastward position (evening star) of 41^o E and back in about 780 days.

When the Earth-Sun angle is near zero as viewed from Mars, Earth can either be between Mars and the sun (called Inferior Conjunction) or Earth can be on the opposite side of the sun as viewed from Mars (called Superior Conjunction).

When Mars and Earth are in inferior conjunction, Earth can receive signals from the Lander, but the Lander will have to broadcast its data almost directly at the sun, which is a hazard for the transmitter. When Earth and Mars are in superior conjunction, Neither InSight nor the Earth radar can transmit or receive data with Earth behind the sun.

Problem 1 – The following table gives the Earth-Sun angle viewed from Mars during the time InSight is operating on the martian surface. During this time, inferior conjunction occurred on May 22, 2016 and July 26, 2018, with superior conjunction on July 27, 2017. When will the next inferior conjunction occur after July 26, 2018?

Month	Angle	Month	Angle	Month	Angle	Month	Angle
9/16	+46	3/17	+24	9/17	-10	3/18	-40
10/16	+45	4/17	+18	10/17	-17	4/18	-41
11/16	+42	5/17	+13	11/17	-23	5/18	-37
12/16	+38	6/17	+7	12/17	-28	6/18	-27
1/17	+34	7/17	+1	1/18	-33	7/18	-7
2/17	+29	8/17	-5	2/18	-38		

Angular data obtained from *Eyes on the Solar System* (February 28, 2013).

Problem 2 – InSight will end its operations after one full martian year (687 days). If it lands on September 20, 2016, during which months of operation will Earth be within 10 degrees of the sun at conjunction, and unable to communicate with Earth?

Problem 3 - Graph the data in the table. During which months will the Earth-Mars angle A) be changing the most rapidly? B) the slowest?

Problem 1 – When will the next superior conjunction occur after July 26, 2018?

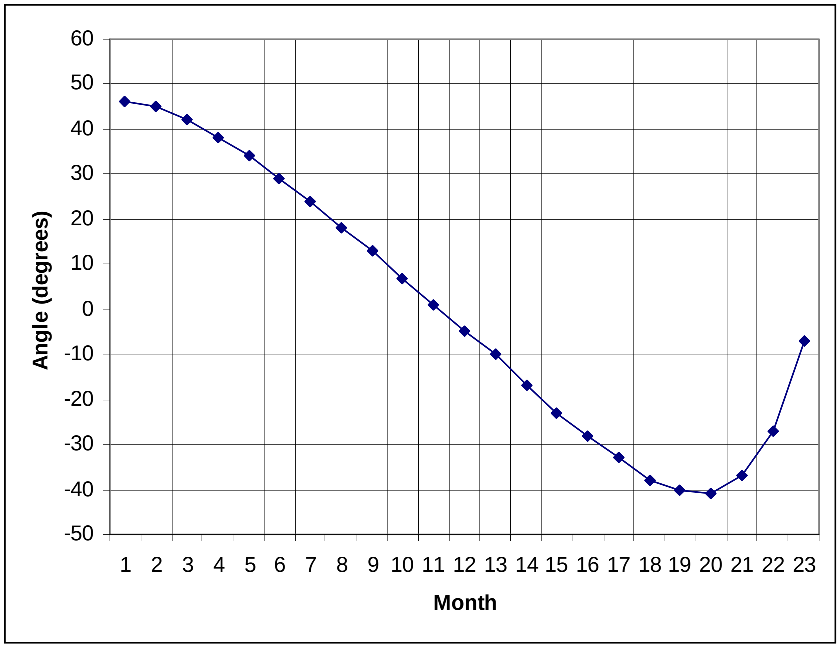
Answer: Each pair of superior and inferior conjunctions happen in cycles. The time for one cycle can be found by the time between the dates of the two listed inferior conjunctions on 5/22/2016 and 7/26/2018. Students can find the number of days between these dates manually (hard), or they can use an online calculator (fun!) like http://www.timeanddate.com/date/duration.html to get 796 days. To find the next superior conjunction, add 796 days to July 27, 2017 (eg. http://www.timeanddate.com/date/dateadd.html) to get **May 4, 2019**.

Problem 2 – InSight will end its operations after one full martian year (687 days). If it lands on September 20, 2016, during which months of operation will Earth be within 10 degrees of the sun at conjunction, and unable to communicate with Earth?

Answer: Conjunction occurs on July 27, 2017. From the table, Earth is within 10 degrees of the sun during the months of **June 2017 to August 2017** so it will be difficult to directly transmit or receive data during this time.

Problem 3 - Graph the data in the table. During which months will the Earth-Mars angle A) be changing the most rapidly? B) the slowest?

Answer: Students may use Microsoft Excel. X-axis may be the month number.
A) June-July, 2018.
B) During September-November, 2016 and February-April, 2018. Slow changes correspond to a nearly flat 'slope' while fast changes correspond to the steepest slope.



Transferring digital data from place to place takes time. Like water flowing into a lake, the faster it flows the more rapidly the lake fills up and overflows. With computer data, we have a similar problem. You have probably had to do this yourself many times. Each time you copy your playlist from your PC to your portable music player, you will have to wait a certain length of time. The transfer rate is fixed, so the more songs you want to transfer the longer you have to wait. Here's how this works!

Problem 1 - Suppose you want to transfer 1000 songs from your PC collection to your music Player. Each 4-minute song takes up 4 megabytes on the PC, and the cable link from your computer to your Player can handle a transfer rate of 3 million bytes/second. How many minutes does it take to transfer all your songs to the Player?

Imagine a lake fed by one large slow-moving river that brings water to it, and a second small, fast-moving river that takes water from the lake. If the rates at which the water enters and leaves the lake are not in step, the lake's water level will overflow. The InSight lander has a similar problem. It is gathering data at one rate, but transmitting it to Earth at another rate. We don't want to lose any of the data, so the data has to be stored in a memory device called a buffer.

InSight has two instruments that generate constant streams of digital data. The SEIS seismometer produces 48 megabytes/hr and the HP3 produces 2 megabytes/hr. This data is stored in a 500 megabyte buffer. Every 2 hours, the data in the buffer is transmitted to Earth at a rate of 4 megabytes/sec.

Problem 2 - How long will it take to fill up the buffer with data?

Problem 3 - How long will be required to transmit the buffer data to Earth during each 2-hour transmission cycle?

Problem 4 – The receiver on Earth can be scheduled to contact the Lander as often as once every 2 hours. How large a buffer would you need so that you could gather as much data as 4 megabytes/sec over 2 hours? How long does it take the instruments to gather this much data?

Problem 1 - You want to transfer 1000 songs from your PC collection to your music Player. Each 4-minute song takes up 4 megabytes, and the cable link from your computer to your Player can handle a transfer rate of 3 million bytes/second. How many minutes does it take to transfer all your songs?

Answer: 4000 megabytes x (1 second/ 3 megabytes) = 1333 seconds or about **22 minutes**.

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Problem 2 - How long will it take to fill up the buffer with data?

Answer: The data enters the buffer at 50 megabytes/hr and the buffer contains 500 megabytes, so it can store data for 500 MBytes/(50Mbytes/hr) = **10 hours**.

Problem 3 - How long will be required to transmit the buffer data to Earth during each 2-hour transmission cycle?

Answer: In 2 hours at a data rate of 50 megabytes/hr you have 100 megabytes stored in the buffer. At a transmission rate of 4 megabytes/sec it takes 100 Mbytes/(4 Mbytes/sec) = **25 seconds** to transmit the100 megabytes from the buffer to Earth.

Problem 4 – The receiver on Earth can be scheduled to contact the Lander as often as once every 2 hours. How large a buffer would you need so that you could gather as much data as 4 megabytes/sec over 2 hours? How long does it take the instruments to gather this much data?

Answer: 2 hours equals 2 x 3600 = 7200 seconds. At a transmission rate of 4 Mbytes/sec, this equals 7200 sec x 4 Mbytes/sec = 28,800 Megabytes or **28.8 Gigabytes.**

The instruments gather 50 Megabytes/hour, so it would take them 28,800 Megabytes/(50 MB/hr) = 576 hours or 24 days to gather this much data.

What this says is that if you had a buffer this large (28.8 gigabytes) it could store 24 days of data from InSight and only take 2 hours to transmit to Earth. The danger of waiting so long to transmit data (every 24 days) is that something could happen to the lander and you would lose all this data! That's why scientists try to download their data as often as possible.