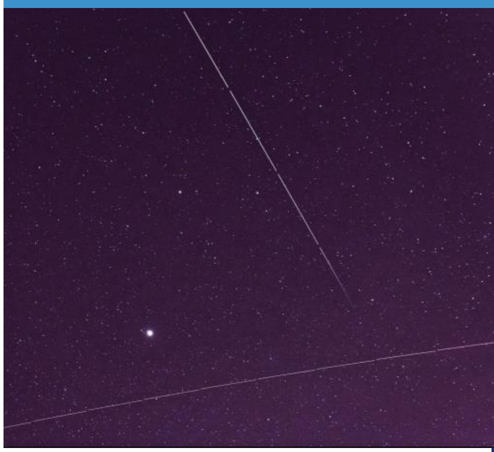
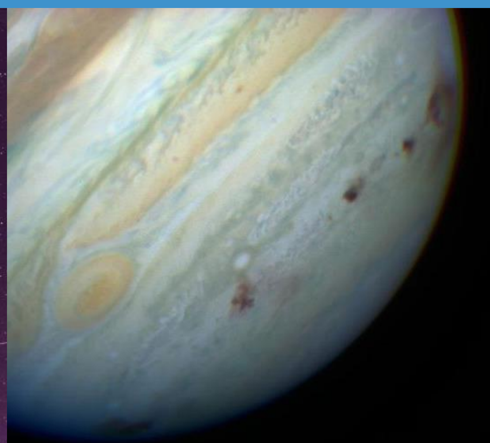
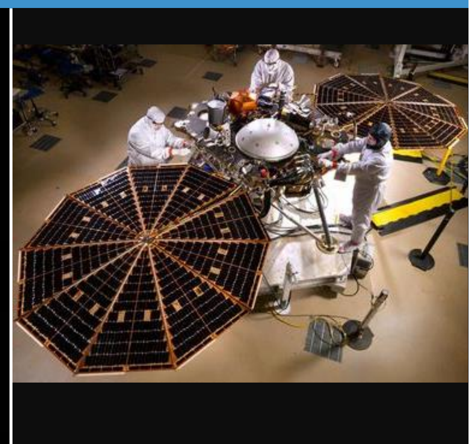
All Of The Above

YOUR MONTHLY DOSE OF SPACE AND TIME







Observe

A COLD SHOWER

On the night of December 13th, if you can brave the cold, the second-best meteor shower of the year makes its annual appearance. This shower has some unusual characteristics which make it a phenomenon to attempt to witness.

Remember

DEATH OF A COMET

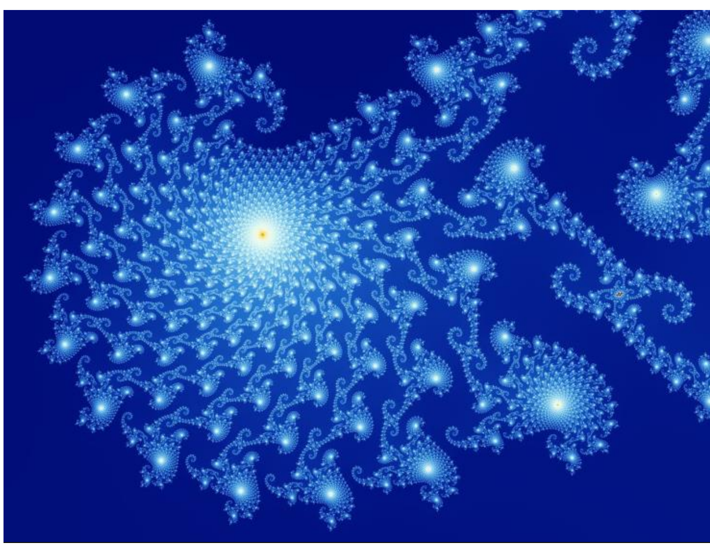
In July of 1994, astronomers witnessed the collision of the comet Shoemaker-Levy 9 with the planet Jupiter. This was the only witnessed impact between two solar system bodies in recorded history, at least of this magnitude.

Explore

PROBING MARS

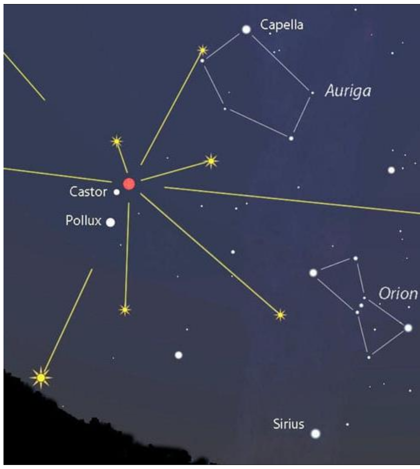
On November 26, 2018 NASA's InSight spacecraft landed on Mars successfully, sending an image within minutes after reaching the surface in Elysium Planitia after a 7 minute plunge through the atmosphere.

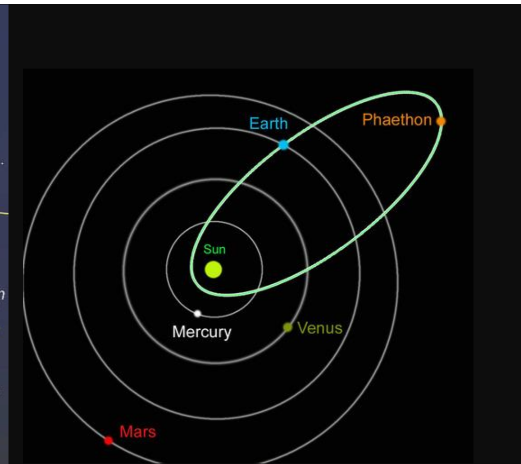
Consider



ENGINEERING IN THE 21ST CENTURY

I believe we are at the start of the greatest revolution in science and engineering since the Renaissance, in which several fields of study are converging toward each other to generate sudden advances in technology across every realm of human endeavor. Beyond our existing vision of what is possible to achieve, these technologies will enable developments we have not yet even dreamed of accomplishing.





THE GEMINID METEOR SHOWER

On the night of December 13-14th, the Earth passes through the orbit of a stream of debris, consisting of trillions of small pebbles and sand. This stream orbits the Sun in a strongly elliptical path that intersects Earth's orbit at a high angle, traveling at dozens of miles a second. As each pebble crashes into Earth's atmosphere, it is heated by friction, reaching temperatures over 3000°F, causing the outer surface of the pebble to vaporize. The vaporized molecules crash into molecules of our atmosphere, stripping off their electrons along a path several feet wide and many miles long. As the free electrons recombine (almost instantly) with the stripped molecules, a bright glow is emitted, creating the streak of light we see as the meteor hurtles toward the ground. Within seconds the meteor is slowed to the point where it stops vaporizing, or completely turns into vapor, and the streak of light suddenly comes to an end.

Although meteors can be seen on any night of the year, streams of material orbiting the Sun cross Earth's orbit only on specific dates of the year, each creating a "meteor shower" when anywhere from 5 to 100 (or more) meteors can be seen in an hour. Almost all of these orbits of sand and pebbles correspond to the orbits of ancient comets whose frozen gas and water have boiled away from approaching the Sun hundreds or thousands of times over their lifetimes. Only their solid particles remain, no longer bound in a single object, but spread out over their orbit.

The American Meteor Society (of course there is one) lists 102 meteor showers, but really only 9 are noticeable to all but the most serious observer, and of these only 3 can regularly produce dozens of meteors an hour. Those showers are the Perseids in August, Quadrantids in January, and the Geminids in December. Here in Connecticut, the Perseids peak on a cloudy night more often than not; in my experience the Geminids are much more likely to occur on a clear night.

The later on the night of the 13th you start looking, the more meteors you will see. The peak is near 2am, though admittedly only for the incredibly brave person who is planning on doing not much the next day. However, even at 9pm you should be able to catch as many as 10 an hour. Bundle up warmly, sit facing east, tilt your head skyward, and wait.

3200 PHAETHON

Although *most* meteor showers are caused the remains of evaporated comets, a handful, including the Geminids, have been traced to asteroids. The asteroid 3200 Phaethon orbits the sun in approximately the same track as the Geminid meteor stream. (The 3200 indicates the order of discovery of all known asteroids; Phaethon was discovered from images taken with the IRAS infrared space telescope in 1983). The name Phaethon represents the son of the Greek sun god Helios, and this asteroid approaches within 13 million miles of the Sun's surface (Mercury is 36 million miles from the Sun).

Phaethon came within 6.5 million miles of Earth on December 17, 2017. Although its debris cloud (caused, presumably, by its gradual breakup as it repeatedly reaches extreme temperatures in proximity to the Sun) intersects Earth's orbit, Phaethon's minimum distance from Earth is 1.8 million miles.
During the 2017 close approach, the enormous radar telescope in Arecibo, Cuba obtained grainy images of it, and established a size of 3.6 miles in diameter.

THE END OF COMET SHOEMAKER-LEVY 9

Jupiter, as the second most massive object in the solar system, has a major effect on both asteroids and comets, serving as a “shepherd” of the asteroid belt, and altering the orbits of several known comets. In the late 1960’s or early 1970’s, Jupiter captured a large comet into a spiraling, unstable orbit. In 1993, astronomers Caroline and Eugene Shoemaker, and David Levi discovered their ninth periodic comet during a survey looking for near-Earth astronomical objects. Upon computing its orbital motion, they were surprised to find it orbited Jupiter in a roughly 2-year orbit, had passed within 25,000 miles of Jupiter’s cloud tops in July of 1992, and was projected to collide with Jupiter in July of 1994.

Soon after the discovery of the comet, it was found that it consisted of 21 separate bodies, having been pulled apart by Jupiter’s intense gravitational field during its close encounter with the planet in 1992. The estimated sizes of these fragments ranged from 1000 feet to 1.2 miles in diameter. These were large enough so that there was a lively debate about what would be visibly seen as the pieces entered Jupiter’s atmosphere.

In addition to several Earth-based telescopes, the Hubble Space Telescope, ROSAT X-ray telescope, and three interplanetary probes – Voyager 2, Ulysses, and the Galileo spacecraft then on its way to Jupiter were trained on the planet at the predicted times of the first impact – at 4:13pm on July 16. A massive fireball, reaching temperatures of 42,700F was observed rising 2000 miles above the limb of the planet (all of the impacts occurred on the side of Jupiter facing away from Earth), and as the planet rotated, a huge black spot about half the diameter of Earth marked the impact location. Over the next several days the other 20 fragments struck Jupiter, the largest releasing over 6 million megatons of energy (about 600 times the energy contained in the world’s entire nuclear arsenal). The black marks, easily visible in small telescopes, persisted for several months. Shock waves were observed circling the atmosphere of Jupiter for several hours after each impact. Infrared observations showed a global temperature rise, followed by cooling to below the original temperature, and a slow return to normal over several months.

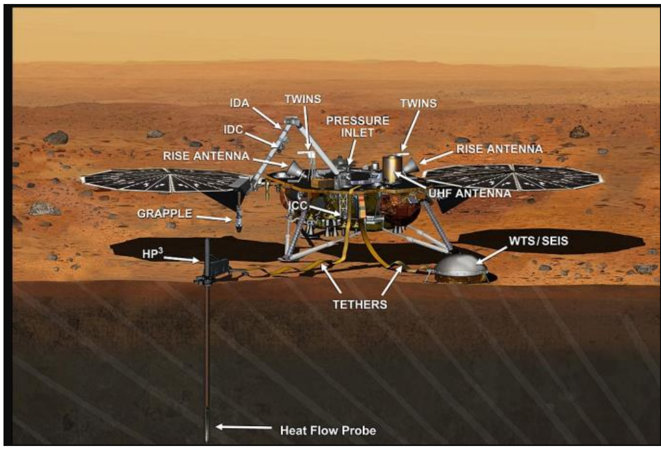
Detailed observations of the spectrum of the fireballs, the marks left behind, and the shock waves allowed planetary scientists a once in a lifetime opportunity to study what the lower levels of Jupiter’s atmosphere contain, as material was lifted up to the cloud tops during the explosive impacts. A variety of sulfuric compounds – diatomic sulfur, carbon disulfide and hydrogen sulfide were detected, and the absence of water vapor and sulfur dioxide detection surprised astronomers.

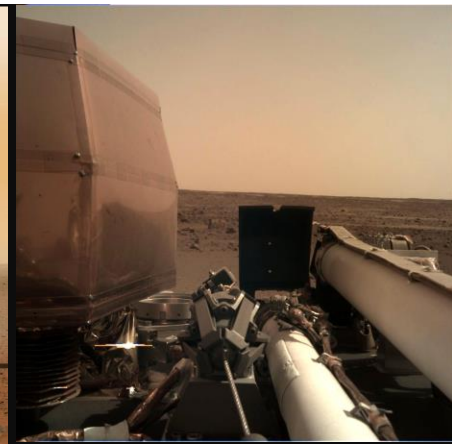
LET’S DO THAT AGAIN!

On July 19, 2009, amateur astronomer Anthony Wesley of Australia recorded a large dark spot in the cloud tops of Jupiter. Subsequent observations confirmed an apparent impact mark, which persisted for several months. Although there was no discovery of the impacting object, it is believed to have been an asteroid about 1000ft in diameter.

AND AGAIN, AND AGAIN, AND AGAIN?

Impacts on Jupiter appear not to be as rare as we may have imagined. Amazingly, on June 3, 2010, Wesley again observed the results of an impact, which was caught on video by Christopher Go of the Philippines. Smaller events were also seen on September 12, 2012, and March 17, 2016.





NASA INSIGHT ARRIVES AT MARS

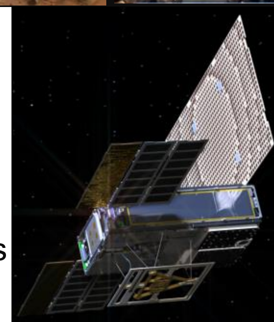
NASA launched the Mars InSight mission on May 5, 2018, taking advantage of a close approach of Mars to Earth's orbit. After a 205-day trip through interplanetary space, followed by a 7-minute fiery descent through the atmosphere of Mars, Insight has sent back several preliminary photos to show that its systems are running properly, and deployed its solar panels successfully and began charging its internal battery system.

The Insight lander is a stationary vehicle, measuring 20x5x3 feet, and with a mass of 789 pounds, carrying a 110 pounds of scientific instruments. The mission is designed to last about 2 years, though typically expected lifetimes are dramatically extended in NASA robotic missions.

Insight carries three major experiments. The Seismic Experiment for Interior Structure will measure vibrations in the surface beneath the lander, including "marsquakes" caused by motion of material within the mantle and core of Mars, as well as vibrations from the impact of meteors, and even tidal disturbances in the ground from the gravitational pull of the small moon Phobos. The accumulation of this data will allow planetary scientists to better resolve the interior structure of the planet, specifically, whether the core is purely solid or sheathed in a liquid outer core.

The Heat Flow and Physical Properties Package is a very exciting test of our ability to robotically drill to significant depth into a distant surface. A shaft will be driven 16ft into the interior, trailing a tether with very sensitive thermometers placed every 4 inches to profile the temperature of the subsurface. From these measurements, the thermal flow of energy through the outer crust will be directly measured. This in turn allows modeling of the evolution of the interior over the history of the planet.

The Rotation and Interior Structure Experiment uses radio signals sent back to Earth to precisely measure the rotation of Mars on its axis, and the wobble of the axis over each Martian orbit. Again, this information allows modeling of the core and mantle of the planet, to determine their sizes and densities.

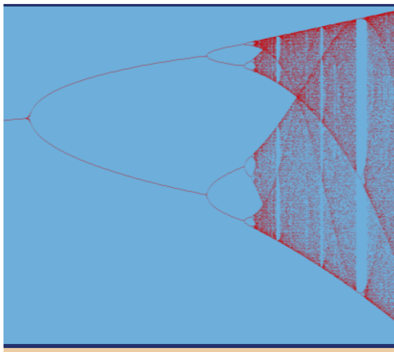


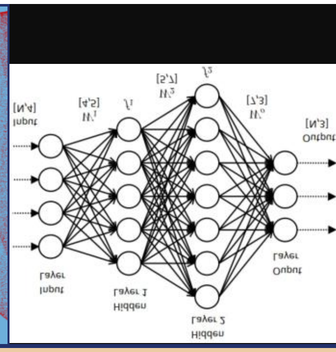
MARS CUBE ONE

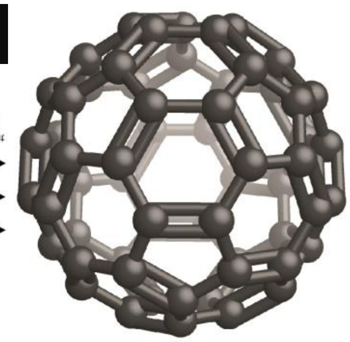
One of the most exciting new technologies in our exploration of space is "nanospacecraft". Better known in the industry as "CubeSats", these are very small packages, created from standard cubes 4 inches on a side.

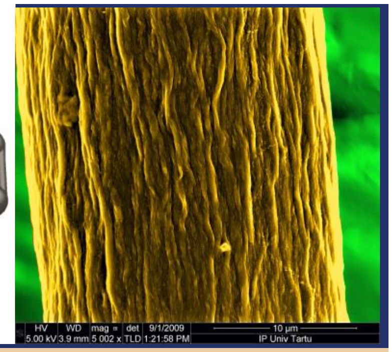
Along with the InSight lander, this mission included a technology demonstration of sending CubeSat units into interplanetary space. Two probes, each consisting of 6 CubeSat units, weighing 30 pounds, accompanied InSight to Mars, and then provided a communications link while Insight descended through the atmosphere, out of line of sight from Earth. In addition to the relay radio, each of the probes (nicknamed WALL-E and EVE) hosts a wide angle camera, navigation tracking system, and a star tracker to maintain attitude control.

The Mars Cube One craft succeeded in their mission, and proceeded to fly by Mars, approaching to within 2200 miles of the planet. They are now in elliptical orbits about the Sun, where they will continue to operated for several weeks until their electronics and/or propulsion systems fail.









THE CURRENT ENGINEERING REVOLUTION

We live in the time when most of the engineering practices in use since the industrial revolution will undergo fundamental changes, moving us forward rapidly and dramatically into a new world of technologies and products, some of which we have not even dreamed about. Several new developments, all starting in the last decades of the prior century will bring this about.

Our current approaches to science and engineering seek to simplify the phenomena we are seeking to understand and control in order to apply known and rather old solutions. Hence, when we design just about anything – a car's engine, a spacecraft's instruments, a circuit pattern for a computer chip, furniture, food packaging, or the plumbing in your home – we generally end up with simple shapes, smooth surfaces, and easily-understood behavior. Yet the natural world is not this simplistic. Consider the shapes of clouds, the bark of a tree, the flow of a stream over rocks – none of these follow simple patterns that can expressed in trivial mathematical equations, if they can be expressed mathematically at all. Starting in the 1980's, research began in several areas that in combination can be called "complexity science" – chaos theory, fractal geometry, self-reproducing dynamics, and emergent behavior. Today the mathematics in many of these areas has matured, while there still remain large areas of open research.

The greatest technological development since the 1980's has occurred in the area of information processing and distribution. Computing capacity has advanced by factors of millions, becoming a universal element in everyone's lives, and the Internet has enabled immediate transfer of information across the entire globe. In engineering, these advances allow extremely detailed modeling of designs long before they are fabricated, reducing the need to build prototypes, or conversely, allowing the development of much more capable products. Applying this computing power to complexity science has been increasingly yielding products that embody complex geometries and behaviors – materials with fractal internal structure, cryptography and data compression in computing, surface texturing – but we are still in the early years of what will be possible.

The area of artificial intelligence, which began all the way back in the 1950's, has finally emerged from the academic world to solve previously unsolvable problems in engineering, and is now advancing at such a rate that predictions of achieving truly "intelligent" machines within the next few years are being commonly accepted as accurate. Although often accompanied by what I consider irrational fears of supplanting human intelligence (more on that in a future column), the rise of artificial intelligence has already enabled self-controlled machines and vehicles, vastly improved use of the huge volume of information now available to all of us, and is finding efficient solutions to problems all across the field of engineering. It is when we begin applying AI to complexity science to develop future products that the revolution I am observing around us will really begin to accelerate.

Another field that has emerged from academia into real products is the cluster of technologies known as "nanotechnology". Here, the advances in making computer circuits ever smaller in size crossed over into manufacturing materials on a molecule-by-molecule basis. Through development using a single element, carbon, we have devised a variety of new materials, including fullerene and carbon nanotubes, with unusual physical, optical, electrical and thermal properties. Carbon nanotubes have tensile strength far exceeding other materials, allowing the creation of very light yet strong structures, as well as extremely high thermal conductivity and unique optical properties. Fullerene carbon can be introduced into the human body, absorbed by cells, and selectively activated with light to destroy cancer cells. Nanotechnology is also producing new methods of sensing chemicals, and working toward development of micro-robotics, as well as enabling the rise of quantum computing, which is an entire revolution in and of itself.

It is when all of these developments come together over the next two decades that we will see the products of this revolution – imagine self-reproducing micro robots, controlled by artificial intelligence, growing buildings on the surface of Mars, using 1/100th of the mass used in traditionally engineered structures, or taking a pill containing micro robots that travel through the body and automatically repair damaged cells, reversing the effect of natural aging. Or my recurrent vision – a powder of robots that you sprinkle in your house, which become active at night and collect all loose dirt and dust and take it out into your yard. You are living in the time when all of this, as well as things we haven't even yet imagined, will become more than just idle dreams, and our lives will be dramatically improved as a result. It is my hope that some of you will become the leaders of these innovations.