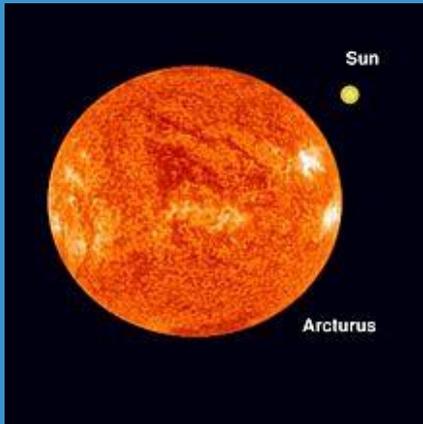


# All Of The Above

YOUR MONTHLY DOSE OF SPACE AND TIME



Observe

## ARC TO ARCTURUS

In this month of late sunsets and early sunrises, we use the most familiar constellation in the sky to look at the future of our Sun.

Remember

## INTIHUATANA

A co-worker traveled to Peru last month to visit the Inca ruins at Machu Picchu near the winter solstice, including the sun stone Intihuatana. I was envious, except for the traveling part...

Explore

## THE STARLINER

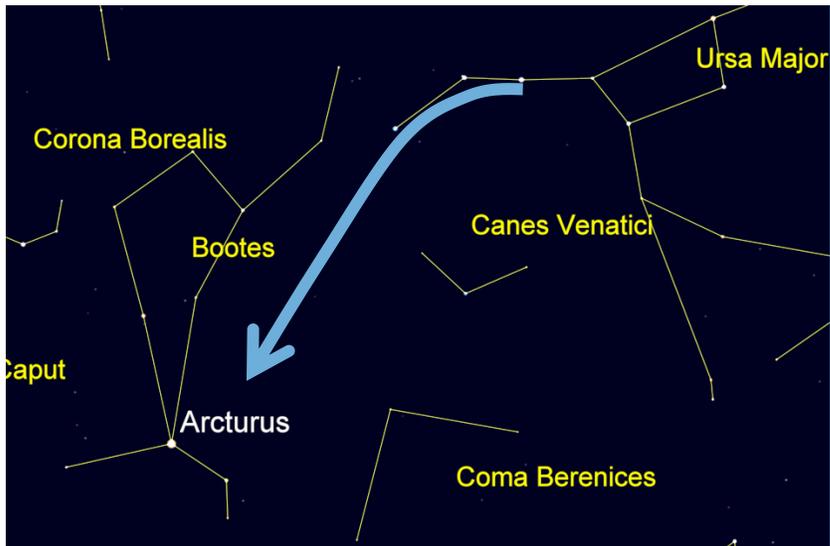
Boeing's solution to returning America to manned spaceflight prepares for its first unmanned test flight.

Consider



## WHAT'S WRONG WITH INFINITY?

You've all heard me try to avoid using the word infinity, instead stumbling with phrases like "without limit", or "indefinitely large". So what is my problem with this commonly used word?



## ARCTURUS : The Future of the Sun

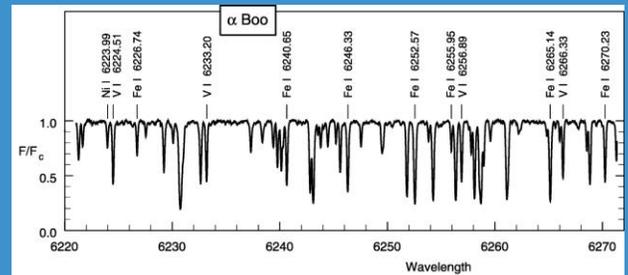
The brightest star in the constellation Bootes (The Herdsman), Arcturus is one of our closer stellar neighbors, 36.7 light years from Earth. Arcturus is a star with about the same mass as the Sun ( $1.08 M_{\odot}$ ), but about 3-6 billion years older than our star. Thus, it represents the likely condition of our Sun near the end of its life. The star is one of the very few stars close enough to us and large enough that with extremely precise measurements we can determine the apparent diameter of its disk. Combined with parallax measurements to determine its distance, we can establish that this reddish star is a monster, about 25 times the diameter of the Sun. Hence a “red giant”, filling about  $1/3^{\text{rd}}$  of the orbit of Mercury, and gradually expanding. Eventually it should reach the size of Earth’s orbit.

Arcturus is also close enough to Earth to observe its motion though space directly over time - what we call its “proper motion” - which is observed to be about 2 arc seconds a year, corresponding to a speed of 76 miles per second. The motion is, however, highly unusual in that it is traveling perpendicular to the Milky Way’s plane, passing through the relatively narrow space that contains almost all of the Milky Way’s stars.

At the start of the 1933 Worlds Fair in Chicago, the exhibit “Century of Progress” used the light of Arcturus, focused on a photocell, to throw the switch that opened the exhibit, based on the estimated distance of 40 light years, and the fact that the prior Worlds Fair in Chicago opened in 1893.

## Finding Arcturus

- Face North
- Locate Ursa Major
- Find the last three stars of the “Dipper”’s handle
- Draw an arc through these stars and follow it down to the brightest star in that direction
- See if you can trace out the rest of the constellation Bootes!



The spectrum of Arcturus is shown above as a plot of light intensity as a function of wavelength, over a narrow section of the red part of the spectrum. Each dip in the curve is a wavelength at which light from the star is absorbed by electrons in atoms of gas in its atmosphere. Several of these absorption lines are marked with the corresponding element symbol. We see lines of nickel (Ni), vanadium (V), and iron (Fe). The presence of these heavy metals with high concentrations indicates a star approaching the end of its lifetime.

### Arcturus in various cultures

Greek - Guardian of the Bear

Arabia - Haris al Shamal - Keeper of the North

Japan - Mugi-boshi - Star of Wheat

Indonesia - Bintang Biduk - Star of the Boat

Inuit - Uttuqalualuk - The Old Man



## INTIHUATANA: Hitching Post of the Sun

During the late 1400's, at the height of the Inca empire in Peru, emperor Pachacuti ordered the construction of a royal estate at Machu Picchu, high in Andes mountains. Lost after the Spanish conquest in the 1500's, the site was brought to the world's attention by the American explorer Hiram Bingham in 1911. At the very peak of the estate lies an intriguing altar structure topped by a pillar, all carved from solid rock.

The sides of the altar and pillar are aligned nearly perfectly along a north-south line. The top of the pillar is cut at a slight,  $13^\circ$  angle, inclined so the top surface faces slightly north. Machu Picchu lies at a latitude of  $13^\circ$  south of the equator. As a result, at local noon on the solar equinoxes, when the Sun lies above the equator, the pillar casts no shadow. Furthermore, at the winter solstice, with the Sun at its maximum northern travel (recalling Peru is in the southern hemisphere), the pillar casts the longest shadow of the year. Thus, the Intihuatana forms an ideal gnomon for tracking solar motion and most likely was used to set the Incan calendar.

The name Intihuatana translates roughly as "where the sun is tied", and the Incas apparently believed these stones essential to keeping the Sun in its proper place and motion through the skies. Several such stones existed throughout the Incan empire, but the Spanish viewed them as heretical, and destroyed all that they could find. Surprisingly, Machu Picchu was never known by the Spanish, who arrived a mere 100 years after its construction. This suggests a sudden downfall of the families centered on Machu Picchu, and it is only due to this rapid decline that this massive estate, and the Intihuatana in particular, has survived in so excellent a state of preservation.





## BOEING'S CST-100 STARLINER

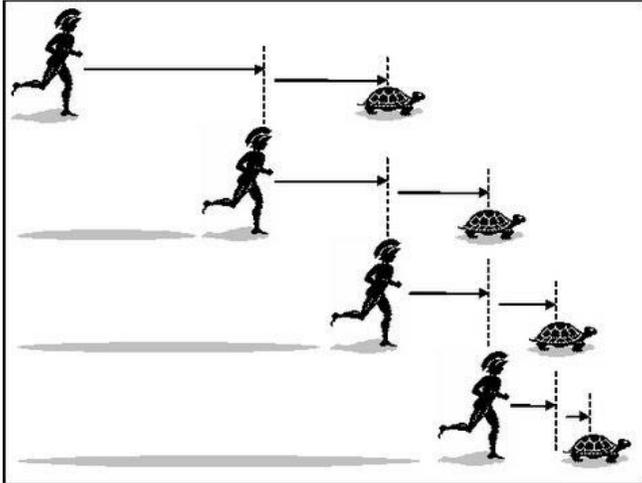
It has now been seven years since astronauts launched into space on an American-built spacecraft, following the retirement of the Space Shuttle. Two private companies, SpaceX and the Boeing-Bigelow partnership, were selected by NASA to develop new manned capsules enabling flights to Low Earth Orbit, to reach the International Space Station. While the successes of SpaceX are well known, Boeing's development of the StarLiner vehicle has not had as much coverage.

The StarLiner is a capsule slightly larger than the Apollo command modules, and smaller than the Orion Multipurpose Crew Vehicle which is being designed to allow missions beyond Earth's orbit. The capsule is capable of carrying a crew of up to 7, though NASA's planned crew size is 4, with one of the seats available for tourists. The extra space would then be used to transport time-critical cargo.

The capsule will launch initially on ULA's Atlas V single-use rocket but has been designed (through NASA's insistence) to be compatible with other launch systems including SpaceX's Falcon 9. Following re-entry, the heat shield is jettisoned, revealing an airbag landing system, and the craft descends on parachutes to a ground landing. Each craft is designed to be refurbished and reused up to 10 times, with a 6-month refurbishment schedule.

Boeing is on schedule for an exciting fall. An unmanned test flight (the first) of the Starliner is planned for October, followed by the first manned flight in December.





## WHY NOT INFINITY?

About 450BC, the early Greek philosopher Zeno of Elea posed the following paradox. The great warrior Achilles and a common tortoise are raced against each other. The tortoise is given a head start, and the race begins. By the time Achilles reaches the spot where the tortoise started, the tortoise will have moved ahead to a new position. By the time Achilles reaches that new position, the tortoise has again moved. Each time Achilles reaches where the tortoise was last, the tortoise has moved again, hence Achilles can never catch up to the tortoise.

Let's restate the paradox in a more revealing manner. In order for Achilles to catch the tortoise, he needs to pass an infinite number of previous tortoise positions. But nothing in the real world can act an infinite number of times, therefore Achilles cannot catch the tortoise.

The standard way in which this paradox is resolved (it's a paradox, because obviously Achilles *will* pass the tortoise) is to note that the distances between successive positions of the tortoise that Achilles passes become smaller and smaller, and therefore the time needed by Achilles to cross each of these distances also becomes smaller. When we add up the infinite number of these shrinking times, modern mathematics shows that the sum approaches a limit, which is the actual time it takes Achilles to reach the tortoise.

Zeno created several equivalent paradoxes, all leading to the apparent conclusion that motion is impossible. He did not actually believe motion was not possible, rather he attempted to use these examples to challenge the validity of the rules of logic, which appear to be properly applied in these cases, but lead to impossible conclusions. Answering the paradox using the mathematical concept of a limit really does not resolve Zeno's question. The real problem in the argument is logical and related to the use of the questionable concept of "infinity".

All valid human concepts are formed from either from generalizing direct observations (like the concept of a chair), or from generalizations of other concepts (furniture), and in these generalizations, the essential characteristics are retained, but the details, or measurements, of the characteristics are not included in the concept's definition. For a mathematical concept, such as a circle, the generalization is more of an ideal, in which all observed real circles are only approximations. In the particular case of "infinity", we have a much trickier situation, since we can not directly observe anything more than "many", and the extension to a magnitude larger than any number involves a very high level of abstraction indeed.

The real resolution of Zeno's paradox centers on where the concept of infinity is applicable. In any real-world observable situation which a human consciousness is analyzing, there are no "infinities". There can be very large or very small numbers, but the mind cannot experience infinity. In the case of Achilles and the tortoise, the infinitely many positions which Achilles must reach involve smaller and smaller distances between them. Below some size of consideration - whether the smallest distance the human eye can see, or the smallest distance that can be measured in the sand of the track, or the size of an atom, there is a limit beneath which there is no meaning to distance. And that is the key.

In the real world there is always a limit beyond which differences in magnitude (large or small) become literally meaningless. It is true, in the mathematical ideal context, that Achilles needs to pass an infinite number of positions. However, in the next sentence of the restated paradox, where the context changes from the ideal to the real world, the concept infinity becomes inapplicable. One cannot say that nothing can act an infinite number of times, nor does anything in the real world ever need to, because in the real world infinity loses it meaning. This discussion of Zeno's paradox, and its resolution, are based upon the brilliant work done by the philosopher of mathematics Patricia Corvini in untangling the relationship between abstract mathematics and the real world that surrounds us.