OBSERVING PICTURES FROM SPACE:

SEEING IN 3-D

Developed for the Stardust-NExT Mission by Dee McLellan

How exciting to get a picture from a spacecraft traveling through our solar system! The picture could be taken of a place relatively close to Earth, like the Moon, as done by the LUNAR RECONNAISSANCE ORBITER (LRO). It could be taken by a camera on a spacecraft heading to the very edge of the solar system, where NEW HORIZONS is currently zooming. Or perhaps scientists are guiding a robotic spacecraft, as when NASA explore Mars with rovers like Spirit and Opportunity, and understanding the terrain is critical to keeping the rover on a safe path.

But the images we receive from space can be quizzical to us grounded back on Earth. They are usually flat and two dimensional, like the shot of comet Tempel 1's surface at the left. Just what are we looking at? Are those dark circles we see some dark mineral? The rims of craters? Indentations? How can we make sense of images from outer space?

To aid perception, NASA scientists often use three-dimensional (3-D!) imaging to offer depth and contrast. For example, a trained driver here on Earth looks at the Mars' surface using 3-D glasses to steer the rovers safely. NASA uses 3-D imaging to study pictures as well – from our moon, of Earth in orbiting observation studies, and our solar system's smaller bodie, like comets and asteroids.

To get our observation skills up to speed, we are going to do what scientists do: find interesting ways to picture solar system images in 3-D so our vision – and understanding – becomes clearer. We will focus on images from the NASA Missions of Discovery associated with comets: STARDUST and DEEP IMPACT. And we will learn about comets as we go!

A LITTLE BACKGROUND ON COMETS

A comet is a rocky, icy solar system object that orbits around the Sun in an oval shape called an ellipse. Comets are unique in that they are drawn from far reaches of the solar system by the Sun's gravity, whip about the Sun, and then shoot back out on their orbit back to the coldest reaches of the solar system. Some of them have orbits of a few years, and some many hundreds or even thousands of years.

Comet Halley Image courtesy: NASA

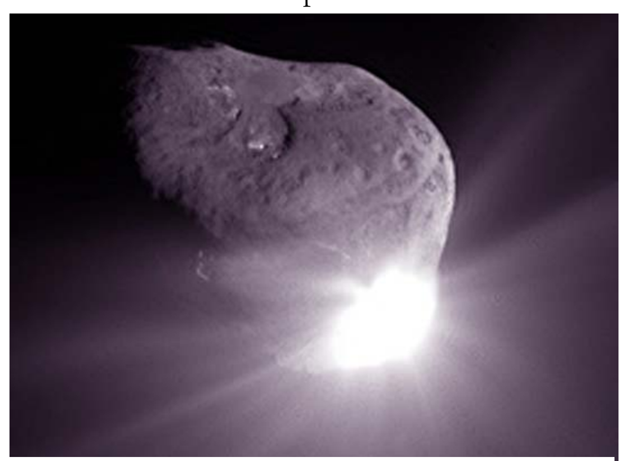
When they are fairly close to the Sun, comets glow brilliantly and leave a gleaming dust trail, making them one of the most thrilling objects we get to see in the night sky. They are believed to be leftovers from the early formation of our solar system, making them treasure troves for scientists to study.

A TALE OF TWO MISSIONS: STARDUST to STARDUST-NExT

Nucleus of comet Wild 2, taken from the Stardust spacecraft. Image courtesy: NASA

STARDUST was originally launched in 1999 to visit one of our solar system's smaller bodies, comet Wild 2 (pronounced "Vilt" 2). It flew within 236 kilometers (147 miles) of the nucleus of the comet in January 2004, collecting cometary particles and interstellar dust for a sample return to Earth in 2006. Photographs taken during this flyby showed jets of dust and a rugged textured surface. Analysis of the Stardust samples suggests that comets maybe more complex than originally thought! After STARDUST's mission was complete, it hung out in orbit around the Sun, awaiting its next orders. The spacecraft was recently reinstated to study another comet, this time Tempel 1. New mission's name: STARDUST-NExT of course!

You may recall that comet Tempel 1 received a visit from *another* NASA spacecraft back in 2005: DEEP IMPACT. That spacecraft released a copper impactor directly into the orbital path of Tempel-1, which caused the comet to crash into ["run over"] the impactor, forming a crater on its surface. The Deep Impact spacecraft took a variety of pictures before, during and after the impact in hopes of better understanding just what lies below a comet's surface. However, the explosion caused by the impact raised enough dust and material that the crater DEEP IMPACT formed was obscured.



Nucleus of comet Tempel 1 seconds after colliding with Deep Impact's impactor, taken from the spacecraft. Image courtesy: NASA

In February, 2011, the STARDUST-NExT spacecraft will take pictures of comet Tempel 1 nearly seven years after that event. The Stardust NExT camera will try to capture any changes in the comet's surface and even take images of the crater left by the July 4, 2005 Deep Impact mission (no small feat – the spacecraft is zooming in its orbit *very* fast – and the comet is as well!). By taking pictures up close, many details of the comet's surface should be seen, details which are not typically visible even using powerful telescopes here on Earth.

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OUR MISSION TODAY

But just what can we learn from these pictures Stardust-NExT captures of Tempel 1? Even with top cameras, the spacecraft will be far away (200 kilometers) and flying by fast; often images can be indistinct. Plus they are two dimensional – flat-looking – and may not have color.

It can be hard to understand objects or features in two dimensions. We are spoiled. Our two eyes give us binocular vision, which helps us make sense of our world. But a 2-D picture of a distant solar system body we have no experience of is much harder to make sense of. Is that a crater or a mountain or a valley? Is that darkness a shadow – or dark minerals? Or some other geological feature altogether?

What to do?? Let's find ways to see in 3-D!

SEEING IN 3-D: Our eyes are designed to help us see everything in three dimensions. Our two, side-by-side eyes give us binocular vision and our ample experience in the world helps our brains take what we see and make sense of geography and terrain.

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2-D PICTURES VS. STEREO 3-D PICTURES

Let's begin by understanding vision in 2-D vs. 3-D. Think about looking at a cube. It is even better if you can find one. A dice works well and you can find one in many games. Think of the cube or look at a dice. You can also use the picture below.

- Draw what shape you see when you look straight down at a dice on your desk.

Draw what you see here:

Now turn the dice so that you look directly down at one corner. Draw what you see.

- Is it the same shape?
- Close one eye. What shape is the outline of the dice? Try to draw this.

Draw what you see here:

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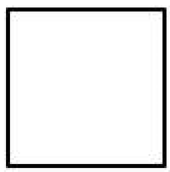
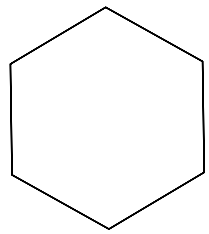
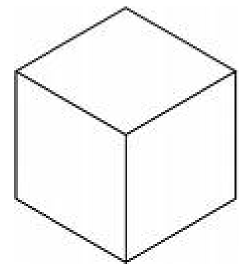
Notice that if you look at the cube from any one side, all you see is a square. Did you draw your die on its corner in two dimensions or three or both?



cube - each side is a square



cube on its end– 2-D



cube on its end– 3-D

One of the reasons you see in 3-D is because you have two eyes. Plus you have loads of experience in your world and know what to anticipate. Our eyes are trained to look at 2-D pictures and see 3-D because our brains make a connection to the three dimensional objects all around us – you <u>expect</u> that die to be 3-D! If you close one eye and look at the 3-D cube, it will be easier to see the flat, 2-D hexagon image with a "Y" shape in the middle.

So what about our picture from space? Because the camera has only one lens – one eye! – the picture a camera takes is two dimensional. Double whammy? When we are looking at pictures from a place in our solar system or beyond, we don't have the experience to identify the 3-D shapes in the image.

Hmmm…, what if we could do something to the pictures to give them a 3-D focus? Ah ha! Stereo pairs!

Let's hone in on an example. Look at this original image taken of comet Tempel 1. Whoa, tough to distinguish what's what! One difficulty is that the Sun is shining very brightly on the surface of the comet. It is hard to see 3-D features. If you close one eye, it is even harder to see 3-D.

- ✓ Try to write or draw what this comet might look like in 3-D.

2-D comet Tempel 1

Try to draw how this comet would look in 3-D:

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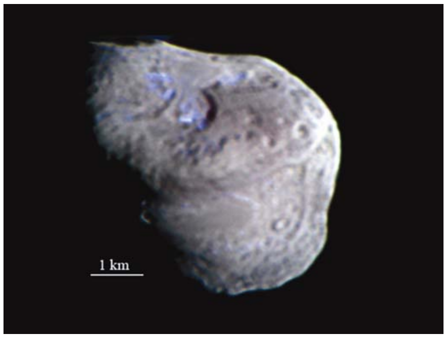
TRY TO SEE 3-D WITH THE HELP OF PICTURES OF COMET TEMPLE 1

Look at these enhanced pictures of Temple 1, developed from images taken by the Deep Impact spacecraft. List some observations.

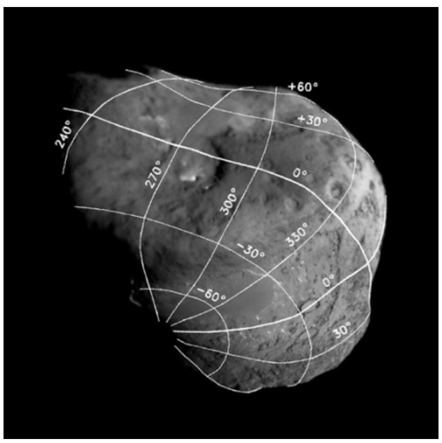
1. What can you learn from each picture about the comet?



Observations:

Composite picture (created from several pictures combined) with some added shading

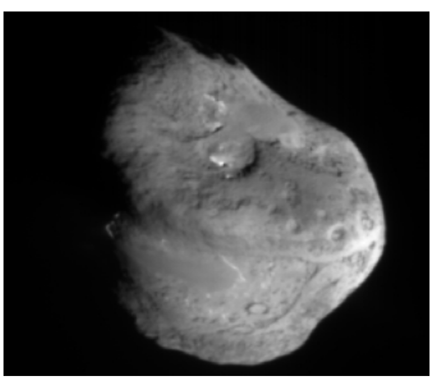
2. How do the lines below help us understand more about the comet?

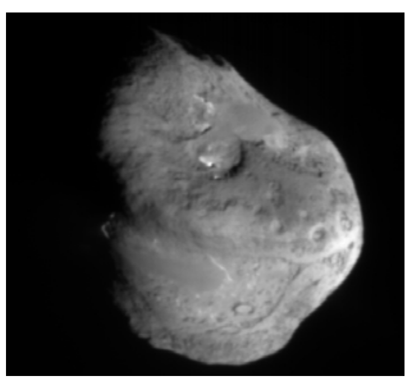


Observations:

2-D comet with some contour lines

3. This is a ***stereoscopic pair***, two images taken from a slightly different angle. What new details do you discover as you compare these images?





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SEEING IN 3-D: STEREOSCOPIC PAIRS

DIRECTIONS:

Hold the stereo pair of comet Temple 1 from the previous page very close to your eyes. Hold it so close that your nose is touching the paper. Focus your eyes on the large crater at the center of the pictures. Now, move the image slowly away from your face, staying focused on the crater.

- ✓ The craters should begin to overlap.
- ✓ Your eyes may feel a slight strain like they're crossing.

When the picture is about 6 inches from your eyes you should feel the image pull together. You'll be looking at a third, merged image your brain has created between the two real images. This third, central image will have the 3-D depth of field. Don't worry if it takes a few tries to get it to work. Once you get the feeling of how to do it, it gets much easier.

TIPS:

A. To make it easier, try placing the stereo pair pictures on you desk.

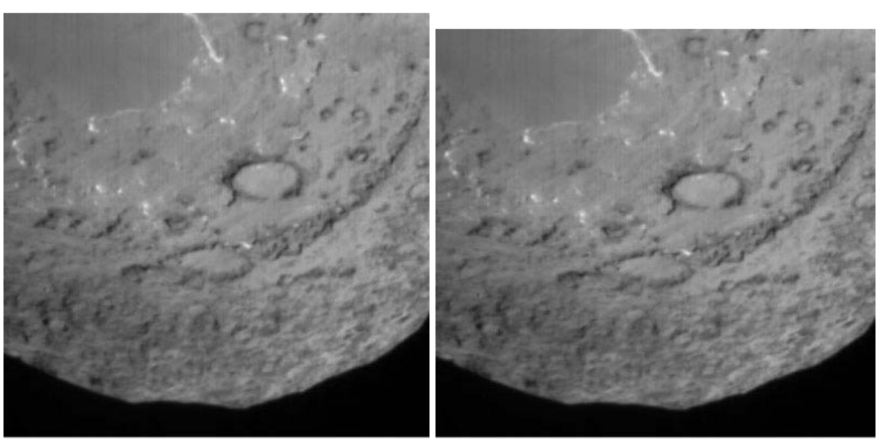
- ✓ This will keep them nice and flat.
- ✓ Then put your head down and your face right on top of the picture.

Slowly raise your head up away from the images. Remember that when the picture is about 6 inches from your eyes you should feel the image pull together and you'll be looking at a third, merged image between the two real images as mentioned above.

B. If seeing the two side images bothers you, try viewing the images through a pair of toilet paper rolls, held like binoculars. Play with the position and angles and you'll find a point where you can see the central merged image with the 3-D effect but not the two side pictures.

(*A word of caution: You may want to do this in private…!* ;])

- ✓ Try to view the stereoscopic pair below that's taking a closer look at comet Temple 1.



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QUESTIONS FOR PONDERING AND ASSESSMENT

1. Describe 2-D verse 3-D vision in your own words.

2. What is binocular vision? How do stereo pairs duplicate binocular vision? Can you think of animals other than humans that have binocular vision? What its particular power or benefit?

3. How might stereoscopic views be helpful when viewing something like the nucleus of comet never seen up close before?

4. Search the Stardust-NExT website for images you'd like to see in 3-D.
   a. Paste your stereo images below.
   b. Compare the 2-D and 3-D images. What were you able to discern in 3-D that you didn't see or were uncertain about in the 2-D shot.

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5. Extra Extra, Read All About It!!

You are part of a team reviewing the very first images returned from Stardust's flyby of comet Wild 2. The media is thrilled to learn more and it's your job to write the press release that goes with this first set of images. Using what you have learned about comets in general, and observing these two images with your stereoscope in particular, to help your adoring public:

- Understand what they are looking at in the image and
- Reconcile (match) this version of a comet with that of a comet soaring across the sky.
- Extension: Develop a News Team with whom you develop an entire news cast on the breaking news, presenting it to your audience (the class).

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HOW TO MAKE YOUR OWN STEREOSCOPIC PAIR

It's easy to make stereoscopic pairs from photographs taken at home.

DIRECTIONS:

1. Take two pictures of the same object, moving the camera 10 degrees to one side or the other between them.
   - ✓ For ten degrees move about two inches to the side for every foot you are away from the object being photographed.

2. Download them onto your computer and size them or print them and trim them to be 2 inches tall and wide.

3. Paste them side by side on a computer or use tape to connect them if you are using prints.

MAKING A STEREO PAIR FROM ONE IMAGE

How can you create a stereo pair when all you have is a single picture at one angle? Here's a simple trick.

- ✓ Use copy/paste on the computer to create two side by side copies of the image. Then select the right hand image and squash or compress it vertically.
- ✓ This simulates the change in angle needed to provide the 3-D illusion. The effect isn't perfect but can still be impressive.

Now go online and find some of your own comet or space pictures and try to make stereo pairs. Here are some good websites to try:
http://stardustnext.jpl.nasa.gov/multimedia/
http://stardust.jpl.nasa.gov/photo/index.html

Or, take some pictures with a camera and make them 3-D. Once you have practiced, you will be ready for the images of Temple 1 that will be taken by the Stardust-NExT spacecraft.

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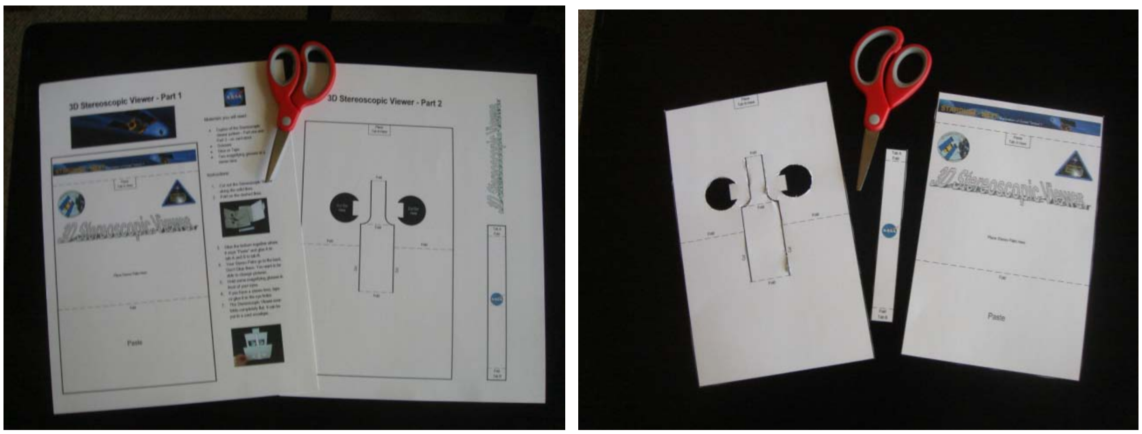
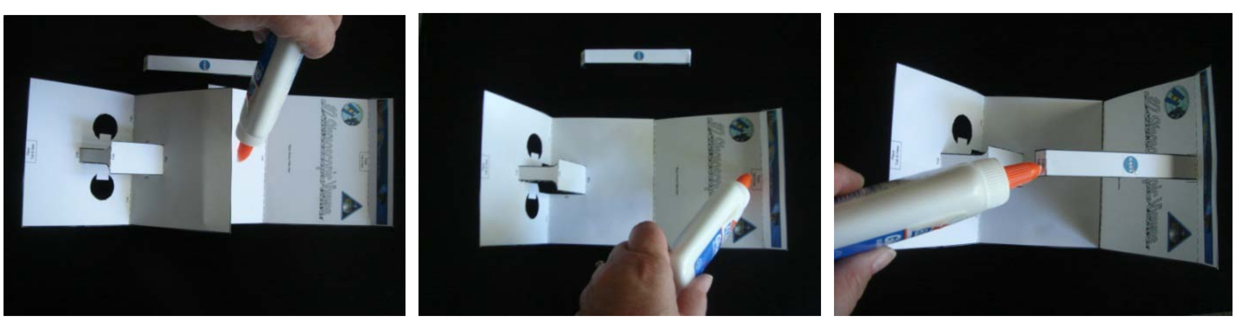
How to Make a Stereoscopic Viewer

Materials you will need:
Copies of the Stereoscopic Viewer pattern – Part 1 and Part 2 – on cardstock
Scissors
Glue or Tape
Two magnifying glasses or a stereo lens (a four inch focal length)



1. Cut out the Stereoscopic Viewer along the solid lines.

2. Fold on the dashed lines



3. Glue the bottom together and glue A to tab-A and B to tab-B

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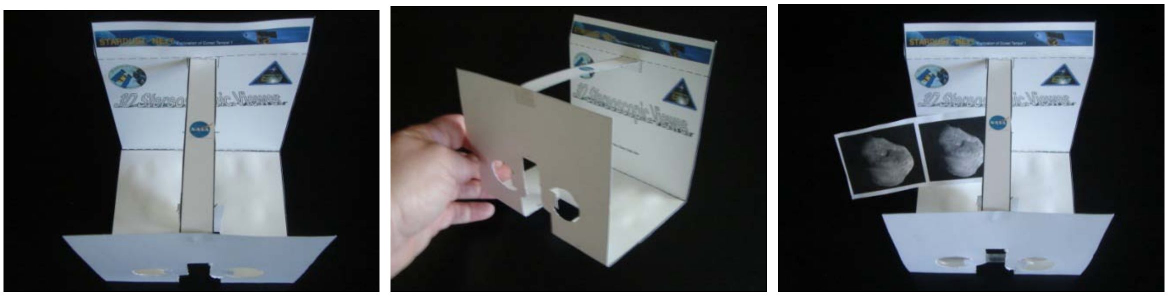
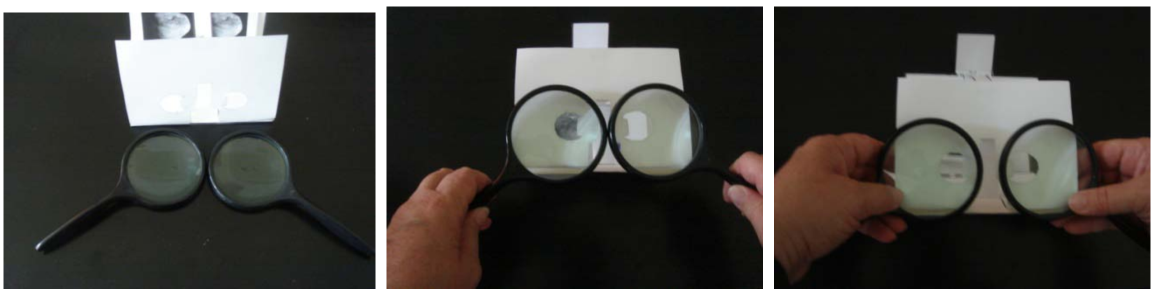
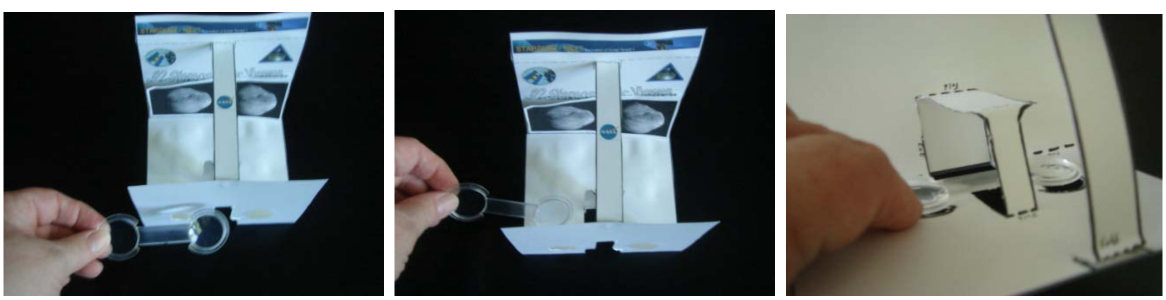


4. Your Stereo Pairs go in the back. Don't glue them. You want to be able to change pictures.



5. Hold some magnifying glasses in front of the eye holes.



6. If you have a stereo lens, tape or glue it in the eye holes.

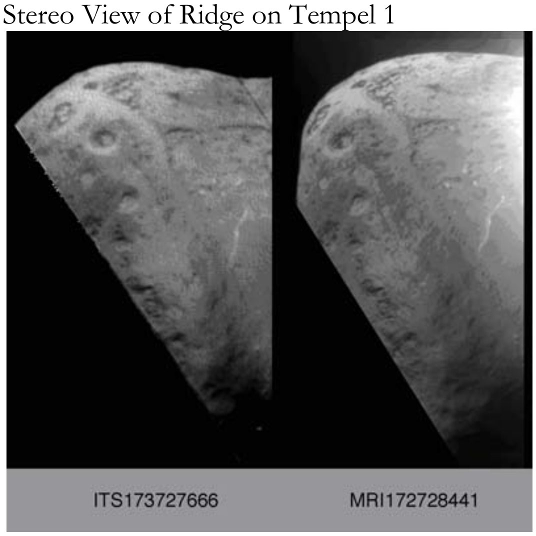
7. The Stereoscopic Viewer even folds completely flat. It can be put in a card envelope.

Try these Stereo Pairs in your viewer:

Name: ______________________________

US Capitol

Stereo View of Ridge on Tempel 1



Stardust-NExT