DARPATech, DARPA's 25th Systems and Technology Symposium
August 9, 2007
Anaheim, California
Teleprompter Script for Dr. Robert Tenney, Program Manager, Information Exploitation Office

The Mapping Revolution

» **TODD HUGHES:**
We are at the beginning of a Mapping Revolution.

Mapping technology has already radically changed how we all live: Google Maps directs us to any city in the country; NorthStar guides us through back roads around highway traffic; Garmin helps us locate nearby points of interest.

For consumers,
mapping technology is a tremendous convenience.

For soldiers,
it is a necessity that literally shows the path to mission success.

Just ask the hundreds of soldiers in Iraq today who carry handheld GPS devices on every single patrol.

My name is Todd Hughes, and I envision maps of the future that are far more powerful.

Imagine a map that represents not two spatial dimensions, but three.

Imagine a map that details, at the highest levels of precision, location, shape, texture, temperature, elevation, color: all of the things your eyes can see and many of the things they can’t.

Imagine that information for every object in a region: every building, window, door, roof,
fire escape, dumpster, pothole, manhole cover...
everything.

Imagine that map with imagery from right now, not months or years ago, and with the ability to turn back the clock to see what’s changed.

Imagine a map that not only shows the route but also highlights where the enemy may attack along the way.

And imagine holding this exquisite microcosm of the Earth in the palm of your hand.

This is the
Mapping Revolution,
and it promises to change forever the very idea of the map.

The impact of the Mapping Revolution on warfare will be staggering.

Soldiers will have unprecedented familiarity with terrain they have never seen with their
own eyes.

Commanders will plan and rehearse missions for specific urban areas before the troops arrive, or even while en route to their destination.

They will know in an instant when the shape of the battlefield has changed.

For our military forces,

the Mapping Revolution will transform geospatial intelligence into something approaching geospatial omniscience.

This vision is not as
far-fetched as you might think.

In fact, much of the essential technology is here and needs only an infusion of innovation.

We are in position,
in both space and time,
to transform mapping technology if only we have the imagination to do so.

The reason is this:
The Mapping Revolution follows in the wake of a previous revolution in sensor technology.

We now possess sensors, both airborne and terrestrial, that deliver data with precision unimaginable just a few years ago.

Of course, we are all familiar with wide area video sensors such as those found on unmanned surveillance drones like the Predator.

But perhaps the most important breakthrough technology in this arena is LIDAR: Light Detection and Ranging.

Like its celebrated cousin RADAR, LIDAR sends out a signal and captures the returning bounce.

Instead of sound waves, the LIDAR sensor emits and receives photons.

A LIDAR sensor can measure the shape and elevation of an object down to the centimeter, detecting objects quite literally smaller than a breadbox.

Sensors of the future—indeed, the near future—will be able to measure the entire surface of the earth at this incredible level of precision.

This astounding sensing ability makes possible a huge advance in map technology:
maps with nearly absolute 3-dimensional accuracy.

Today cartographers estimate location and elevation using
stereo extraction,
calculating from two images of the same area that are slightly offset.

Errors in the range of tens of meters are commonplace, a phenomenon pejoratively known as
“cartographic license.”

With LIDAR, cartographic license will be banished and the old ways of map-making by hand
will go with it.

There is another emerging technology of comparable importance:
the hyperspectral sensor.

These sensors detect light in areas of the spectrum well beyond those our mere human eyes can see.

Astronomers determine the chemical composition of planets light years away by studying molecular patterns in the hyperspectral realm.

When we turn these sensors inward,
to our own planet,

it becomes possible to see now not only the surface features of an object but also its composition.

The hyperspectral sensor can tell us whether the building is made of wood, concrete, or brick;
the road is paved or gravel;
the paint is enamel or acrylic.

And, like LIDAR,
we can expect that in the near future sensors to cast a hyperspectral gaze over vast areas of the globe.

The sensor revolution has created for us the raw materials for the Mapping Revolution.

There are, I believe, several challenges that we must overcome to bring it about.

These are technical barriers waiting for the most enterprising and creative engineering minds to surmount.

One such challenge is that the sensor data I mentioned a moment ago needs a home where all its various forms—
from video to hyperspectral to LIDAR—can live alongside each other.

More precisely, they will live *on top of* each other, each source of data constituting an overlay.

This is how online mapping services show the roads, gas stations, and restaurants overlaid on a satellite image.

We need to apply a layer technological innovation on this idea.

Imagine holding a cube directly over a point on the Earth and releasing it.

As it falls, it passes through layers of data—electro-optical, video, SAR, sonar, hyperspectral, LIDAR,
and so on—
each aligned precisely to that point.

The cube gathers all the data for the place at which comes to rest.

This data cube—
a “geocube” if you will—could be delivered instantly to the commander stationed anywhere on the planet.

We must develop a new kind of repository,
a Geospatial Representation Integrated Database,
capable of aligning, storing, retrieving, and transmitting data
in this way.

This is not simply a data management issue to be addressed by conventional database solutions.

It is a challenge to reinvent the very structure of geospatial data so that it efficiently captures the many facets of geospatial reality — over an enormous expanse of space and time.

Another challenge is to compose the countless descriptive labels that convey what the map represents.

For generations, cartographers have produced such labels for objects at the
macro scale:
bodies of water, roads, mountains, cities,

and the like.

However,
objects at the micro scale — windows, trees, manhole covers and so forth — are simply too small and too numerous for humans to find, measure, and label
on their own.

Furthermore, the colossal number of such images available from cameras on satellites, unmanned aerial vehicles,
perimeter walls, and even on soldiers' helmets, makes this task simply impossible for human analysts.

Today, the so-called
“pixel to pupil ratio” is so far skewed in favor of the pixels that only a small fraction of imagery can actually be processed.

Nevertheless, there is reason for optimism.

Automated object recognition by computers has exploded in the last decade.

This is due in large part machine learning techniques, where computers are trained to identify patterns in much the same we are trained, namely, by exposure to positive and negative examples.

Researchers in machine learning have empowered computers to recognize and label objects depicted in an image, progressively improving accuracy and error rates while decreasing the number of training examples required.

And while image recognition is still out of reach of typical human capabilities —

which is about 30 thousand classes —today's systems are capable of recognizing more than a hundred image types.

Further algorithm advances, in step with expected advances in computation speed, promise to shrink this gap sooner than we might expect.

I believe we are now in the fortunate position to direct "computer vision" technology at military image data to great effect.

We can regain the advantage against the pixels by reinforcing human eyes with an army of all-seeing computers.

These computers will,
in real time, interpret pixels as objects,
label the objects, and transform the integrated database into something we can truly call a map.

And let us not limit ourselves to "pixels"
in the conventional sense of 2-dimensional
color pictures.

We can readily conceive of a world in which computer vision technology is capable of divining the world of objects from
3-dimensional LIDAR data and hyperspectral data beyond the range of our human eyes.

Indeed, we will engineer a form of synesthesia into computer vision systems, so that they can see objects from sound waves collected from acoustic sensors.

The power of new ideas will move us ever closer to this world.

Overcoming these challenges will present us with an amazing opportunity to create maps that not only passively represent the physical terrain but actively reason over it as well.

Let's suppose we have an automatically generated map of the world with precision down to the centimeter and labeled with the shape, location, and category of every single object.

Such a map can tell us a lot more about getting from point A to point B than the maps we use today.

Consider a hostage rescue situation,
in which U.S. Forces must liberate a civilian held up in a building in the center of a dense urban area.

There are a number of entirely new and
mission-critical questions the commander could put to the map.

Are there any barriers on the roads leading to the building area?

Is there a rooftop landing zone within 50 meters of the building?

What path should my forces take to secure the building?

What exits could the enemy use to get out of the building?

Is there a vehicle parked near to an exit that wasn't there yesterday?

Is its engine warm?

Will I be able to see it from the courtyard nearby?

These are difficult questions — even for military professionals —and today they take a long time to answer.

However, research in cognitive technology holds great promise for what I like to call “automated geospatial reasoning.”

I believe we can enable computers to understand the spatial and temporal dimensions of reality as humans do,
but at scales that far outstrip the capacities of our human minds.

With automated geospatial reasoning technology, we can develop a mission planning system that resembles an Oracle:
no sooner will the commander ask the question than it will have an answer,
the right answer.

There is much work to be done to create the mission planning Oracle.

My plan is to lay the foundation for this reasoning technology now so that when the new map is born, it emerges with intelligence.

This is the technology landscape before us.

To give shape to this map of the future, we must harness the creative energy of industry, academia, military, and government.

It begins with a conversation about the possibilities.

It is followed by a commitment to one or more research programs.

In time there is a conversion of research technology to military-grade solutions.

Consider my remarks to you today as the start of the conversation.

If we work together,
the commitment and conversion will not be far behind.

It is fitting that the next step on the journey toward the Mapping Revolution should take place here,
at DARPATech.

For fifty years, DARPA has been the engine of technology transformation for our military.

And the fuel for this engine is you.

Your insight, your ideas, and your initiative — these are absolutely essential to effect the change we envision.

As it has done so many times before,
DARPA will show the way.

If we work together, I am confident we will get there.

If we work together,
we will forever change the way we map the world.

Thank you.

So remember when I told you about the pixel to pupil ratio... and how I'm going to solve the problem by adding more pupils.

To show you why I'm so scared of this, let me introduce Brian Leininger because he's going to make a lot more pixels.