Utilizing Space Age Digital Strain Measurement Technology to Identify Zones of Mechanical Weakness in Trees – Final Report

Principal Investigators: Gary Watson and Angela Hewitt, The Morton Arboretum, Alexia Stokes, INRA- UMR AMAP, Montpellier, France, CIRAD - UMR AMAP, Montpellier, France

Collaborators: Philip van Wassenaer, Urban Forest Innovations, Inc., Edward Gilman and Jake Miesbauer, University of Florida

Major In-kind contributors: Dave Leonard, Dave Leonard Tree Specialists, Greg Oltman, GRO Horticulture Inc, Paul Markworth and Dave Scharfenberger, Wachtell Tree Science, Tony Mucciardi, Tree Radar, Inc.

Researchers studying tree biomechanics are constantly striving for a better understanding of tree failure mechanisms by detecting zones of mechanical weakness (e.g. decay, splits, hollows and poor anchorage) through analysis of strain distributions along trees. Technology has been a limiting factor in certain aspects of tree biomechanics research aimed at understanding tree failure. In this project, stereo photogrammetry technology developed by the NASA Space Shuttle program was employed for the first time in tree biomechanics research to overcome limitations of more traditional technology. This imaging technology uses stereo high-resolution video cameras and dedicated software.

The application software known as ARAMIS was developed for NASA to measure space shuttle wing leading edge deformation to verify the cause of the Columbia accident. We used it to measure three-dimensional deformation and strain of the tree trunk surface during mechanical loading. Locally high strains along the stem and roots are indicative of areas of mechanical weakness. This imaging technology is capable of covering the entire trunk with virtual strain gauges, eliminating the need to guess where maximum strains will occur for placement of mechanical gauges.

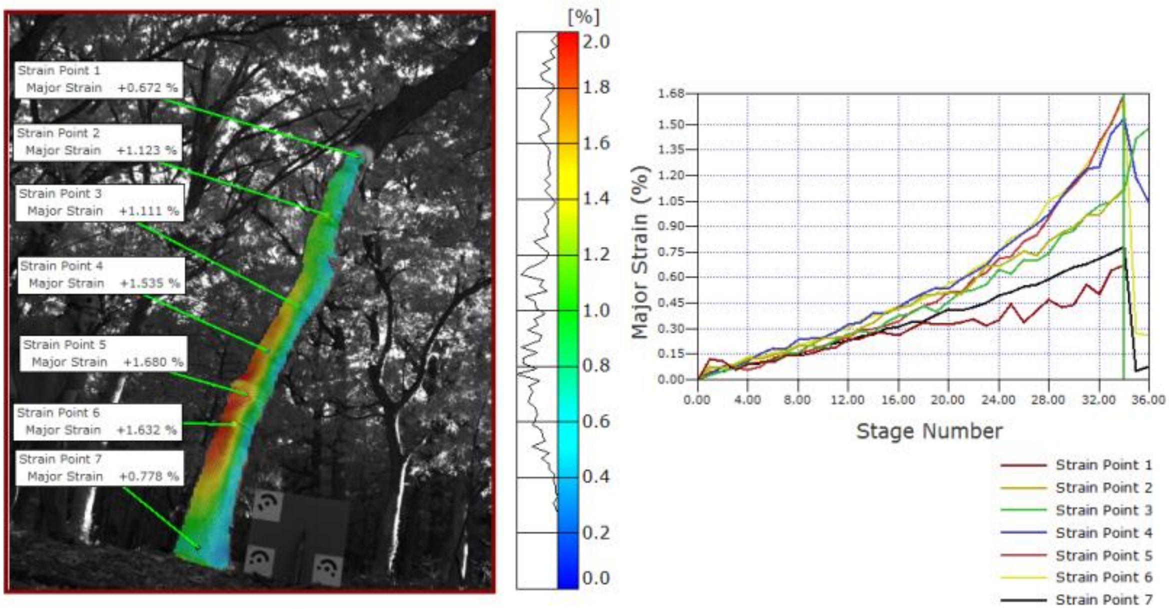
Seven 12-14 inch green ash trees were pulled to failure while recording with ARAMIS. The image at the top of page 2 is an example of the kind of graphic representation of the strain data that can be produced. The red areas are where the surface is under tension (being stretched, also known as major strain) as the tree is pulled to the right. In the image at the bottom of the page, the tree trunk had broken relieving most of the strain.

The images don’t reflect the amount of preparation and follow-up work that went into the test site. The trees trunks had to be stripped of bark, painted with a white base coat, and covered with black dots as an image recognition pattern for the software to recognize. In order to be able to calculate stresses within the trunk, the curvature of the trunk had to be measured and then the tops of the trees had to be removed and weighed before the pulling. Afterwards the trees had to be cut into 1 meter segments and weighed. Wood samples were cut (over 800 20mm cubes) to measure wood properties such as elasticity.

Tree 566, Test 5, System 2

Major Strain Overlay

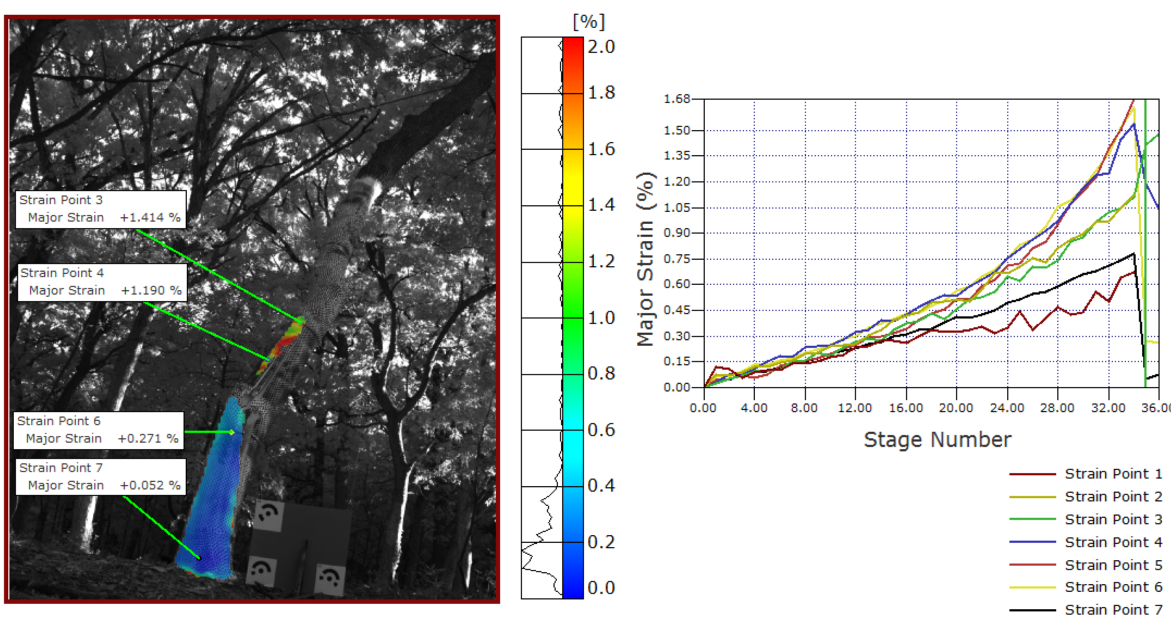
Test to Failure 9/10/2012



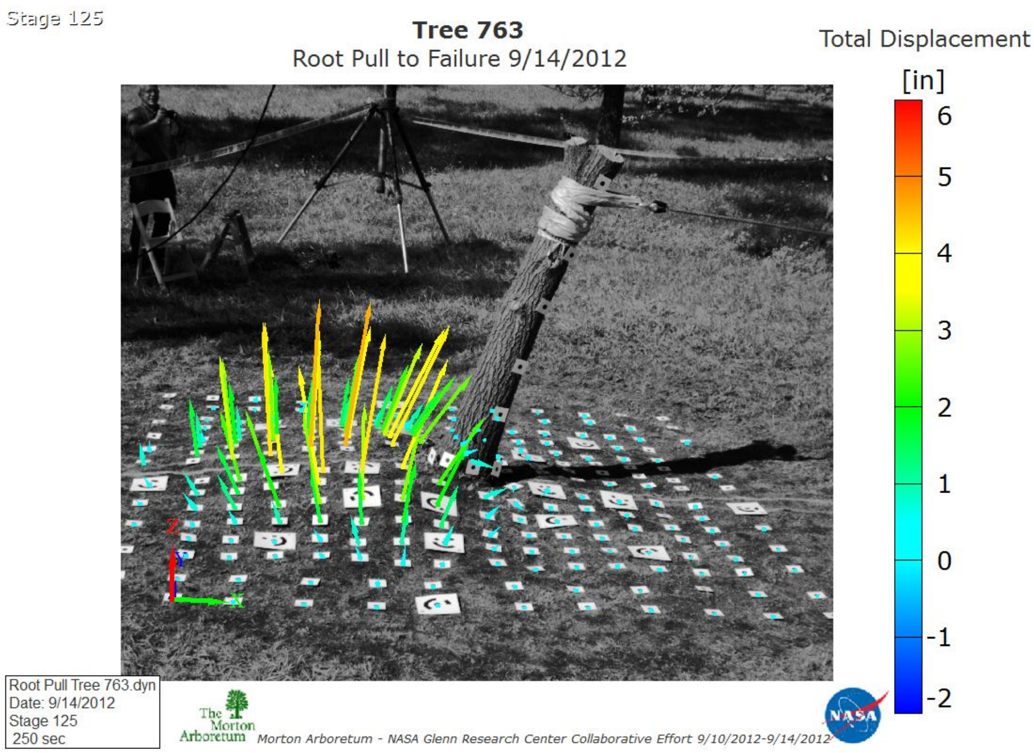
Tree 566, Test 5, System 2

Major Strain Overlay

Test to Failure 9/10/2012



The same stereo imaging camera system, with a different software application known as PONTOS, was used to measure the movement of the entire root plate (the roots and soil that uproot with a tree) surface as trees were pulled to failure. Again, detailed measurement of movement of the root plate surface has been limited by technology. Once again, a dot pattern was established for the software to recognize. The software measures the speed and direction of movement (displacement) of all of the points simultaneously and represents the movement with color coded arrows (see image below). Six 8-10 inch elms were pulled to root failure, indicated by the leveling off of the force needed to tip the tree and root plate.



The only preparation needed was to remove the tops of the trees and clear the soil surface of grass. However, the follow up work was more extensive. The root systems had to be excavated so that ground surface movement could be related to root architecture. This required digging the trees with a 100-inch tree spade, then using an air-knife to remove the soil from the root ball and 2 feet wide and 2 feet deep around the hole it left (see images below).

This project received much attention from the media. Having NASA on site was no doubt part of the attraction. The dot pattern on the trees was often seen in print and on video. The TREE Fund was recognized wherever possible.

Matt Melis and Gary Watson also presented the project to the TREE Fund Board at their meeting in December 2012 and it was well received.

TREE Fund grant programs are vital to the arboriculture industry. This grant is a good example of the impact that a modest TREE Fund grant can have. The project employed a cutting edge technology developed by NASA in tree research for the first time. The grant funds were used to pay for the NASA Space Act Agreement that allowed Matt Melis and Justin Littell to work with us for a week and bring $200,000 worth of equipment. The Duling grant was the key to getting the project off the ground, and once underway, additional funding and in-kind support was obtained that totaled many times the amount of the TREE Fund grant. The Arboretum tree crew and research technicians were on site for over a month. Arboretum grounds crews supported with trucks, backhoes and time. Alexia Stokes and Thierry Fourcaud spent six weeks working with us before during and after the data collection week. Industry companies contributed the tree spade, air knife, and personnel time as well.

Since the elm trees needed to be excavated for this project, a second independent project was organized to take advantage of the opportunity. The root systems of the elm trees were mapped with ground penetrating radar before pulling them, and root systems were mapped at the same location after they were excavated to compare the radar locations with field measurements. It is related to this project in that we hope that as we come to understand what kind of root system architecture is most stable, we can then map the root systems of trees to assess the stability of trees non-destructively.

The field data collection through the NASA Space Act Agreement, funded by the TREE Fund, is complete. The international team of collaborators will be engaged in mining that wealth of data, presenting at conferences, and publishing papers for some time. We will keep the TREE Fund up to date on these developments. This research has been a significant step forward in the understanding of tree failures.

Gary Watson
Senior Scientist
The Morton Arboretum