The structural monitoring team's main goal was to select a system of sensors that would allow us to monitor the house's structural integrity at any time in real time. With the ability to detect problems before they get out of hand and even being able to predict potential causes of problems, a house would last much longer and make maintenance easier. The many technologies of Non-Destructive Evaluation (NDE) would allow us to fulfill our goals without having to tear the house apart to check up on its inner workings.

While searching for information about types of NDE, Mark Younger told the team about the NDE sensors being currently used in an overpass bridge inside of CIEMAS. The team began collecting data on that technology: fiber optic Bragg sensors, embedded in the bridge. Also, alternatives were sought out. On Access Science, the team found information on a second type of sensor: Acoustic emission (AE) sensors. Other alternatives found were MEMS accelerometers and strain gauges. The other alternatives involved direct access to the inspection point - which we most likely would not have – and/or only would work on a very small portion of the house. A main goal of the team was to find a technology that would allow us to monitor the house as closely to one continuous object (not just a network of points) as was possible. The research was split up among the team to find out more information about each applicable technology.

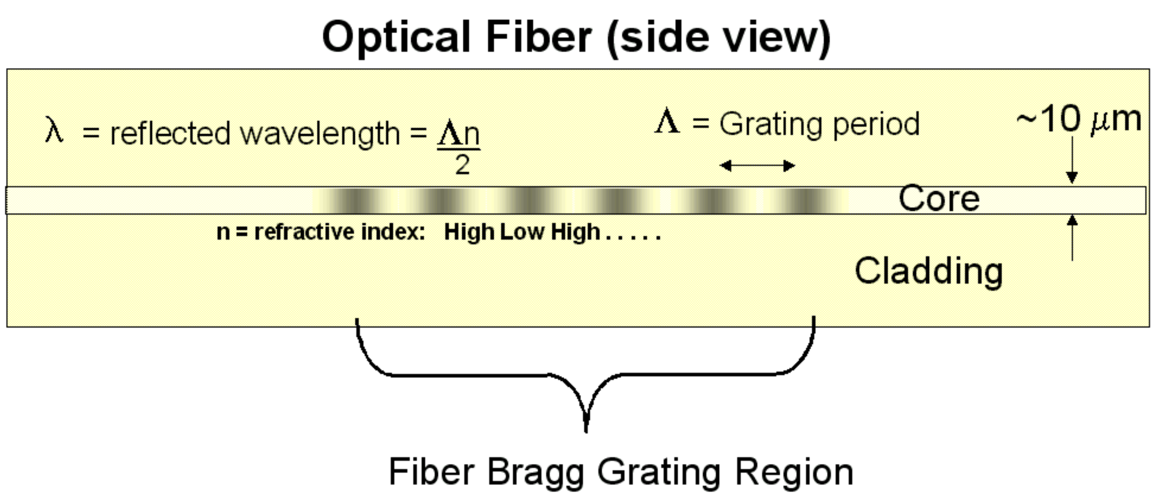
Acoustic emission sensors work by having piezoelectric transducers in contact with the object to be tested. When a deformation occurs sound waves are emitted. When the waves hit the transducer, it generates an amount of current, the amount which, along with triangulation of sensors, allows the pinpointing of damage. Further analysis of the data may allow for problem identification as well. The sensors can be configured to listen all the time, and their effectiveness is not limited by the shape of the object to be tested. This system also works with wood, making it a leading candidate for the wood frame of the house. Since this type of sensor varies greatly from other types, it is very useful to have more than one sensor at work; this allows much more accurate and precise data collection.

MEMS accelerometers were not chosen to compliment the acoustic emission sensors at the recommendation of Professor Henri Gavin, who said that they were not sensitive enough for our purposes.

The sensor that was selected for use on the wood frame was the strain gauge, a device whose electrical resistance varies in proportion to the amount of strain in the device. The most widely used gauge is the bonded metallic strain gauge. The metallic strain gauge consists of a very fine wire or, more commonly, metallic foil arranged in a grid pattern. The grid pattern maximizes the amount of metallic wire or foil subject to strain in the parallel direction (Figure 2). The cross sectional area of the grid is minimized to reduce the effect of shear strain and Poisson Strain. The grid is bonded to a thin backing, called the carrier, which is attached directly to the test specimen. Therefore, the strain experienced by the test specimen is transferred directly to the strain gauge, which responds with a linear change in electrical resistance. Strain gauges are available commercially with nominal resistance values from 30 to 3000 Ohms, with 120, 350, and 1000 Ohms being the most common values. The strain gauge was recommended by Professor Henri Gavin to compliment the acoustic emission system on the wood frame of the house.

When the acoustic emission system and the strain gauges are working appropriately, the following relationship between the two should be apparent: the acoustic emission system will pinpoint the damage and damage type, while the strain gauges measure the vicinity and strength levels of culpable forces around such deformation. With these two bits of information, we should be able to record data on conditions that cause the most amount of deformation to specific areas of the wood frame and take measures against such conditions. As a continuing process, the structural integrity of the house will be monitored and secured as time passes.

Fiber optic Bragg sensors were chosen for the foundation of the house. They are going to either be attached to or embedded in the material of the foundation, so that when deformations occur to the formation, they will have effect on the sensors as well. The sensors detect deformations by measuring a change in wavelength in the light passing through the sensor when the sensor is subjected to strain. They are best for tensile strain, elongation or compression.



One of the main data collection goals of the structural monitoring team is to observe changes in the foundation of the house while tracking soil conditions simultaneously. Geophones were selected, at the recommendation of Henri Gavin, to monitor physical soil shifts and movement. Most geophones have a coil hanging from a spring in the center of some magnets. Ground movements move the case up and down, but the mass stays still, and it induces small currents in the coil as it moves through the magnetic field. This measures velocity of motion. The current is recorded into a computer for analysis. If the Bragg sensors in the foundation detect the house shifting, the geophones will help verify that and help locate the specific site of movement. These two sensors types will cooperate much like the acoustic emission and strain gauges; the fiber optics detect the location, extent of, and type of damage in the foundation, and the geophones detect the location and extent of ground deformation which led to the foundation damage. Data collection will eventually lead to damage prevention as we begin to recognize causes of foundation damage. This will extend the lifetime of the house.

Another research topic was to compare the cost-effectiveness of both direct wiring and wireless sensors in a small structure like the DELTA house. Wireless systems are preferred in larger structures, such as skyscrapers and oil tankers, because the cost of the wiring over such long distances is high. In the house, the wiring cost will not be as much, considering that there will be a number of different systems' wiring running through the walls. If both wireless and wired sensors can be implemented, then the team can measure their relative accuracy and precision. This is not the main difference between the two configurations, though. Wireless sensors use batteries that will definitely have to be replaced eventually. We are trying to design a system where we do not have to have any physical access to the object being monitored and having to replace batteries would complicate that. Direct wiring may increase signal strength, processing speed, and eliminate battery replacement problems, but specific sensors have not been evaluated yet. That is one of the main goals over the next semester.

Another main objective for next semester is the analysis of the physical structure of the house. We must find the critical points to place sensors. Since many of these sensors can only cover a certain area, multiple sensors must be placed. This will raise the costs of our project. Finding a configuration of sensors that lowers the cost with no loss of accuracy and precision is preferable. Much of this work will be done in tandem with the Controls team, who is already shaping the wiring paths through the house. The Architecture team could supply information on spots in the house where deformation is most likely to happen. Further research on types of structural damage and their causes will allow us to select parts of the house where the majority of sensors will be placed. A thorough analysis of the blue prints and construction documents will allow for accurate placement of sensors and also recognize potential problem areas where sensors may not be as effective. Working with Civil engineering professors, such as Henri Gavin, will be essential to decide on the sufficient placement of sensors. The system will be configured with the two criteria of efficient wire paths and probable deformation.

Software for these programs must also be selected. Since the sensors all pick up signals and interpret them in a very different manner, it is likely that each separate system (Acoustic Emission, Fiber Optic Bragg Sensors, Geophones, Strain Gauges) will have its own program interface where data can be accessed. It will be a task of the engineers in the house to compare the data from each of the sensors and analyze how each type of data can be used with the others.

Multiple contacts were made in the semester. Civil Engineering Professor Henri Gavin met with the team once and through emails multiple times. Over the next semester, the team hopes to meet with him as much as possible to gain information on specific sensor equipment and the placement of those sensors in the house. Professor Gavin also supplied a list of further contacts to seek out. They include: Dr. Lawrence Virgin (Duke University), who uses fiber optic sensors for Navy projects; Dryver Houston (University of Vermont), involved with fiber optics; Daryll Pines (University of Maryland), involved with civil structures; and Deborah Chung (Suni Buffalo), involved with smart concrete; and Jerome Peter Lynch (Michigan University).

Three industry contacts were made: David Sinay, Acoustic Emissions Application Sales Manager of the Physical Acoustics Corporation; Mark Jones of Keehitech; and Tim Allmendinger of Geospace Technologies.

The structural monitoring team has evaluated types of non-destructive evaluation and has selected specific types of sensors for separate sections of the house. Bragg fiber optic sensors were chosen for the foundation of the house. Geophones were selected for the soil around the foundation. Acoustic emission and strain gauges were chosen for the wood frame. The team must decide on specific equipment to use, the placement and configuration of the sensors, and the networks and programs that will allow for interpretation of data. With such decisions made, the team will be able to start constructing a prototype system.