Learning Objectives
At the end of this class, you will:

- Have a better understanding of the fundamental concepts of LiDAR
- Discover current applications of LiDAR in the civil industry
- Learn how to prepare LiDAR data in ReCAP for use in additional downstream Autodesk Software
- Learn how to use LiDAR and other data in Infraworks, 3DS Max, & Revit software
- Learn how to bring LiDAR data into AutoCAD Civil 3D and use it for design
- Examine prospective innovative concepts

Description
This presentation will explore using a combination of LiDAR (light detection and ranging)-derived existing models and proposed Civil Information Modeling (CIM). Topics to be covered include an introduction to 3D laser scanning and use of ReCap software to exploit LiDAR data for obtaining as-built or existing conditions. We will also leverage the point clouds in InfraWorks and 3ds Max software for preliminary and conceptual design. Additionally, we will use AutoCAD Civil 3D and Revit software to generate a CIM/BIM model by blending LiDAR data with proposed design. We will demonstrate how to avoid potential construction issues by combining these technologies to virtually construct the project. We will also discuss integrating industry innovations, including unmanned aerial systems (UAS) and automatic machine grading (AMG).

Your AU Experts
Rusty Steel is the Technology Manager at CEC Corporation. Having a background in Survey and all aspects of Infrastructure Design he oversees IT and other technologies while specializing in 3D design, modeling, and CIM coordination with Infrastructure Design at CEC. With 12 years of experience in designing major civil projects, training other experts in the industry he has worked in most major design software. He has gained professional Autodesk certifications in AutoCAD and Civil 3D and has recently developed an Autodesk Certified Training Center in Oklahoma City. Of the 38 Autodesk Certified Instructors he is the only based in Oklahoma.

Bartley Estes is the LiDAR Project Manager at CEC Corporation. With an educational background in GIS and remote sensing, he is responsible for managing all LiDAR data acquisition and data processing at CEC. Having experience in both LiDAR development and sensor integration, he is recognized among industry experts in the geospatial community.

Both Bart and Rusty have been invited to speak at various venues, academic institutions, conferences and user groups. These include: the Oklahoma Department of Transportation, Oklahoma State.
**Fundamental and Integral concepts of LiDAR**

**What is LiDAR?**
LiDAR is a 3D remote sensing technology that uses pulses of light to measure and record objects from a distance. LiDAR data is most commonly referred to as a “point cloud”. While the 3D scene looks like a model, it is actually comprised of millions of individual survey points. Because the sensor is using pulses of light to collect measurement data, the reflective properties of the object are recorded in addition to the XYZ coordinates.

**Data Density**
Incredibly high pulse rates of LiDAR sensors allow for an over-abundance of point measurement data. The amount of available data is unmatched in comparison to traditional photogrammetric means and conventional topographic survey methods.

**Accuracy**
Different levels of accuracy exist among the many different LiDAR sensors and manufacturers. Accuracies can range from GIS/GPS grade to survey/engineering grade. In combination with survey control, LiDAR routinely achieves the accuracies required for civil engineering applications.

**Acquisition Window**
LiDAR data can be collected both day and night with no negative effect on data quality. Multiple pulse returns allow for superior penetration of tree canopy. Therefore, there is no need to rely on “leaf-off” conditions like traditional photogrammetric methods.

*Figure 1: Example of a LiDAR point cloud*
How does it work?
LiDAR “point cloud” data is the culmination of a few different ingredients. The recipe is comprised of GPS, IMU, range, and intensity measurements. Each of these factors is crucial in providing an accurate and precise dataset.

**GPS – Where are we?**
Global Positioning Systems are used to record the location of the LiDAR platform, be it aircraft or terrestrial vehicle. A high epoch rate is typically used to keep up with the platform, which is traveling at a high rate of speed.

**IMU- What conditions are affecting us?**
Because the LiDAR sensor is usually mounted in a fixed position on the platform, the system is affected by the same stresses as the vehicle itself. The IMU measures inertia and compensates for that movement so that the resulting LiDAR data is not negatively affected by things like a gust of wind, a speed bump, drift, or any other type of minute movement.

**Range/Scan Angle - How far away is everything?**
Each laser pulse is emitted and the GPS time is recorded for each pulse. As each pulse returns to the sensor, the return is detected and the GPS time is recorded. Each pulse travels at the speed of light, so by knowing the leave and return time, the sensor can precisely measure the distance of every pulse return.

![Figure 2: Integrated LiDAR Components (credit: Ohio Department of Transportation)](image-url)
Aerial LiDAR

Aerial LiDAR is arguably the most versatile platform for collecting 3D scan data. Sensors can be mounted on a wide array of aerial vehicle types ranging from fixed-wing aircraft to rotorcraft. Aerial LiDAR is typically best leveraged for wide area terrain mapping and coastal bathymetric surveys. Cross-country utilities are also commonly surveyed using low-altitude corridor mapping.

Aerial LiDAR point densities are typically lower than ground-based LiDAR. The point spacing still remains high enough to produce a highly accurate and precise DTM. Aircraft can obviously cover more area faster and are not affected by obstructions, so project accessibility is usually not an issue. However, mission planning and operational costs are higher. While planning data acquisition, additional constraints must be considered. The operator must determine things like: optimal altitude, cruise speed, FOV, pulse rate, and other normal flight operation constraints.
Mobile LiDAR
Mobile LiDAR is the preferred platform for civil engineering applications. LiDAR sensors are mounted on to SUVs or trucks that are used to collect LiDAR data down roadway corridors. The pulse rates and point densities are much faster and higher than aerial LiDAR, so mobile LiDAR data is incredibly dense and detailed.

Mobile LiDAR systems regularly achieve survey accuracies required by engineering applications. These systems allow the user to accurately and precisely survey a corridor at posted speeds, night or day, without ever diverting traffic or putting surveyors in harm’s way. However, this platform is limited to where it has access. These systems are capable of being mounted on railcars and ATVs, so offroad use is possible. Mobile system usually collect in 360 degrees, meaning the sensors are detecting everything around the vehicle. This includes items above and below the vehicle, allowing for bridge/utility clearance measurements and pavement analysis.
Terrestrial/Static LiDAR

Terrestrial LiDAR is a sensor attached to a static fixed height or tripod. Because the sensor is not in motion, things like GPS and IMU components are not incorporated. This collection method oftentimes offers the highest point densities and detail, causing it to be favored by architects and vertical structure engineers.

Terrestrial LiDAR offers a unique aspect, as it allows the user to collect data inside buildings or in tight spaces. This means that in addition to collecting highly accurate and dense exterior information on a building, the user may collect interior data and tie the two together utilizing survey control. This results in a true, engineering grade survey of the entire building.

An emerging industry for terrestrial LiDAR is law enforcement forensics! It is beginning to replace the traditional “preserve the crime scene” procedures. Now, instead of trying to recreate the scene using pictures and sketches, law enforcement can collect the entire scene and virtually revisit it at any time.
Current Applications of LiDAR in the Civil Industry

Topographic Survey & As-Built Documentation
LiDAR at its core is purely a survey tool that collects survey data. The user may leverage the data to create a traditional survey CAD deliverable. By exploiting the point cloud data, one may generate the normal topographic survey entities such as breaklines, planimetric data, and terrain/surface models.

Quantities, Volumes, and Drainage
The point densities that come with LiDAR are incredibly useful when generating highly precise surface models. Traditional methods of creating surface models pale in comparison to the precision derived from 3D scan data. With a precise surface model, the user can achieve higher levels of analysis.
Clearance Analysis
Mobile and terrestrial-based LiDAR sensors allow the user to capture 3D scan data under structures like bridges, utilities, etc. The champion of using LiDAR data for clearance analysis is that the user has information on the entire structure. For example, on a bridge, the user can analyze every point along every beam to find the absolute minimum clearance.
Condition Analysis
Along with extracting location information from LiDAR data, the user may also perform further analysis such as determining the condition of the asset. For example, not only has the LiDAR system surveying the roadway, but also has detected the pavement condition. The user can locate and quantify the level of cracking in the pavement and the wear and condition of the roadway striping. This is especially useful when determining the compliance of ADA ramps. Analysis may be performed in the office, rather than in the field.

FIGURE 9: MOBILE LiDAR DATA DEPICTING CRACKED PAVEMENT, WORN STRIPING, AND CURB CONDITION
Preparing LiDAR data in ReCAP for use in additional downstream Autodesk Software

ReCap basic concepts
ReCap is constantly growing and evolving and can do more than what I am going to show you. If time allows I will touch on some of those other tools, but for this class I want to focus on a few primary things. In this presentation I am going to use ReCap purely as an Autodesk funnel or translator of the LiDAR data for Autodesk Software.

As Bart mentioned LiDar’s default file type is an .las. Autodesk software like Civil 3D can handle a .las, but the software works best when the .las is translated into a .rcs (recap scan file) or a .rcp (recap project file) which is ReCap and Autodesk native LiDAR filetype. The best way to think of .rcs and .rcp is a .rcp is a collection of .rcs'.
Some of ReCap’s other useful tools
Some other immediate benefits to ReCap is the ability to define and then modify what coordinate system and units the originally scan data was and change it to something different or confirm it and leave it the same.
Another quick benefit of ReCap for downstream use is I can quickly clean and or manipulate point cloud data. One example of cleaning is trimming excess points that fall well outside the realm of the project out of the data set. Be it vertical noise (like a lase picking up a bird overhead) or horizontal excess data like roads outside of your scope of work. It is very easy to throw a window around that data and delete it. I then generally push out a new cleaned .rcs so I don’t disturb the raw data. An example of data manipulation for downstream use is like in the following photo:

With minimum effort I can rotate this data delete the bridge and export a point cloud that has just the underpass data and then clean the underpass out and just have a data set with the overpass data.
I have had to use this method specifically to take the now two pointclouds into Civil 3D and generate two separate surfaces from the pointcloud data. One surface model of the overpass and the other surface of the underpass. As you know I can not quantify a surface in Civil 3D if it the surface has multiple vertical locations at the same horizontal location. In that case, like this overpass and underpass scenario I must have two separate surfaces. Once I do that I can easily do things like cut crossections through these pointclouds and quantify things like clearances.

In most cases for a quick turnaround I purely pull Bart’s .las into ReCap, change the coordinates from UTM to stateplane and then save my .rcp project and it is ready for the next downstream program.

**Using LiDAR and other data in Infraworks, 3DS Max, & Revit software**

**Infraworks**
We will pick up where we left off with our generated .rcp file from ReCap. First we will step through the basic setup of a basic Infraworks model. I will walk through the process of building a large scale infraworks data set with information like wide area surface from USGS data with draped aerials. I’ll bring in models from multiple programs like 3ds max and others to populate the infraworks model. Then I will step through the process of importing the LiDAR point cloud into Infraworks and what adjustments that are sometimes needed. In the past if I wanted to apply motion or an animation to a an object within a point cloud it would have been done in 3ds max, but very soon if not already the object can be animated in max then brought into Infraworks where the point cloud would reside and then analyzed.
3DS Max
With 3ds max we will take a 3ds modeled “proposed” object such as a new statue going in an existing courtyard and walkthrough the steps of bringing the pointcloud into the same scene with the statue, applying the necessary light and materials and generating a static render. We will also generate a simple video by using a similar scene but applying machine to both the camera and some of the objects in the scene.

Revit
We will not spend much time in Revit as we don’t claim to be experts in that software, but we will show bringing a pointcloud .rcp file into revit and a few basics on how that is being used to date.

Bring LiDAR data into AutoCAD Civil 3D and use it for design

Quickly generate usable existing conditions in Civil 3D from LiDAR data
In Civil 3D we will step through an in-depth look at bringing in LiDAR pointcloud data into Civil 3D to generate things like a surface model and linework for design plans. After generating the dense detailed surface model from LiDAR we will quickly compare what more will be available in comparison to the same sight with a traditional topo survey.

Quickly generate 2D traditional design plans in Civil 3D from LiDAR data
In Civil 3D we will give example of workflows we are using for both a civil site design scenario and an example of a proposed roadway scenario. We will quickly generate Plan and Profiles, Cross Sections, and incredibly informative earthwork quantities.

In-depth workflow on generating an AMG ready model in Civil 3D from LiDAR data
In Civil 3D we will give example of workflows we are using for both a civil site design scenario and an example of a proposed roadway scenario to generate AMG ready models to be delivered to the contractor. We will spend some time looking at AMG models and typical issues that can be caught by using a dense existing surface model derived from LiDAR data.

Prospective innovative concepts
We will show examples of innovative ways we are using LiDAR data within Autodesk software to more easily calculate things that have always been done more traditional ways. Some of those examples are very dense ponding studies along Interstate highways, and bridge clearance complicated calculations from cross sections with LiDAR data extracted.

We will touch on using LiDAR data from UAS and how that ties to the mobile and terrestrial data we have been using for our other examples.