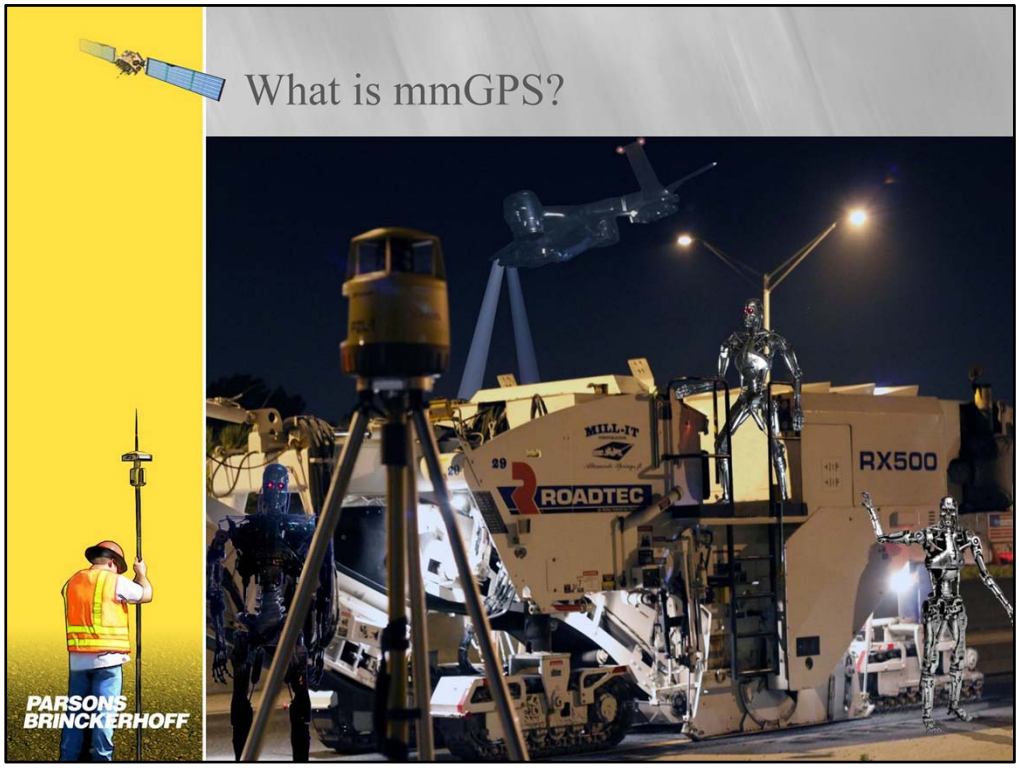
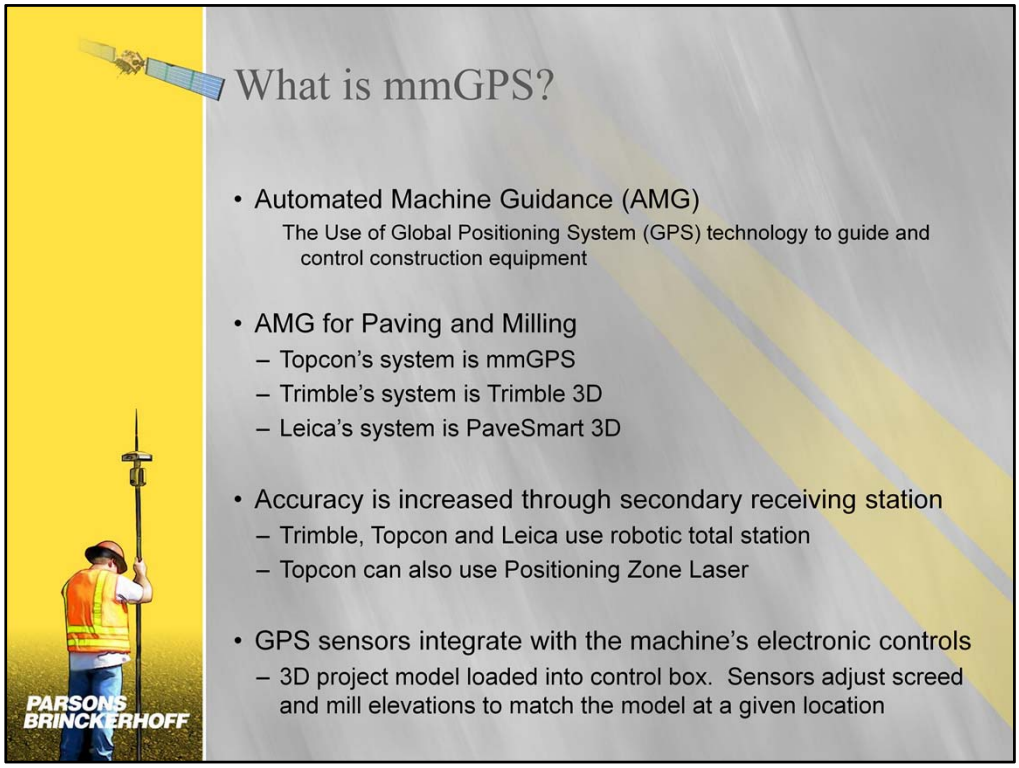
1. Thanks to Rich for organizing this topic and inviting me to share my experience.
2. I have just completed a widening project on SR 417 with the Orlando-Orange County Expressway Authority where we used Automated Machine Guidance for the milling machine and paver.
3. From the time we decided to use automated milling and paving controls, I realized early that this presentation was needed because there is very little information available on the topic.
4. It is obscure, so I expected a small turnout, but it looks like we have a lot of interest after the Burleson bump and the Sadler sponsorship yesterday.

5. So what is Automated Machine Guidance? When I hear the term, I think of something like this.



1. Well, maybe once we reach the singularity, this is how a milling operation will look
2. But, for now, the technology is a little less radical

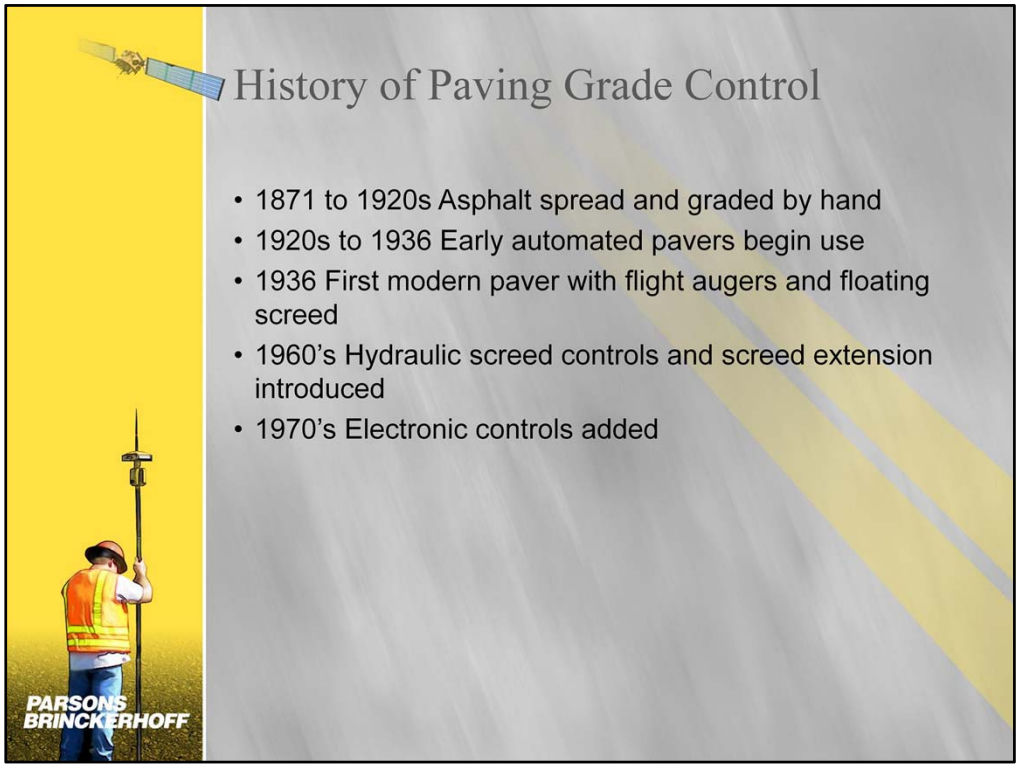


1. Automated machine guidance is the ……
2. mmGPS is a proprietary term for the system that is provided by Topcon which is what was used on our project
3. Trimble's system is Trimble 3D
4. Leica's system is PaveSmart 3D

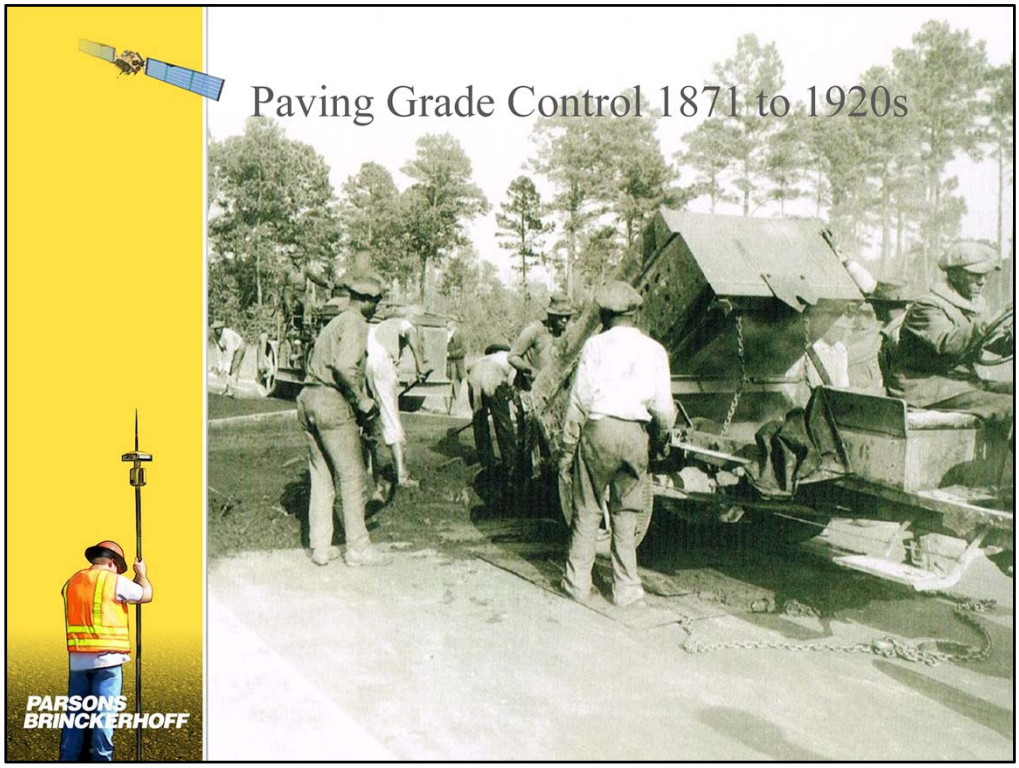
5. As you know GPS is a military system made available for civilian use. They commit to an accuracy of within 7.8 meters at 95% confidence.
6. The heart of these systems is how to augment the signal to provide greater precision

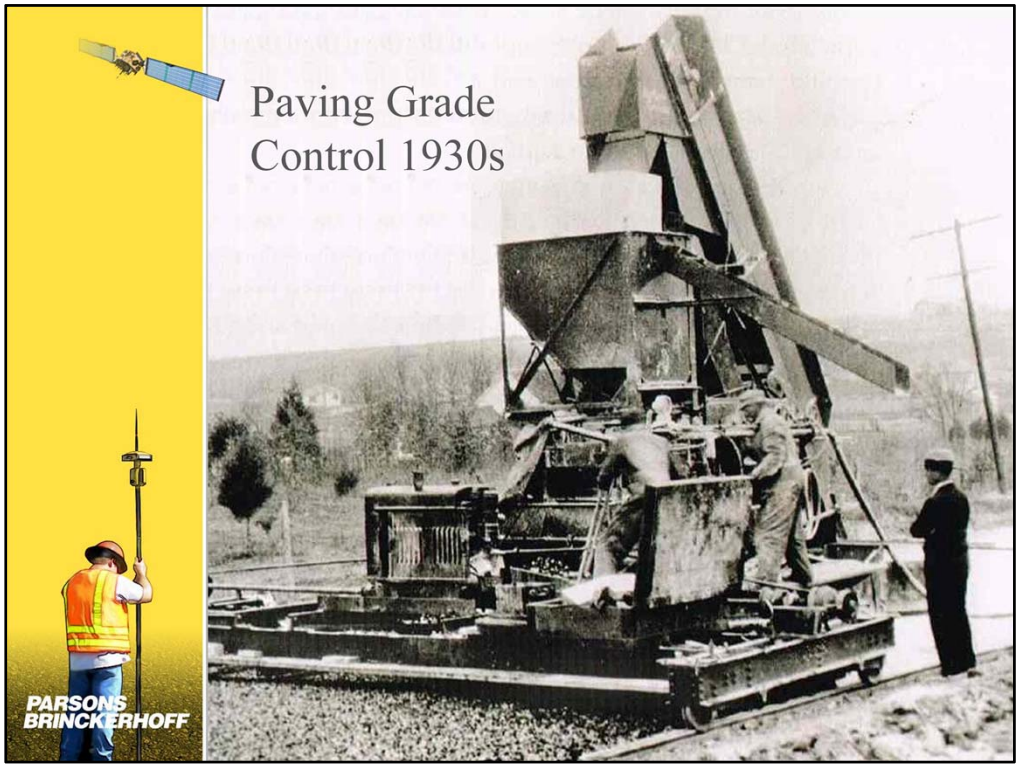
7. These concepts are not new, what is new is the ability to bring the precision to a usable confidence level for vertical and horizontal controls for paving operations

8. Now I would like to introduce Roger Croft with Lengemann, who provided the equipment and the technical support for our project. He is going to show you what the equipment looks like and describe how it integrates with the equipment that you already have.

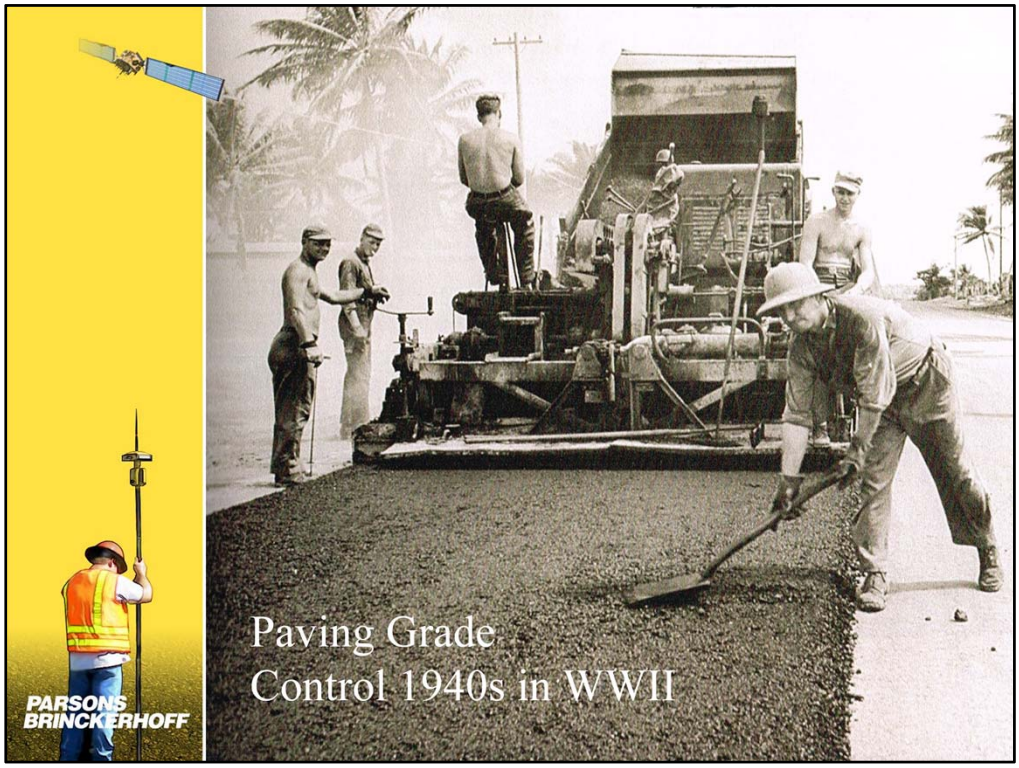


1. Before we talk about how automated machine guidance integrates with current equipment let talk a little bit about how grade control has been accomplished in the past.

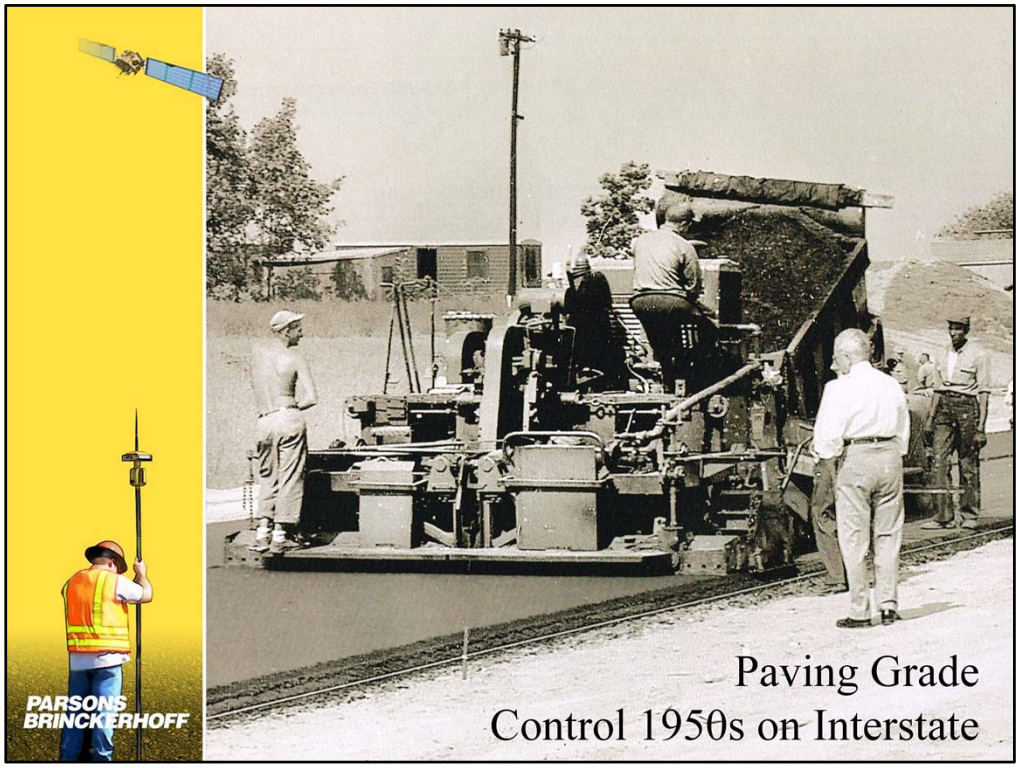

Paving Grade Control 1871 to 1920s
PARSONS
BRINCKERHOFF



This is the first ever Barber Greene paving machine used in 1931

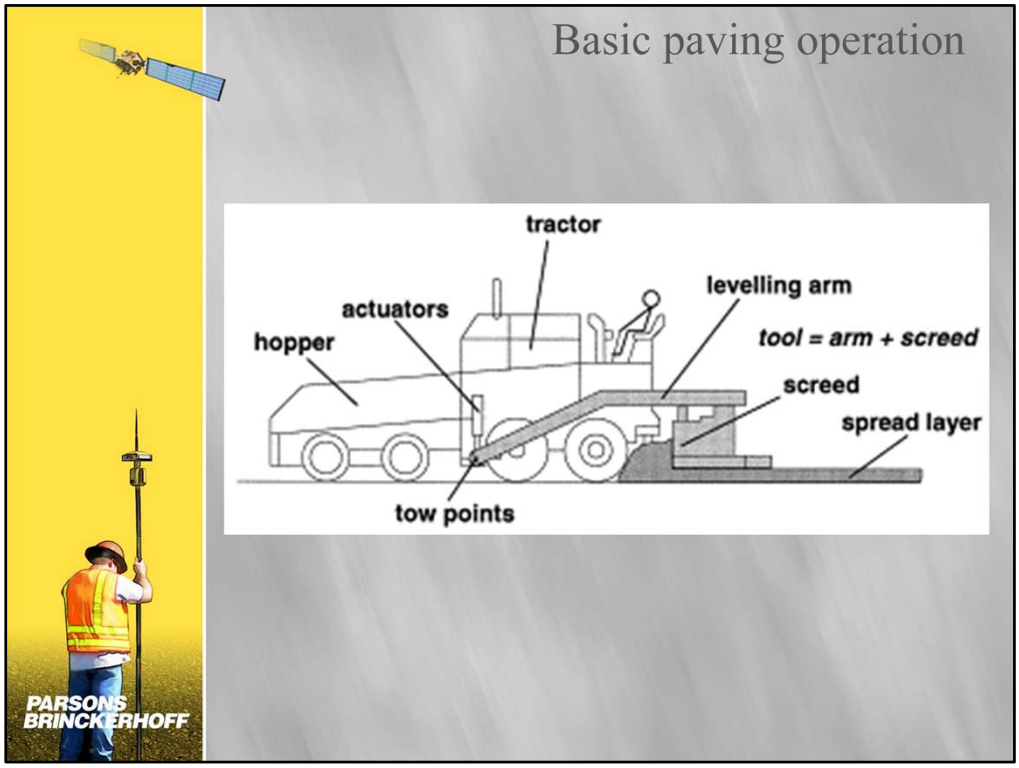


On April 10, 1936 the U.S. Patent Office issued to Barber Greene the initial patent number 2,138,828 "Machine for and process of laying roads" and on December 6, 1938 this patent was granted.

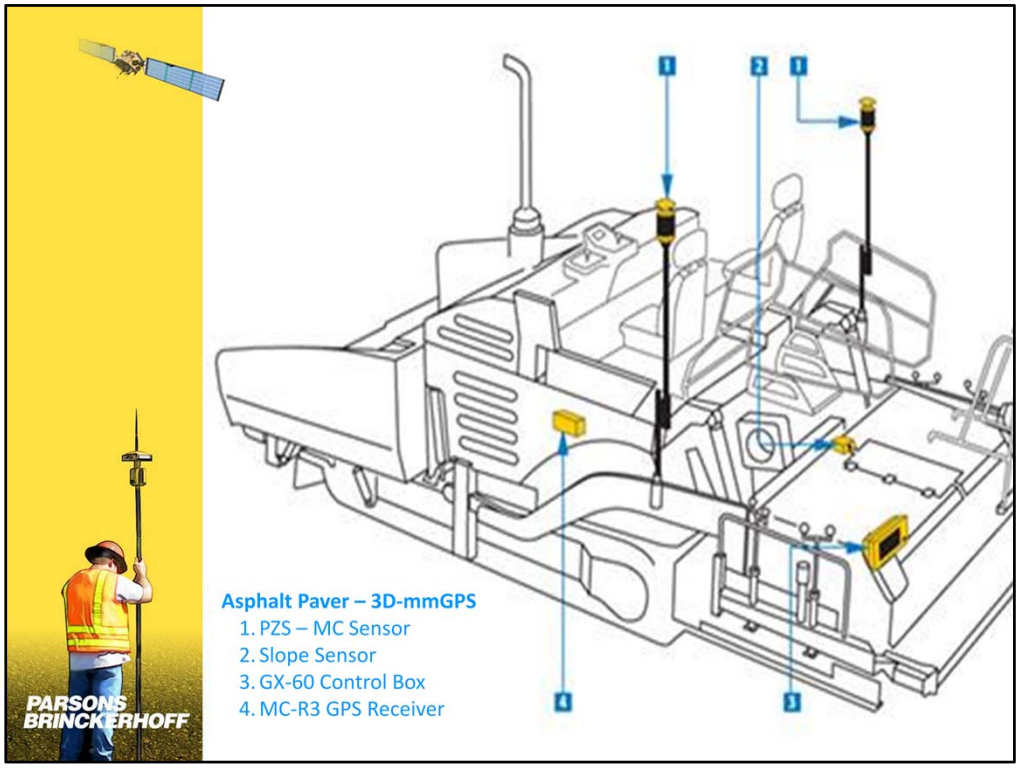


Because the concept was protected by the patent, only iterative changes were made from 1938 to the mid 1950s.
First Synchronized tampers (1945)
First paver on rubber crawlers (1958)
First hydraulic paver (1959)
First automatic screed control (1960)
First hydrostatic paver (1970)

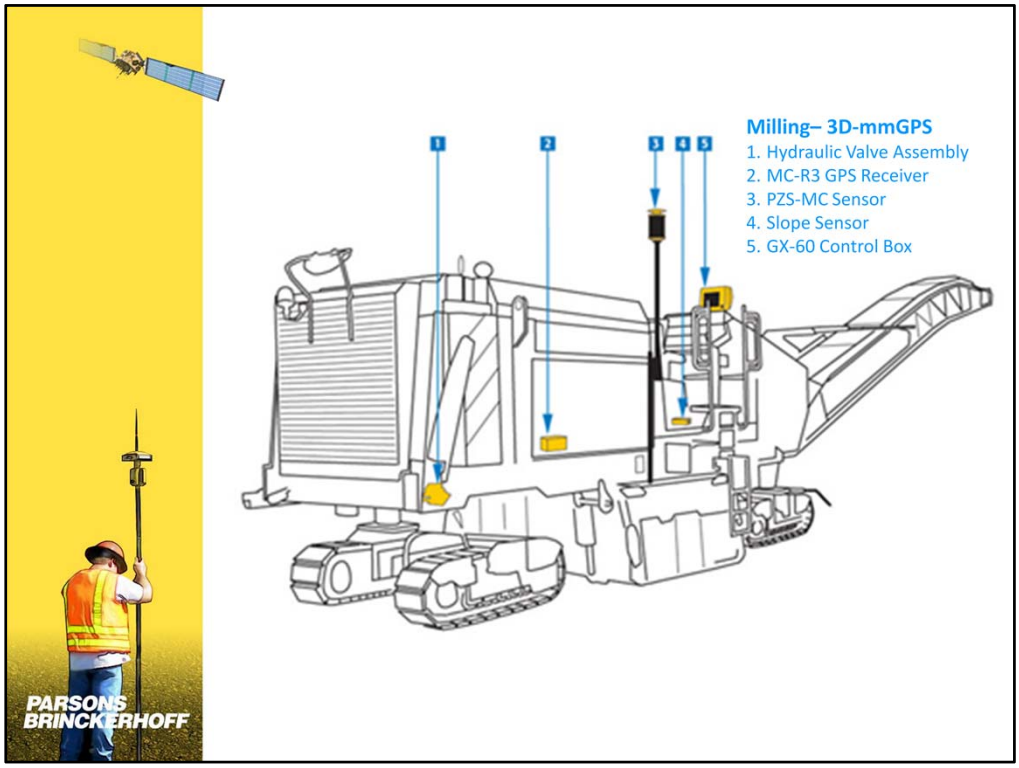
AMG paving operation
PARSONS
BRINCKERHOFF



1. What has not changed since the introduction of the first modern paver in the 30s, are the basic parts of the paver.
2. What we are talking about today is the elevation of the screed here. Up to this point, that elevation with some exceptions was based on a relative depth measured from some existing reference on the project whether that is existing pavement elevation or elevation along some provided baseline.
3. With Automated machine guidance we are breaking the link to the existing elevations. They are still important, but only in a transitory way in terms of maximum or minimum lane pavement thickness, or from an MOT and safety perspective.


PARSONS BRINCKERHOFF
Asphalt Paver – 3D-mmGPS
1. PZS – MC Sensor
2. Slope Sensor
3. GX-60 Control Box
4. MC-R3 GPS Receiver

AMG milling operation


Milling– 3D-mmGPS
1. Hydraulic Valve Assembly
2. MC-R3 GPS Receiver
3. PZS-MC Sensor
4. Slope Sensor
5. GX-60 Control Box
PARSONS BRINCKERHOFF

AMG Control box attached to milling machine

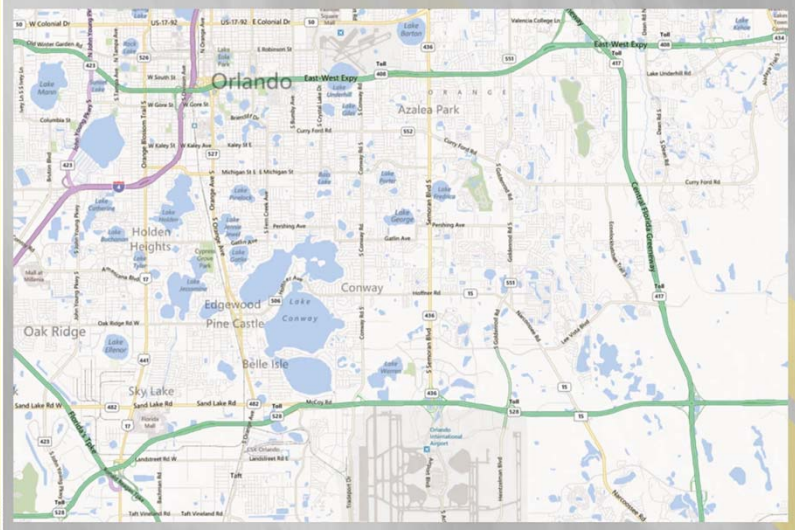
AMG milling operation

Topcon's PZL-1 with revolutionary Lazer Zone™ Technology operates similar to a standard rotating laser, transmitting a unique laser signal. Unlike a standard rotating laser that can only work in a flat plane, the PZL-1 transmits a revolutionary Lazer Zone™ signal that creates a measuring area 10 meters (33 feet) in height!

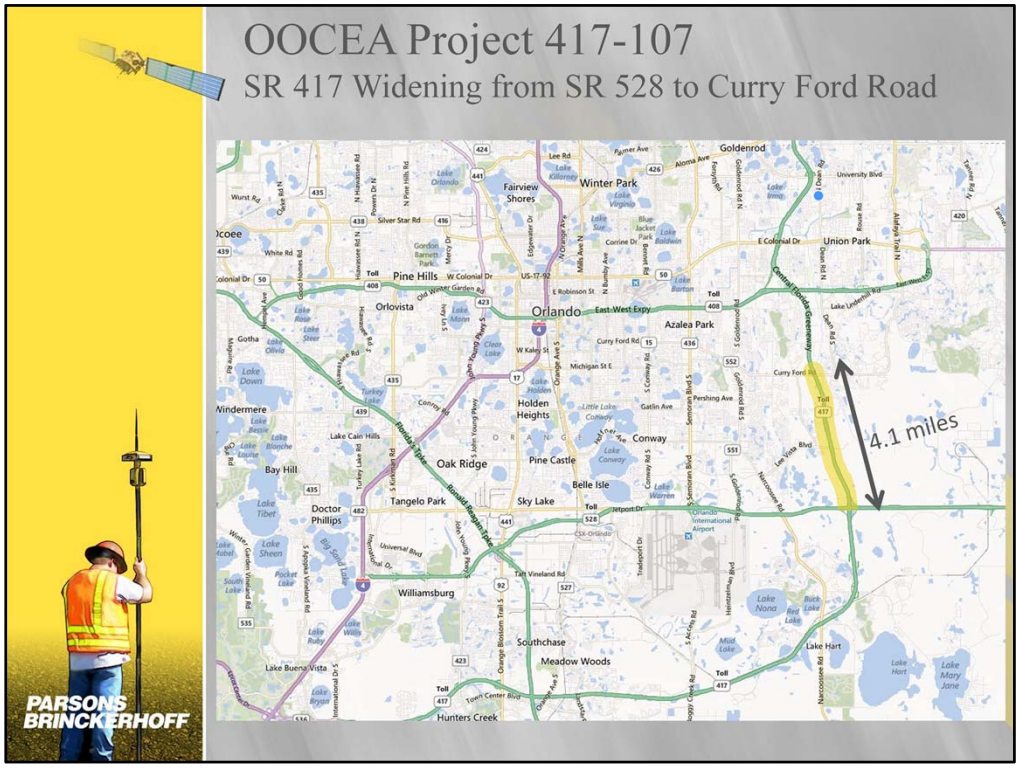
OOCEA Project 417-107
SR 417 Widening from SR 528 to Curry Ford Road
PARSONS BRINCKERHOFF

OOCEA Project 417-107

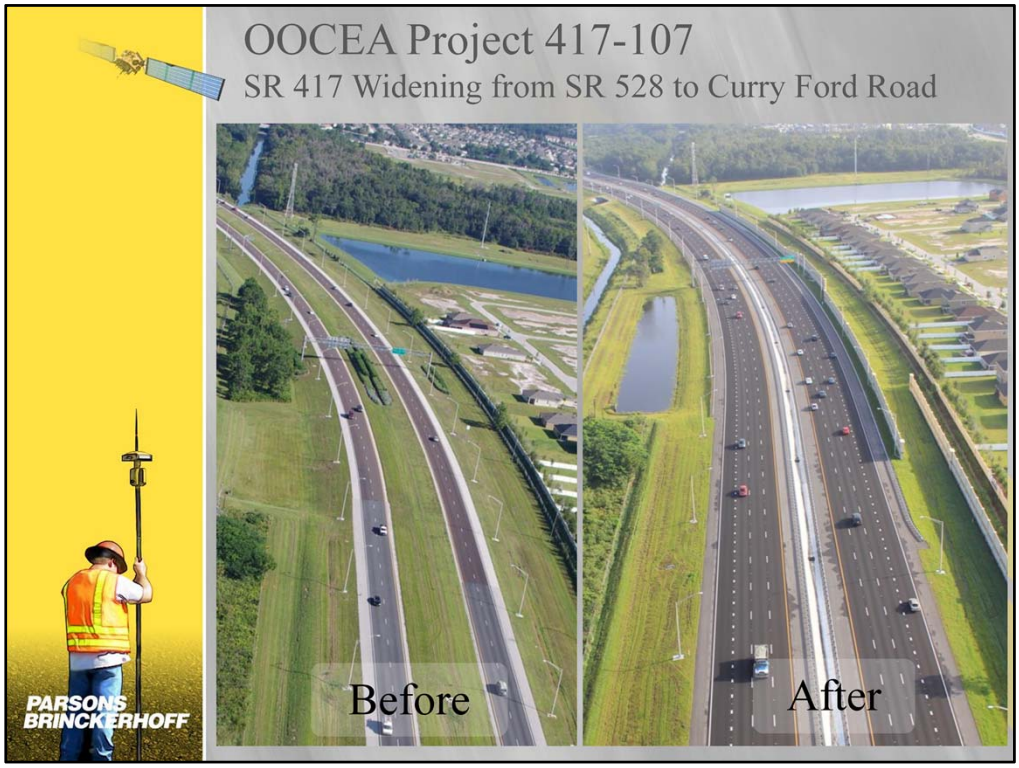
SR 417 Widening from SR 528 to Curry Ford Road



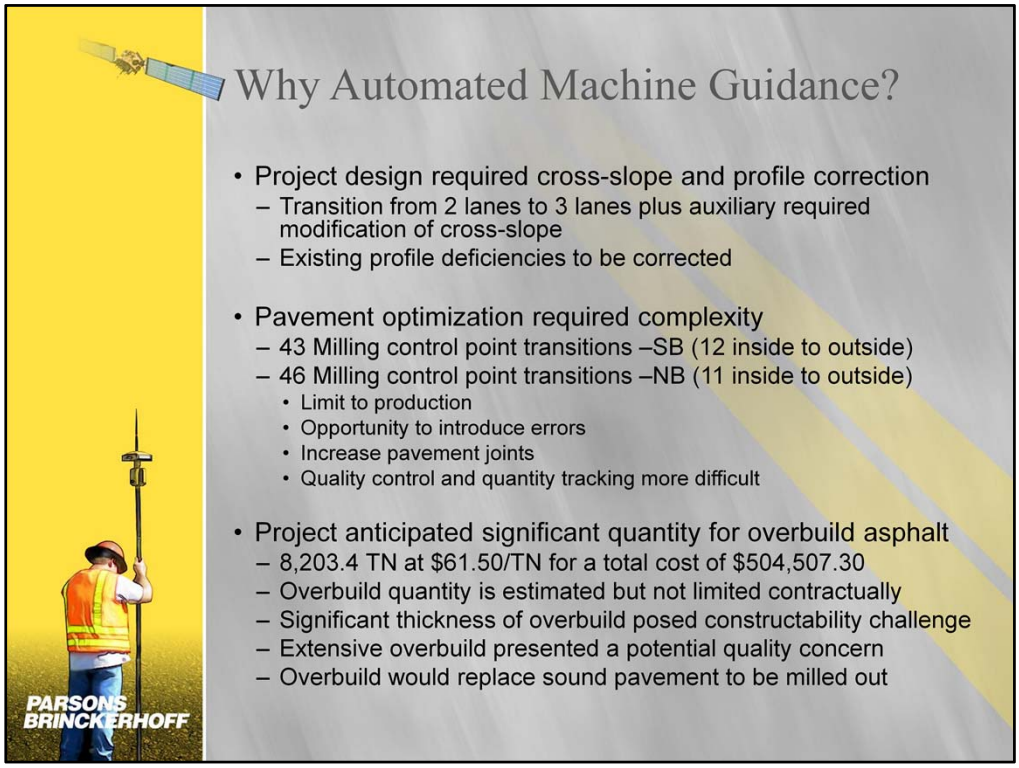
PARSONS BRINCKERHOFF



1. Thanks Roger.
2. So that brings us to us the SR 417 Widening project.
3. OOCEA project 417-107 was the widening from SR 528 to Curry Ford Road on the east side of the Orlando area only about 25 miles from here.
4. The project was four miles long and generally improved the section from 2 lanes in each direction to 3 through lanes and 1 full length auxiliary lane in each direction.



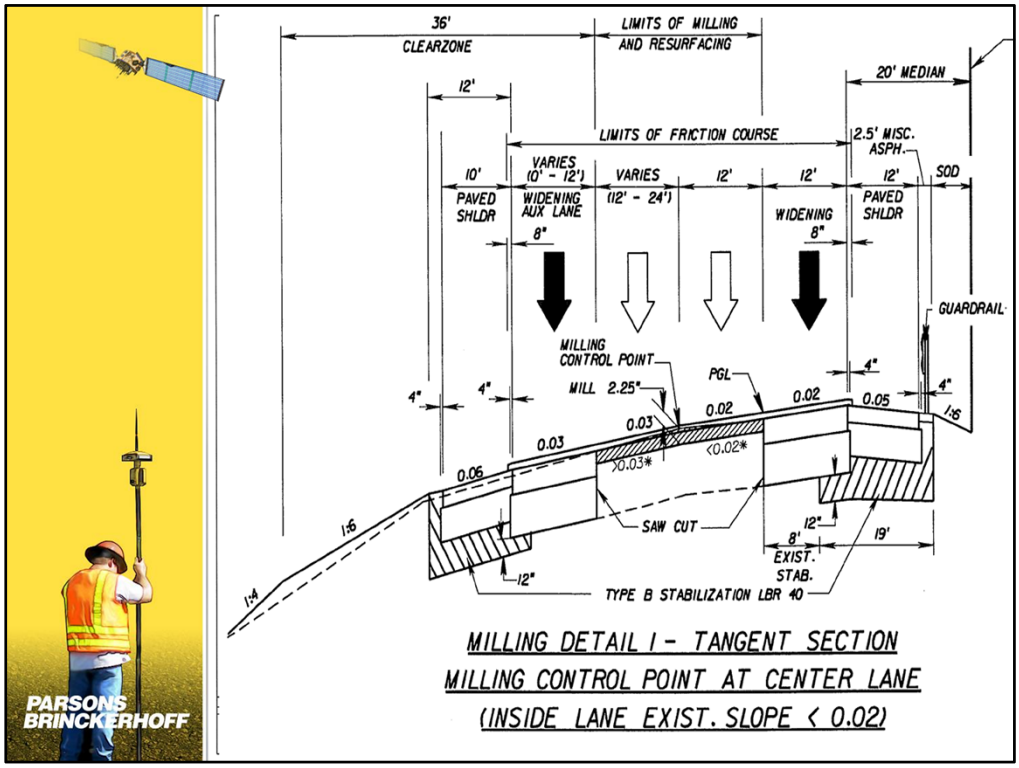
1. You get the idea from the comparison.
2. I'm not sure why I felt the need to label before and after, but obviously we started with 2 lanes and finished with 4 in most places



1. So, why did we choose to use this technology to control the milling and paving for this project?
2. To transform the two lanes that we had into the four lanes that we wanted, we needed to modify both the profile and the cross-slope.
3. To make a transformation like this across four miles of roadway with curve sections and several different typical sections required what became a complex set of milling details.

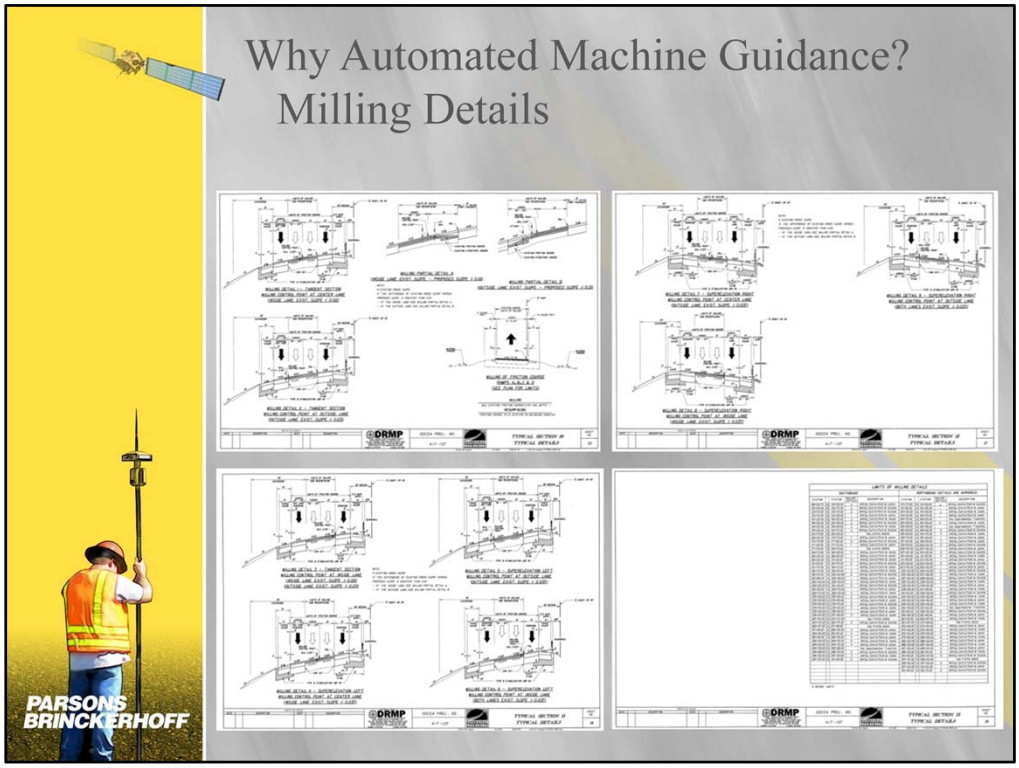
4. Now, I want to be clear here in a room full of designers. I am not criticizing the design. What he was trying to do was economize the asset for the Authority
5. The struggle is that that optimization creates inefficiencies for the construction.

6. Let me show you what I mean graphically so that it makes more sense.

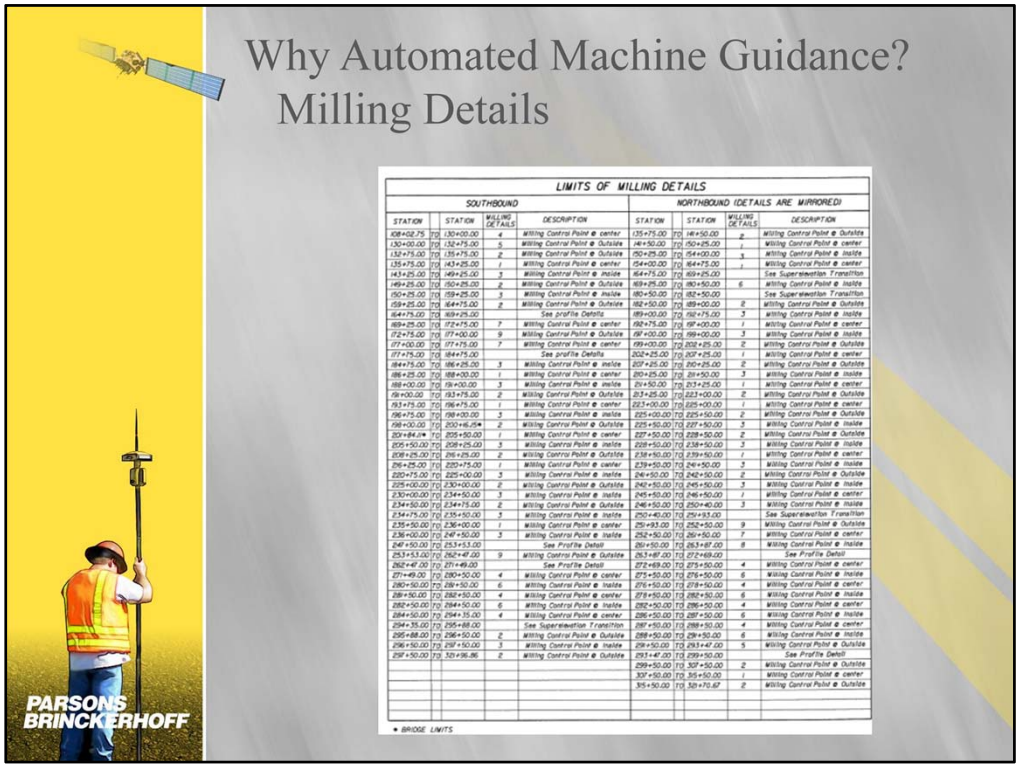


1. What you see here is one of the milling details.
2. Notice that our two lanes fit in between the two proposed lanes and will be the basis of the widening.
3. Each detail provides a milling control point.
4. You can see that this one on the center stripe

5. Now as I click you can see that this detail is one of several on the page



1. As I click again, you will see that this page is one of several that make up the milling plans.



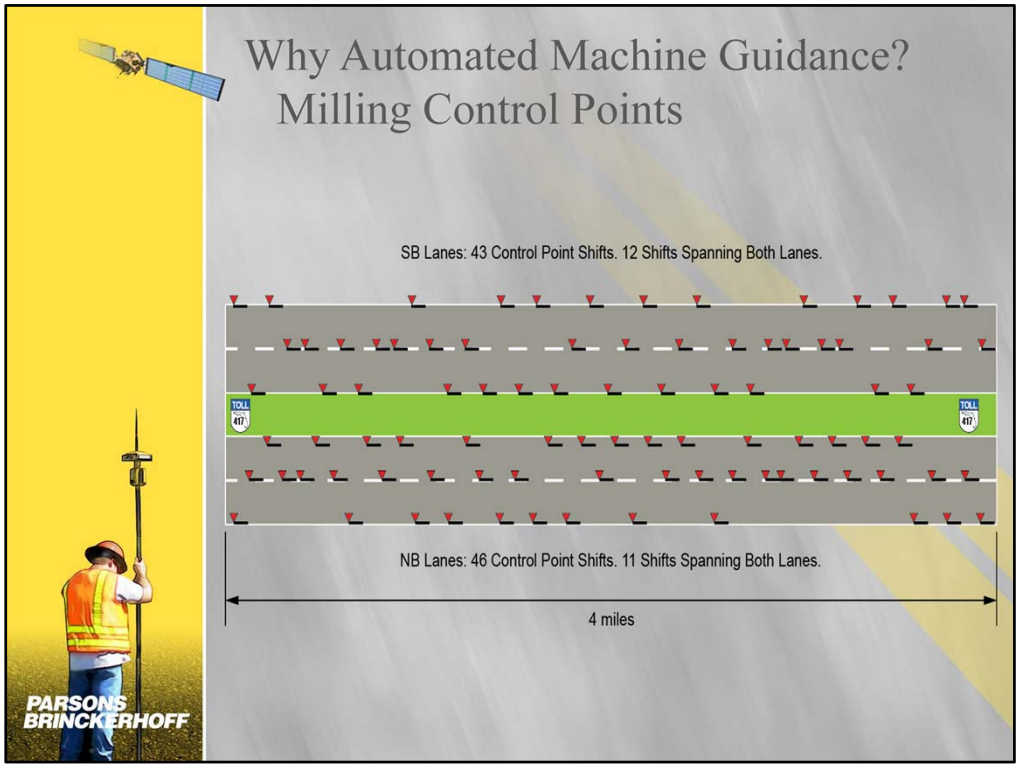
Why Automated Machine Guidance?
Milling Details

LIMITS OF MILLING DETAILS

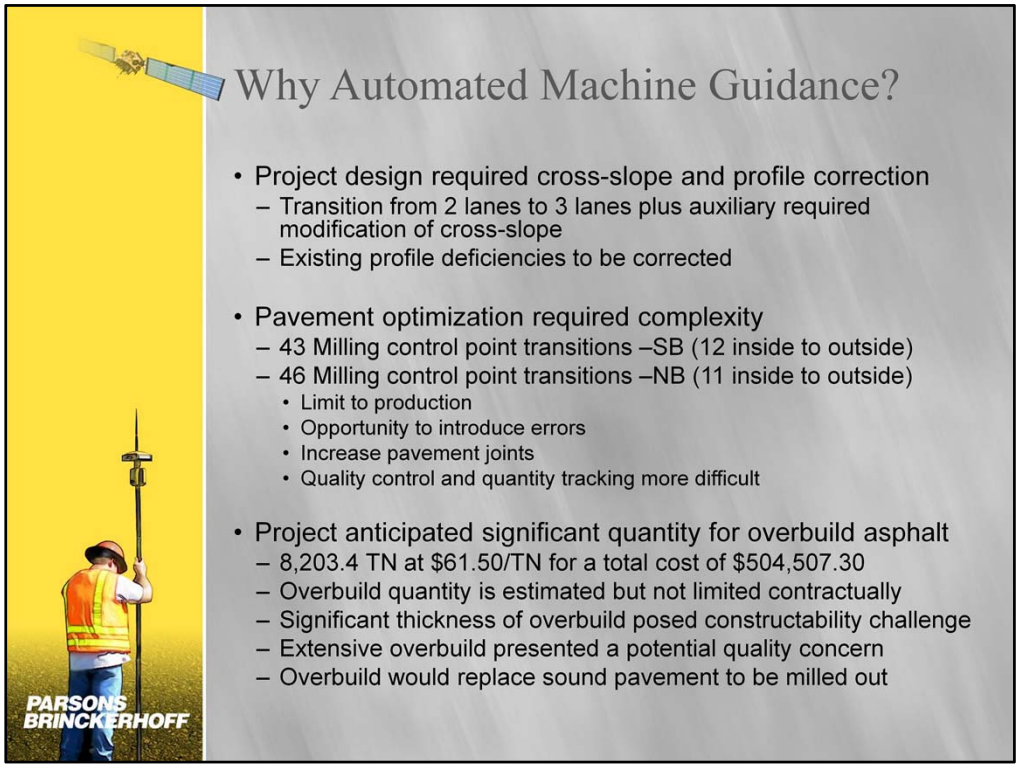
SOUTHBOUND				NORTHBOUND (DETAILS ARE MIRRORED)			
STATION	STATION	MILLING DETAILS	DESCRIPTION	STATION	STATION	MILLING DETAILS	DESCRIPTION
108+02.75 TO	130+00.00	4	Milling Control Point @ center	135+75.00 TO	141+50.00	2	Milling Control Point @ Outside
130+00.00 TO	132+75.00	5	Milling Control Point @ Outside	141+50.00 TO	150+25.00	1	Milling Control Point @ center
132+75.00 TO	135+75.00	2	Milling Control Point @ Outside	150+25.00 TO	154+00.00	5	Milling Control Point @ Inside
135+75.00 TO	143+25.00	1	Milling Control Point @ center	154+00.00 TO	164+75.00	1	Milling Control Point @ center
143+25.00 TO	149+25.00	3	Milling Control Point @ inside	164+75.00 TO	169+25.00		See Superelevation Transition
149+25.00 TO	150+25.00	2	Milling Control Point @ Outside	169+25.00 TO	180+50.00	6	Milling Control Point @ Inside
150+25.00 TO	159+25.00	3	Milling Control Point @ inside	180+50.00 TO	182+50.00		See Superelevation Transition
159+25.00 TO	164+75.00	2	Milling Control Point @ Outside	182+50.00 TO	189+00.00	8	Milling Control Point @ Outside
164+75.00 TO	169+25.00		See profile Details	189+00.00 TO	192+75.00	3	Milling Control Point @ inside
169+25.00 TO	172+75.00	7	Milling Control Point @ center	192+75.00 TO	197+00.00	1	Milling Control Point @ center
172+75.00 TO	177+00.00	9	Milling Control Point @ Outside	197+00.00 TO	199+00.00	3	Milling Control Point @ inside
177+00.00 TO	177+75.00	7	Milling Control Point @ center	199+00.00 TO	202+25.00	2	Milling Control Point @ Outside
177+75.00 TO	184+75.00		See profile Details	202+25.00 TO	207+25.00	1	Milling Control Point @ center
184+75.00 TO	186+25.00	3	Milling Control Point @ inside	207+25.00 TO	210+25.00	2	Milling Control Point @ Outside
186+25.00 TO	188+00.00	1	Milling Control Point @ center	210+25.00 TO	211+50.00	3	Milling Control Point @ inside
188+00.00 TO	191+00.00	3	Milling Control Point @ inside	211+50.00 TO	213+25.00	1	Milling Control Point @ center
191+00.00 TO	193+75.00	2	Milling Control Point @ Outside	213+25.00 TO	223+00.00	2	Milling Control Point @ Outside
193+75.00 TO	196+75.00	1	Milling Control Point @ center	223+00.00 TO	225+00.00	1	Milling Control Point @ center
196+75.00 TO	198+00.00	3	Milling Control Point @ inside	225+00.00 TO	225+50.00	2	Milling Control Point @ Outside
198+00.00 TO	200+16.25*	2	Milling Control Point @ Outside	225+50.00 TO	227+50.00	3	Milling Control Point @ inside
200+84.1* TO	205+50.00	1	Milling Control Point @ center	227+50.00 TO	228+50.00	2	Milling Control Point @ Outside
205+50.00 TO	208+25.00	3	Milling Control Point @ inside	228+50.00 TO	238+50.00	3	Milling Control Point @ inside
208+25.00 TO	216+25.00	2	Milling Control Point @ Outside	238+50.00 TO	239+50.00	1	Milling Control Point @ center
216+25.00 TO	220+75.00	1	Milling Control Point @ center	239+50.00 TO	241+50.00	3	Milling Control Point @ inside
220+75.00 TO	225+00.00	3	Milling Control Point @ inside	241+50.00 TO	242+50.00	2	Milling Control Point @ Outside
225+00.00 TO	230+00.00	2	Milling Control Point @ Outside	242+50.00 TO	245+50.00	3	Milling Control Point @ inside
230+00.00 TO	234+50.00	3	Milling Control Point @ inside	245+50.00 TO	246+50.00	1	Milling Control Point @ center
234+50.00 TO	234+75.00	2	Milling Control Point @ Outside	246+50.00 TO	250+40.00	3	Milling Control Point @ inside
234+75.00 TO	235+50.00	3	Milling Control Point @ inside	250+40.00 TO	251+93.00		See Superelevation Transition
235+50.00 TO	236+00.00	1	Milling Control Point @ center	251+93.00 TO	252+50.00	9	Milling Control Point @ Outside
236+00.00 TO	241+50.00	3	Milling Control Point @ inside	252+50.00 TO	261+50.00	7	Milling Control Point @ center
241+50.00 TO	253+53.00		See Profile Detail	261+50.00 TO	263+87.00	8	Milling Control Point @ inside
253+53.00 TO	262+47.00	9	Milling Control Point @ Outside	263+87.00 TO	272+69.00		See Profile Detail
262+47.00 TO	271+49.00		See Profile Detail	272+69.00 TO	273+50.00	4	Milling Control Point @ center
271+49.00 TO	280+50.00	4	Milling Control Point @ center	273+50.00 TO	276+50.00	6	Milling Control Point @ inside
280+50.00 TO	281+50.00	6	Milling Control Point @ inside	276+50.00 TO	278+50.00	4	Milling Control Point @ center
281+50.00 TO	282+50.00	4	Milling Control Point @ center	278+50.00 TO	282+50.00	6	Milling Control Point @ inside
282+50.00 TO	284+50.00	6	Milling Control Point @ inside	282+50.00 TO	286+50.00	4	Milling Control Point @ center
284+50.00 TO	294+35.00	4	Milling Control Point @ center	286+50.00 TO	287+50.00	6	Milling Control Point @ inside
294+35.00 TO	295+88.00		See Superelevation Transition	287+50.00 TO	288+50.00	4	Milling Control Point @ center
295+88.00 TO	296+50.00	2	Milling Control Point @ Outside	288+50.00 TO	291+50.00	6	Milling Control Point @ inside
296+50.00 TO	297+50.00	3	Milling Control Point @ inside	291+50.00 TO	293+47.00	5	Milling Control Point @ Outside
297+50.00 TO	301+96.86	2	Milling Control Point @ Outside	293+47.00 TO	299+50.00		See Profile Detail
				299+50.00 TO	301+50.00	2	Milling Control Point @ Outside
				301+50.00 TO	315+50.00	1	Milling Control Point @ center
				315+50.00 TO	321+70.67	2	Milling Control Point @ Outside

* BRIDGE LIMITS

1. The last sheet has a table that is the decoder ring for the details.
2. This table shows which detail to use at each station

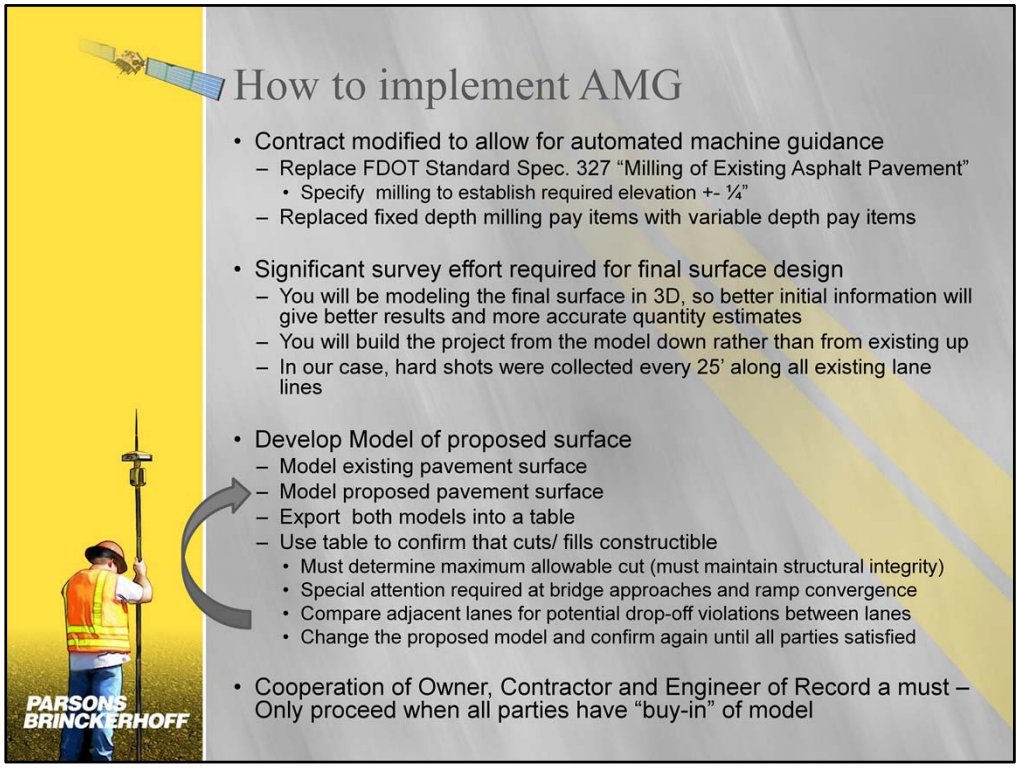


1. Now, before the job began, we color coded the project plans
2. This graphic gives an outline view of what we discovered.
3. The milling control point transitions were going to effect the phasing of the paving operations
4. The most efficient milling and paving operation will be done in long stretches as a circuit around and around the project.



1. In all there were 43 milling control point transitions SB and 46 NB
2. The real challenge are the transition from the outside lane line to the inside lane line because there is no way to maintain a continuous milling and paving operation through those transitions.
3. This will limit nightly production, introduce opportunities for errors, increase the number of joints and make tracking and payment more difficult.

4. In addition, the design was based on standard construction practice of fixed depth milling combined with the use of overbuild asphalt to accomplish the profile and cross-slope corrections
5. Based on this concept the anticipated overbuild asphalt quantity was 8200TN



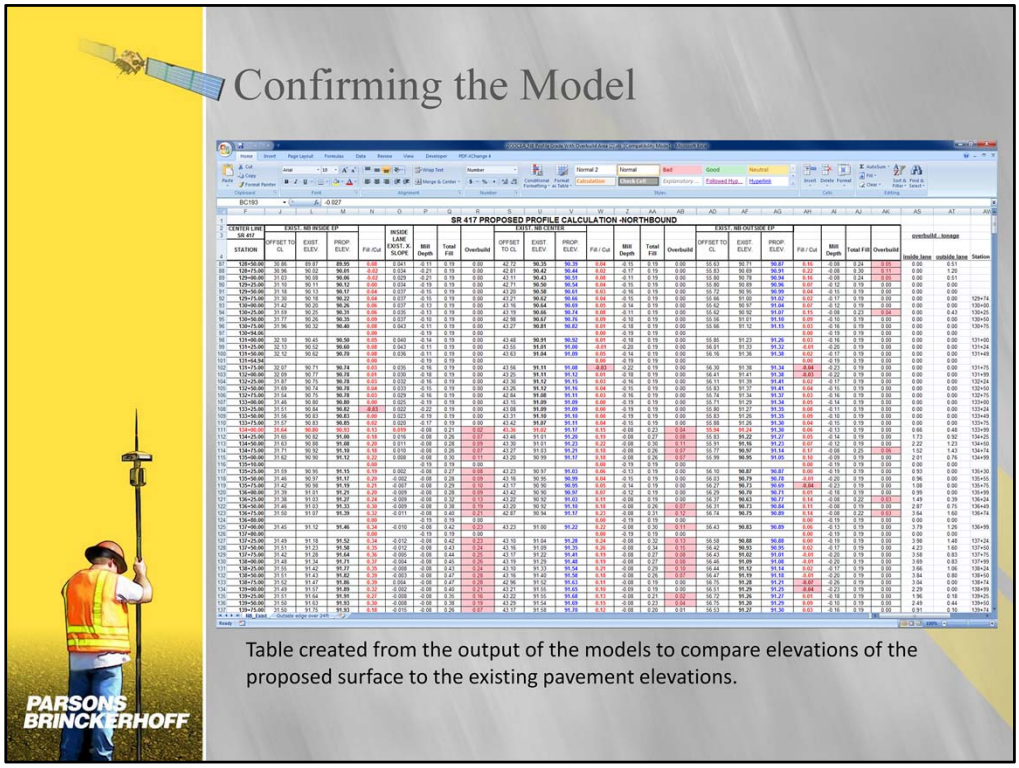
1. Based on the potential savings, the Authority determined that the automated machine guidance would be beneficial for the project.
2. The Contractor agreed
3. Now What?

4. We had to modify our contract. The primary changes were that we replace the standard spec section 327 with a modified version which put the focus more on achieving certain elevation than on certain depth.
5. We replaced our fixed depth milling pay items with variable depth milling items
6. We agreed that the milling and paving would be set to specific grades that would be developed cooperatively with the model developed by the Contractor and submitted for approval like a shop drawing.

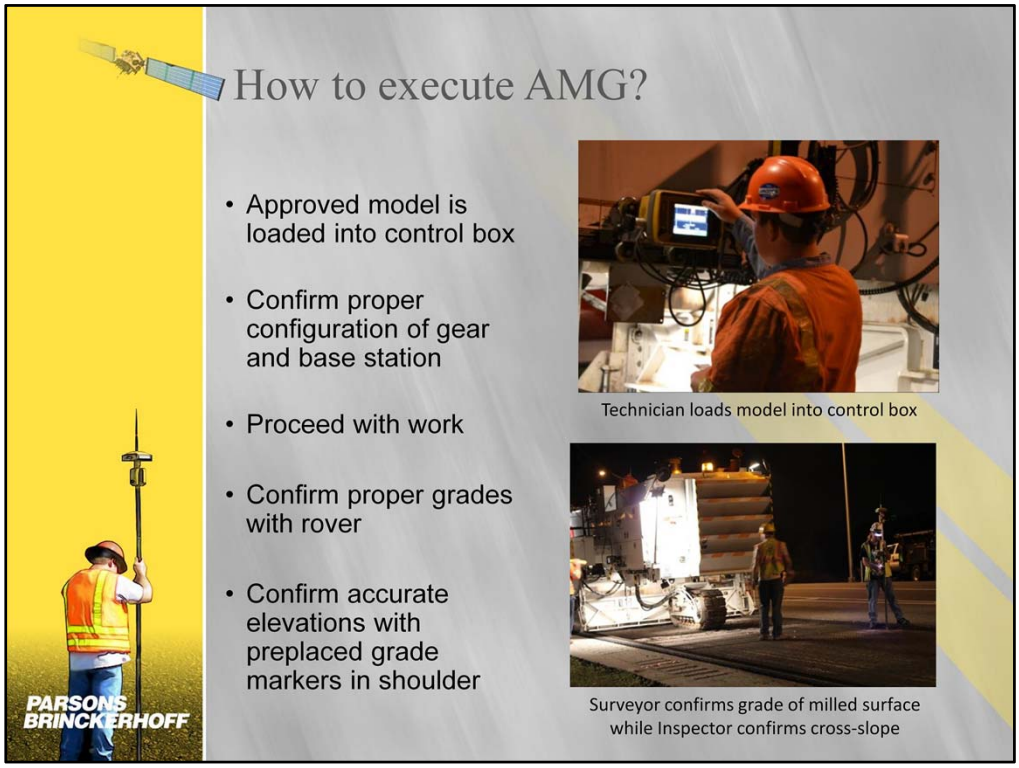
7. Keep in mind, you are building the pavement from the model now rather than from existing. We needed to know what the existing surface elevation were to a greater degree of accuracy that what was needed for the original design. For our project, the elevation were collected at 25' increments along all the lane lines.

8. Finally, you will need to develop a model of the proposed surface. This is an iterative process that will go through several revision before it is ready for use.
9. The process is that you will model the existing pavement, then model the proposed pavement. We then exported the models into a table to compare the cuts and fills.
10. If any issues are identified, the models are adjusted and the process goes again.

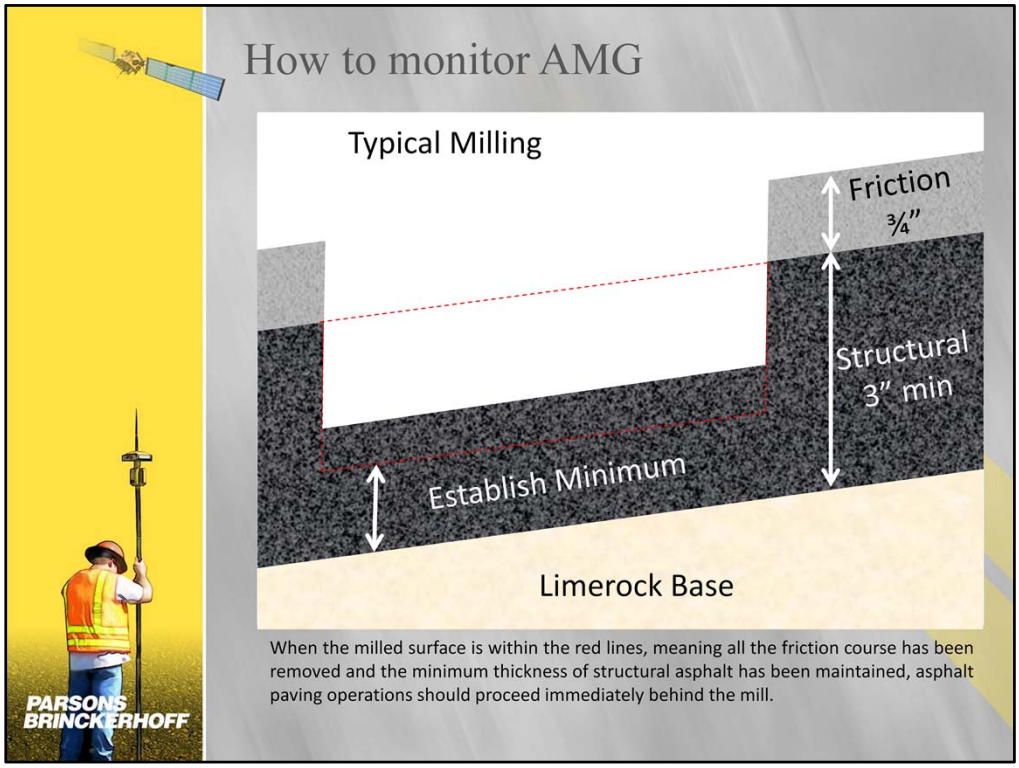
11. This is a good place to give credit where it is due. Hubbard was a great partner in this process. Tony Rogers, Hubbard's field engineer, rose to the occasion and championed this project. He worked tirelessly to make sure that the models were vetted and that the paving operation had the support to make this work.



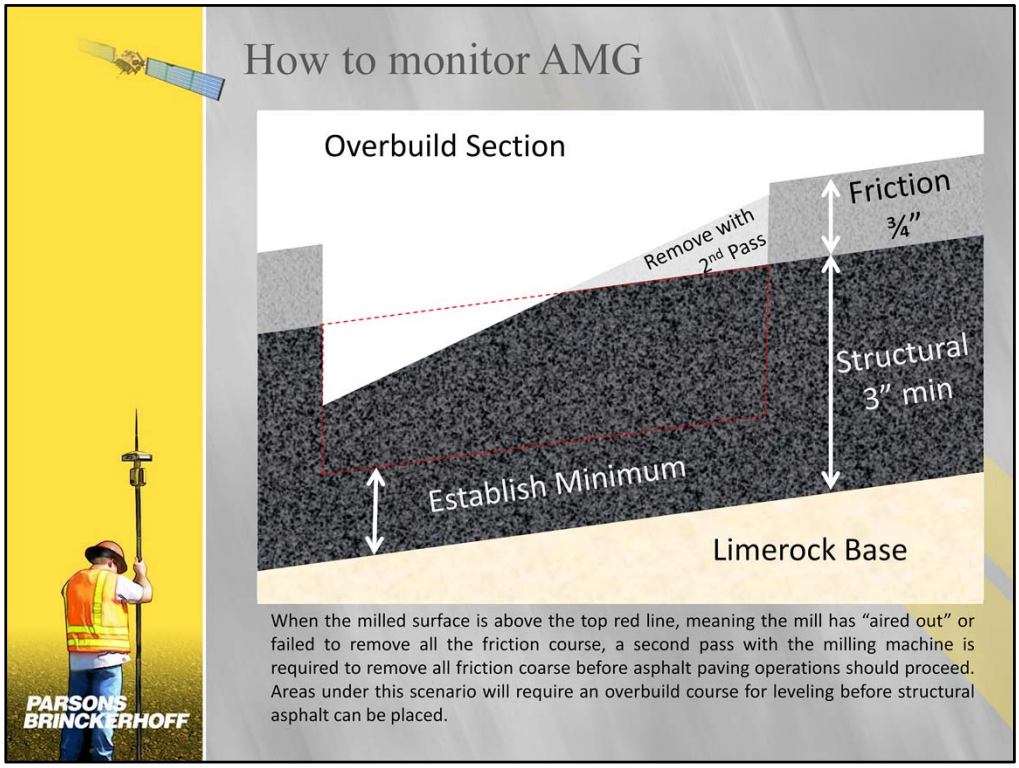
1. Here you can see a shot of the table created by comparing the output of the models. This is how the project model would be scrutinized 25’ at a time, lane by lane.



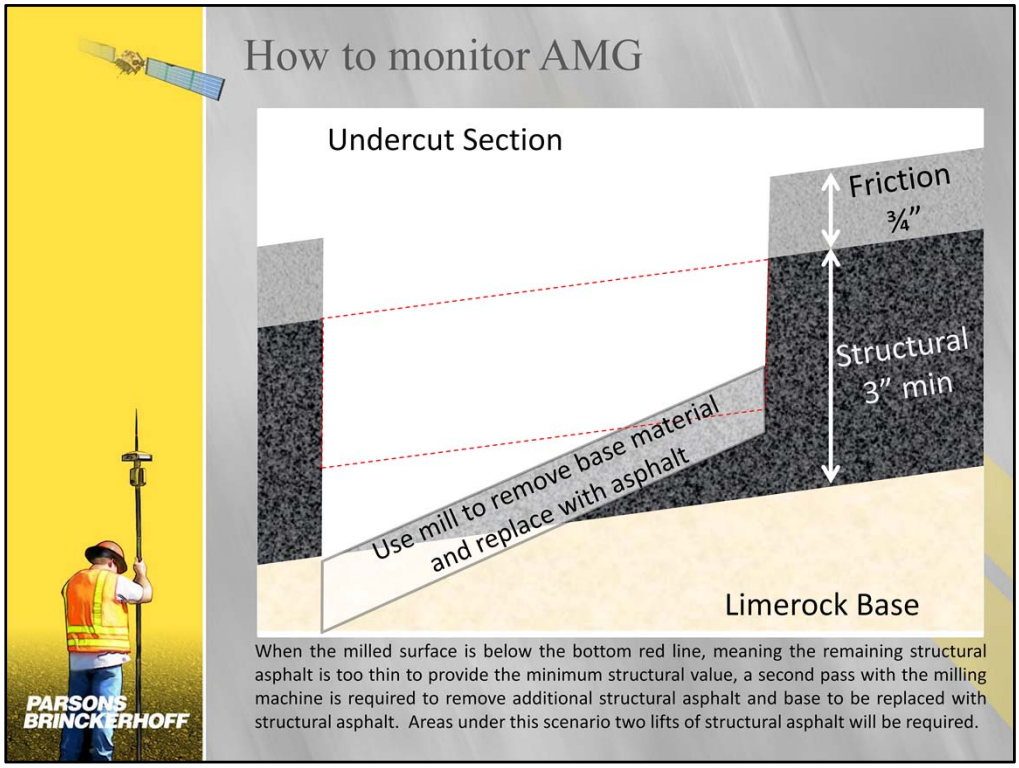
1. Now you are finished with the hard part. The rocket science is all done by the folks who manipulate and create the models.
2. The model is loaded onto a thumb drive and uploaded into the control box.
3. The secondary receiving stations then must be set up and calibrated.
4. Then start working
5. The system that we used allows for addition of a rover, otherwise you would need to set up a secondary system to confirm the proper elevations are achieved.
6. To give a little extra confidence, Hubbard place some grade markers at intervals along the shoulder to confirm surveyed elevations.



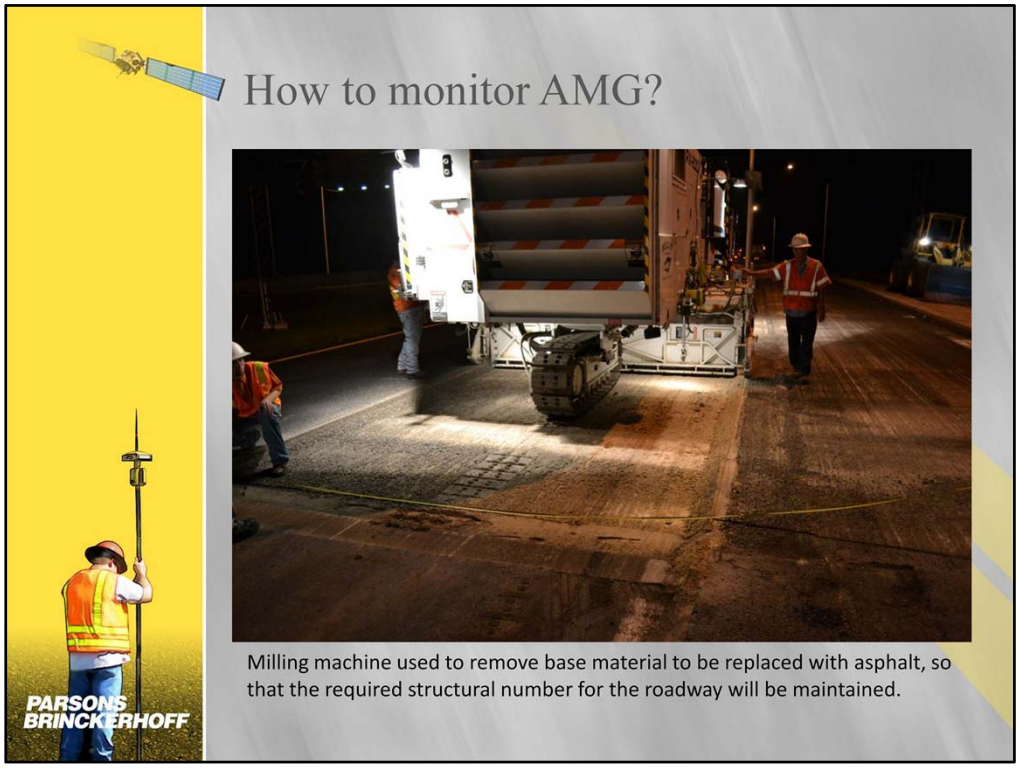
1. AS the milling machine moves forward, the guidance system will adjust the depth of the mill so that the milled surface is built to the elevations prescribed in the model.
2. The depth is variable. The Contractor and the inspectors were provided the tables with the elevations so that the surface could be confirmed during construction.3
3. So long as the mill operates within the red box above, milling and paving operations proceed per plan with variable depth milling and fixed depth paving
4. However, this wont always be the case, so must prepare the procedure ahead of time to be ready to address other scenarios when they arise.



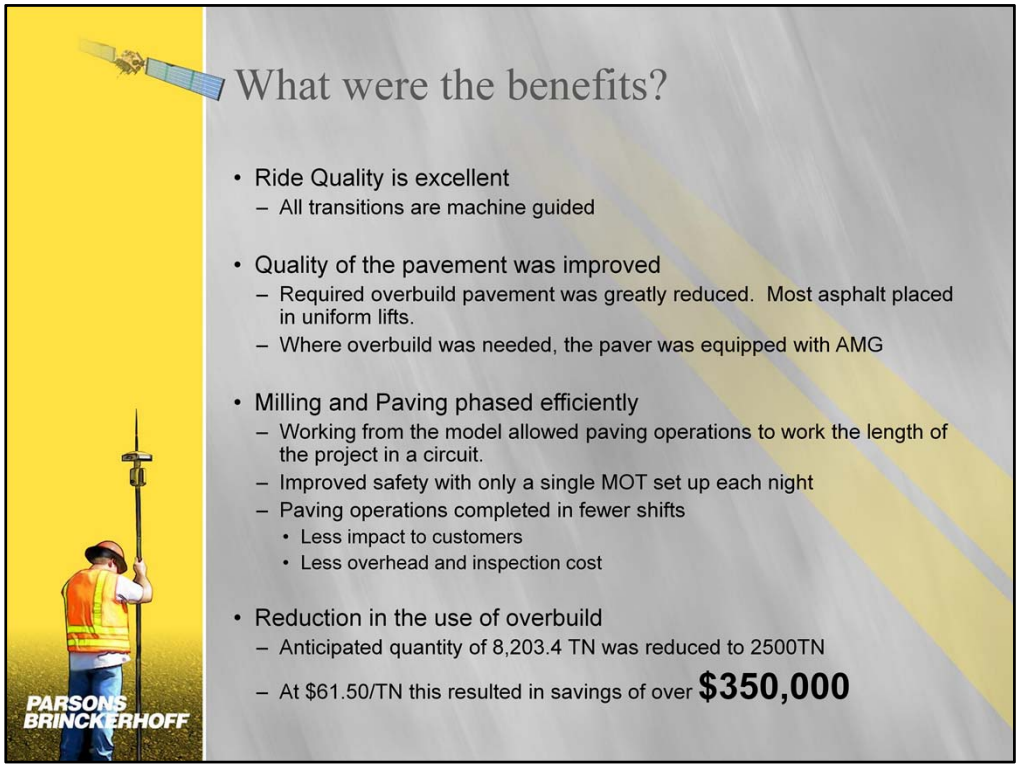
1. The more common scenario was that the mill would air out.
2. This happened in all of the places where we needed overbuild to achieve to the elevations we wanted.
3. The planned process was that, in these locations, the milling machine would make a second pass to remove all the friction course
4. Then the paver would make a first pass to place the overbuild asphalt
5. At that point to the structural asphalt would be place in a consistent thickness lift in a second pass.



1. A less common scenario, we encountered a few times was for the mill to cut too much of the structural asphalt out.
2. Remember, the mill only knows an elevation and doesn't care what it takes out.
3. When the milling depth went beyond 2 ½" , we would begin to core the remaining asphalt to confirm the depth.
4. In many cases, we still had all the depth that we needed and proceed with paving.
5. However, on several occasions, we had to back up the milling machine and undercut another 1 ½" to make sure we achieved the needed structural number.
6. This is a simple process, but it is important to ready with direction for the field team.
7. Otherwise you'll get this call at 2:30am.



1. Here is a picture of the undercut scenario I just described.
2. These are the actual cores from that night. If I remember, the additional 1 ½” of asphalt was only placed for about 400’



1. In conclusion. What were the benefits of using this technology on the project?
2. Ride Quality was improved dramatically from the existing.
3. The quality of the pavement was improved. Where overbuild was needed, the overbuild was built with gps control so that the structural course could be placed with consistent lift thicknesses.
4. The paving train was able to move through the project in a circuit. This saved time and reduced the number of lane closures required.
5. For the bottom line, over 5,000TN of overbuild was eliminated for a project savings of $350,000

Here is the finished product.

1. Does anyone have any questions for me or Roger?
2. My friends from Hubbard are here too if you can coax them up here.