Arlington RAPID

Autonomy Insights Report

March 2021

March 17th, 2021 - April 30th, 2021

Overall Service Area

Figure 1: Autonomy heatmap for the service area

In the above image, autonomy utilization is plotted along the route using blue to red gradient (blue = low autonomy, red = high autonomy). Autonomy utilization is approximately 70% for the time period March 17th - April 30th, 2021. This is on target for a route with this level of complexity. Since the Arlington route is an on demand service area, there are more required manual areas due to a higher number of unprotected turns compared to a typical circulator route.

The total number of interventions for this time period amount to 8,291. Normalizing by autonomous distance driven results in 0.38km between an intervention. This count includes the pre-planned manual only zones where the FA must take over and scenarios where the FA took over to navigate around construction or to improve rider

comfort. In the future, we plan to implement tracking in order to separate planned vs unplanned interventions.

Below are some learnings from reviewing specific logs and areas over the past month.

Areas of Focus

Traffic Light Detection

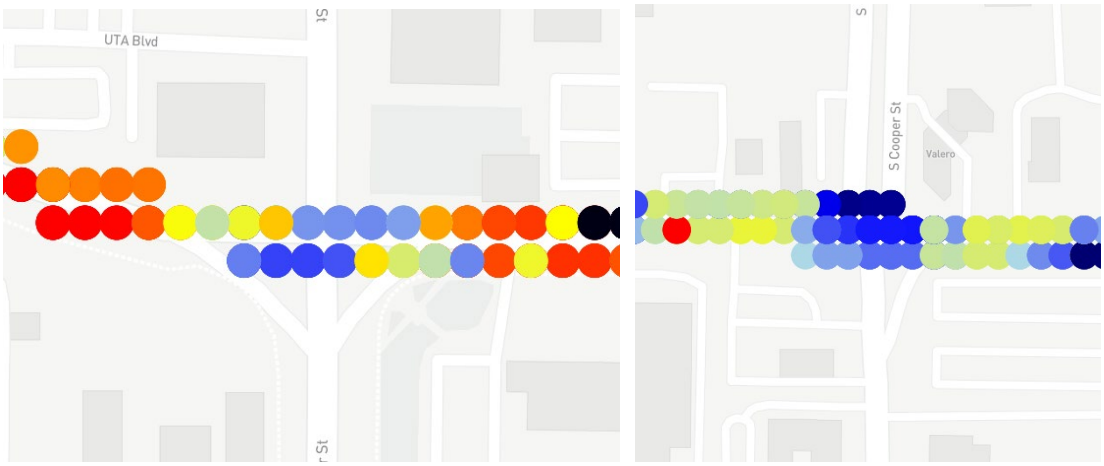

Figure 2: Intersections of UTA and Cooper (Left) Abram and Cooper (Right)

Due to constraints with our new Lexus platform, traffic light detection has been more challenging compared to the GEM. This results in some traffic lights failing to be detected, at which point the autonomy system assumes it is a red light. The Fleet Attendant will have to take over, which can be seen through decreased autonomy utilization near traffic controlled intersections.

This performance degradation has been communicated to the autonomy development team, and a new feature has been created that will practically

eliminate the failed readings we are seeing on the Lexus. This feature will be rolled out to the fleet in our next software release.

Mitchell Street & Cooper

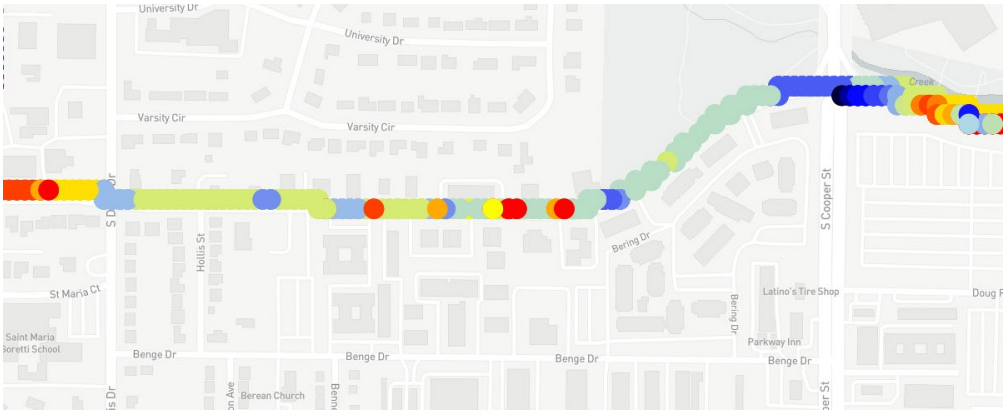

Figure 3: Mitchell Street west of Cooper

Mitchell has relatively low autonomy utilization compared to other areas of the route. This particular section of Mitchell is a challenge for our localization system, as there are many sections characterized by dense foliage and low clear vertical structure. This reduced localization accuracy results in the vehicle driving slightly off center in the lane at which point the Fleet Attendant will take over. The narrow lanes on

Mitchell street combined with the moderate localization explains the lower autonomy utilization in this relatively low complexity area.

Center Street Construction

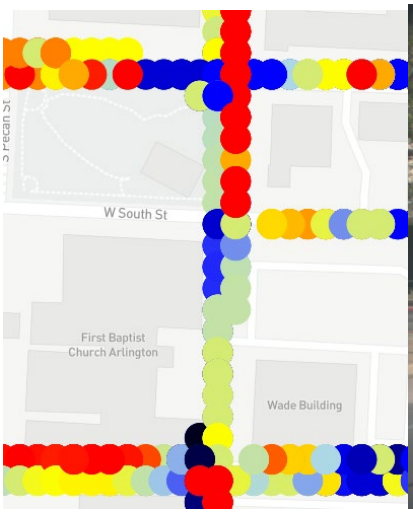

Figure 4: Center Street constructions

Sections of Center street (pictured above) and Abram have seen construction during the month of April. Even if the construction does not change the path the vehicle must take, it can still affect autonomy performance. This is primarily due to retroreflective cones and signs placed close the edge of the lane. Retroreflective objects appear to “bloom” from the Lidar’s perspective. This means that the object can appear larger than it really is, thus the vehicle may not think that it can get around the object while staying in the lane. This Lidar bloom can also be sporadic, causing uncomfortable slowdowns as the vehicle passes. For this reason FAs are trained to take over in these areas to prioritize safety and rider comfort.

Mesquite end of Shift

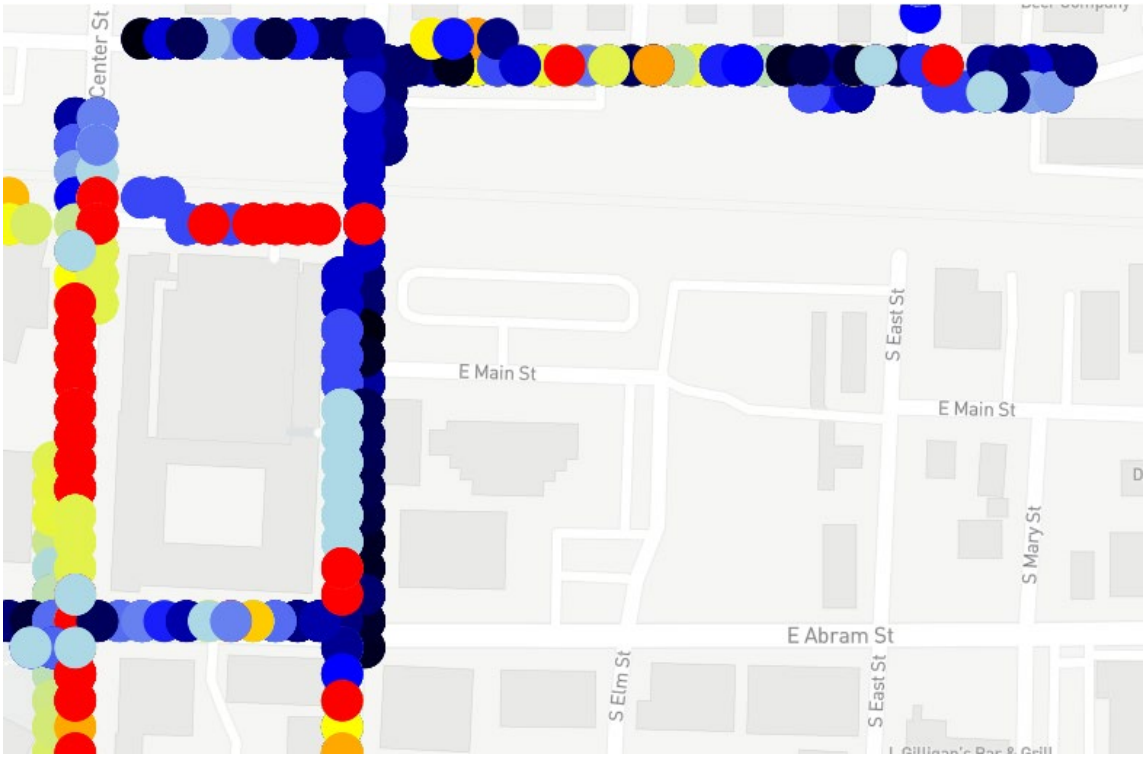

Figure 5: Center Street constructions

Autonomy utilization is very low along Mesquite from Abram up to and along Front street. This occurs as it is the most common route the FAs follow to get back to our office on Front street at the end of their shift or when taking a break. Since the vehicle can only be "told" to hover between its terminals or drive to a pickup/dropoff, the FAs must take over and manually drive to the office, thus reducing autonomy utilization in this area.

Software Updates

There have been no major autonomy software updates since launch on March 17th. Minor changes to the route network based on FA feedback have been tested and rolled out to the fleet. This has included minor adjustments to lane placements for the vehicle to ride more comfortably in the lane and to avoid a manhole covers around the student center stop.

A new stop was added on Front street in the eastbound direction. This way, the vehicle approaching from the west can pick up their passenger before turning around to head westbound once again.

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Arlington RAPID

Autonomy Insights Report

May 2021

Autonomy Heatmap Overview:

Figure 1: Autonomy Utilization Heatmap for April (Left) and May (Right) 2021

Above are the autonomy heatmaps for April and May. Areas in blue denote areas of low autonomy utilization, while areas marked in red denote areas of high autonomy utilization. Autonomy utilization was steady through the month of May at 74%. As will be discussed below, construction along UTA Boulevard and around Greek Row negatively affected autonomy utilization.

For this month, we have started to categorize interventions based on FA (Fleet Attendant) feedback of top causes for interventions.

- Currently, the FAs shift the vehicle into park when picking up passengers at a stop, which causes the vehicle to switch to Manual mode.
- FAs are prompted to take over in predetermined manual zones where the May vehicle needs to perform an unprotected turn. Due to the Arlington route being on demand, these zones are very common
- Construction particularly on UTA often requires the FAs to take over and follow an alternate route

Currently, we are able to automatically filter for interventions occurring due to manual-only zones and switching to park at a stop. We are looking at adding additional insights in the coming months.

Total interventions	= 11,261	100%
Interventions at Passenger Stop	= 2,395	21.3%
Interventions at Unprotected Turn	= 1,040	9.2%

Areas of Focus

Below are specific learnings from discussions with FAs, log review, and in-person testing.

Tree Growth on Greek Row

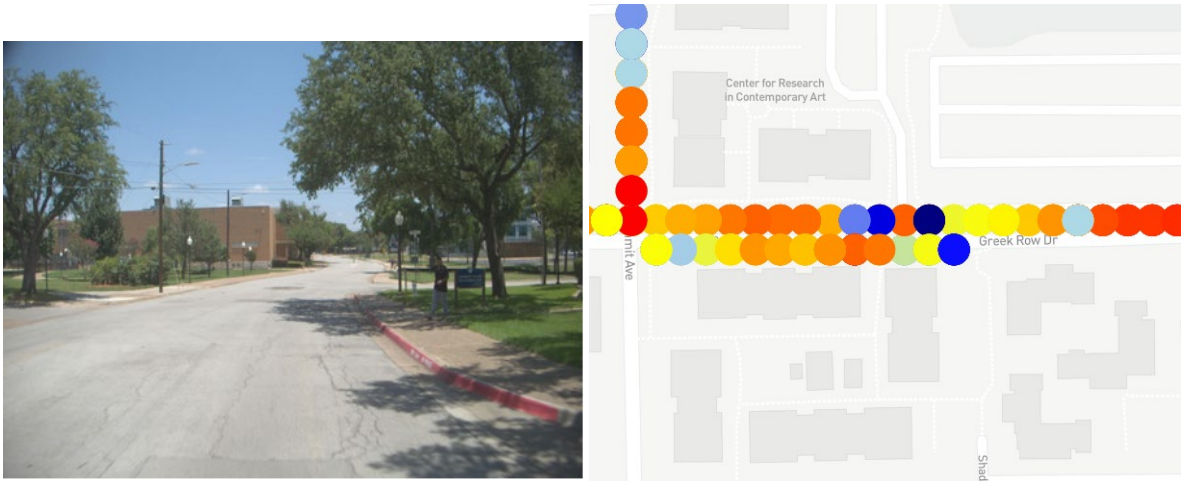

Figure 2: Overhanging Trees (Left) and Autonomy heatmap on Greek Row (Right)

Tree growth particularly on Greek Row has affected autonomy performance toward the end of May. Autonomy utilization is relatively high as seen in the above heatmap, however, FAs have reported the vehicle slowing down while going through this area. The autonomy system is able to go under static objects such as trees or bridges if the vehicle determines there is enough clearance based on its height and a set buffer distance. At a distance, there is additional uncertainty in the exact clearance

between the road and the trees, so the vehicle ops to slow down until it is confident there will be enough space. We are working with UTA to trim these trees to improve autonomy performance.

Construction on UTA & Summit

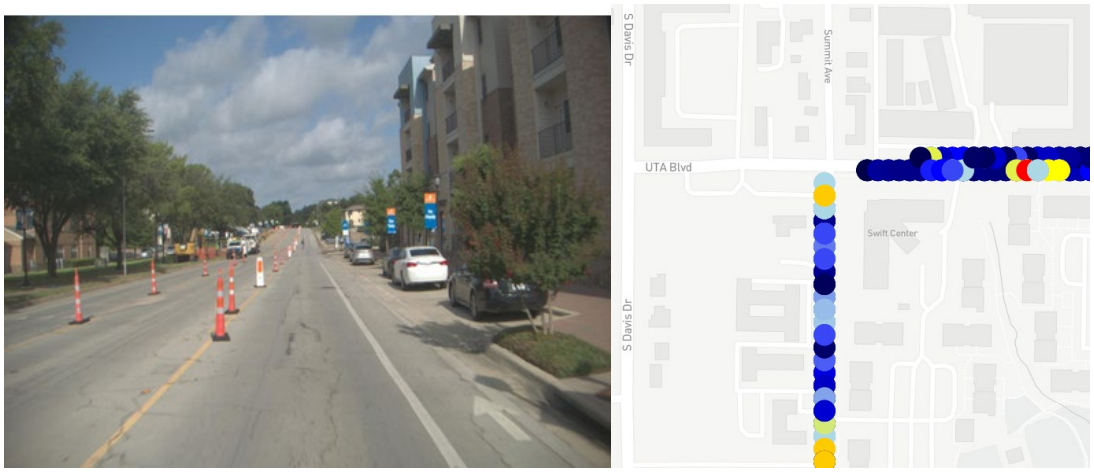

Figure 3: Construction on UTA

Construction on UTA has reduced autonomy utilization along UTA and Summit. The intersection of Summit and UTA was closed to traffic for most of May, thus requiring

the FAs to manually divert when dispatched to stops along the north end of Summit. In addition, the cones shown in the image above, depending on their placement, cause the vehicle to slow down. Prioritizing rider comfort, the FAs will often take over in these areas to ensure a smoother ride.

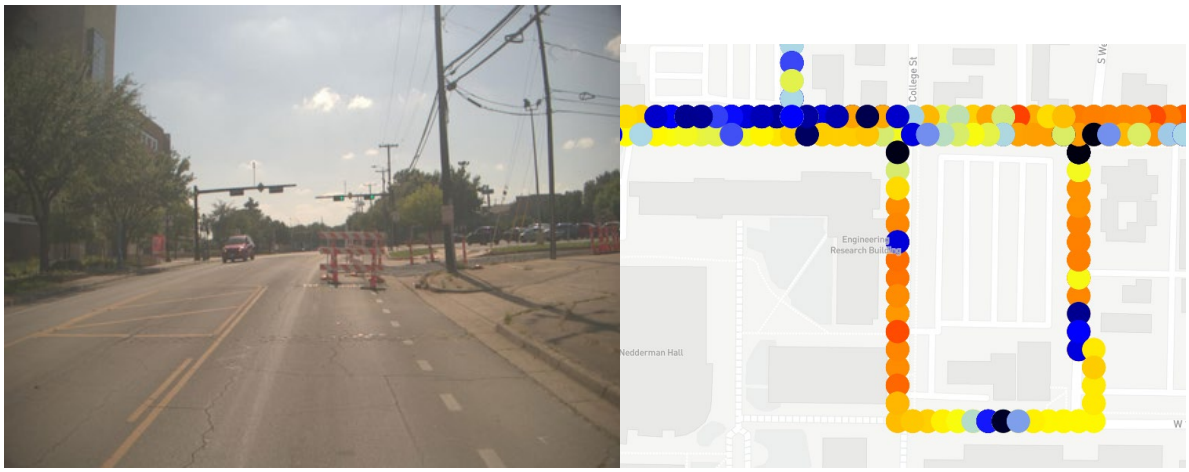

Figure 4: Construction at UTA and Lampe

Additional construction blocking the westbound lane of UTA at Lampe also requires the FAs to take over. Currently, takeovers due to construction cannot be filtered and categorized from our total intervention numbers. This categorization is something we are looking to work on in the coming months.

Mesquite end of Shift

Figure 5:

As mentioned in the previous report, the FAs must manually drive to the office (located at the top right corner of the above image) as the vehicle is dispatched by default to circulate between two stops while awaiting a ride. The fix for this is to dispatch the vehicle to the office on Front street when an FA's Via shift is complete. This feature will be tested and implemented in June.

Software Updates

Improvements to traffic light detection were released in May. These changes can be seen through improved autonomy at the intersections of Mitchell & Copper as well as Abram and Cooper. Depending on the lighting conditions, the traffic light detection previously would not have enough certainty in the state of the light, so it would default to red. This resulted in the FAs taking over in problematic intersections. This issue is still present at sunrise and sunset when there is maximum glare into the traffic light detection camera; however, we are working on a long-term solution that will be entering testing at the end of 2021.

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Arlington RAPID

Autonomy Insights Report

June 2021

Autonomy Heatmap Overview

Figure 1: Autonomy Utilization Heatmap for May (Left) and June (Right) 2021

Above are the autonomy heatmaps for May and June. Circles in blue denote areas of low autonomy utilization, while areas marked in red denote areas of high autonomy utilization. Average autonomy utilization was 68% for the month of June. This autonomy percentage does not filter for times where the FA was driving through a required manual zone, such as an unprotected turn, or around a construction diversion. Filtering for times where the vehicle was in a manual only zone or had to divert around construction, the autonomy utilization increased to 80% for the month of June.

Manual takeover information is listed below. Currently, we filter for takeovers that occur in the following areas.

- Passenger Stops: The Fleet Attendant (FA) must manually shift into park when they have arrived at a passenger stop. This results in the autonomous system switching to manual mode.
- Require Manual Zones: These are areas/actions that are outside of the vehicle's Operation Design Domain (ODD) such as an unprotected left turn. The vehicle is programmed to come to a stop, requiring the FA to take over.

Interventions	= 14219
Interventions / km	= 0.4 km
Interventions at Passenger Stop	= 1396, 9.82% of total
Interventions at Require Manual Zone	= 3101, 21.81% of total

Areas of Focus

Below are specific learnings from discussions with FAs, log review, and in-person testing.

Construction on UTA:

Figure 2: Construction on UTA & Summit (Left), Barrier along UTA & Lampe (Right)

Throughout the month of June, construction has continued on UTA, which is a heavily trafficked area of the route. As seen in the above left image, cones along the westbound direction of UTA cause the vehicle to slow, so FAs will often take over to improve the ride for the passengers.

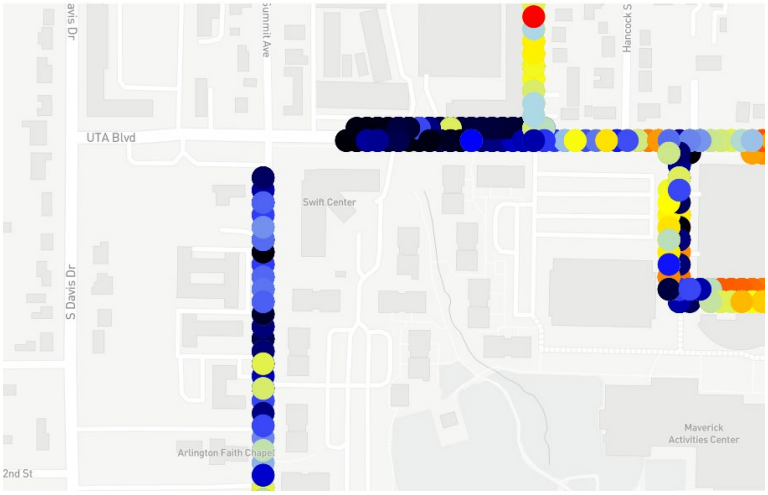

Figure 3: Reduced autonomy utilization along UTA and summit due to construction

Shrub Growth on Mitchell

Figure 4: Shrubs on Mitchell EB

As mentioned in previous reports, the vehicle can have difficulties when foliage encroaches into the drive lane. This is especially problematic with large objects near/in the road as our system may momentarily predict that the object will move into our path. This causes the vehicle to behave cautiously and slow down. In anticipation of these slowdowns FAs often preemptively takeover.

Dispatch to Office at End of Shift

Figure 5: Autonomy Utilization on Mesquite before June 23rd (left), Autonomy Utilization on Mesquite after June 23rd (right)

Starting on June 23rd, Via began dispatching the AVs to the office (at the top right corner of the image) at the end of the FA's shift. FAs most commonly drive north in the right lane of Mesquite up to Front Street at the end of their shift. Before this change, the FA would need to manually drive to the office, since the vehicle's last command was to continue hovering. Autonomy utilization along mesquite has greatly improved due to this change.

As vehicles began driving this section more often in autonomy, FAs began reporting that overgrown foliage from Mesquite to Front street was causing the vehicle to slow down. This was quickly remedied with route changes that moved the vehicle's nominal lane placement away from the shrubs.

Software Updates

There were no software releases for the month of June.

Appendix

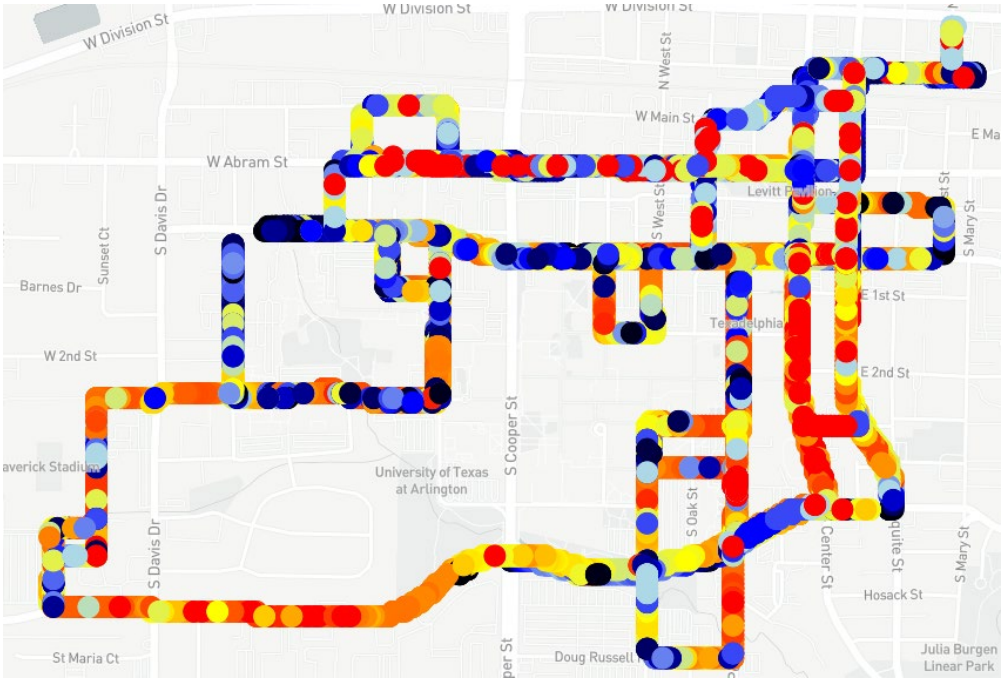

Figure A1: Autonomy Heatmap for June 2021

Figure A2: Autonomy Heatmap for May 2021

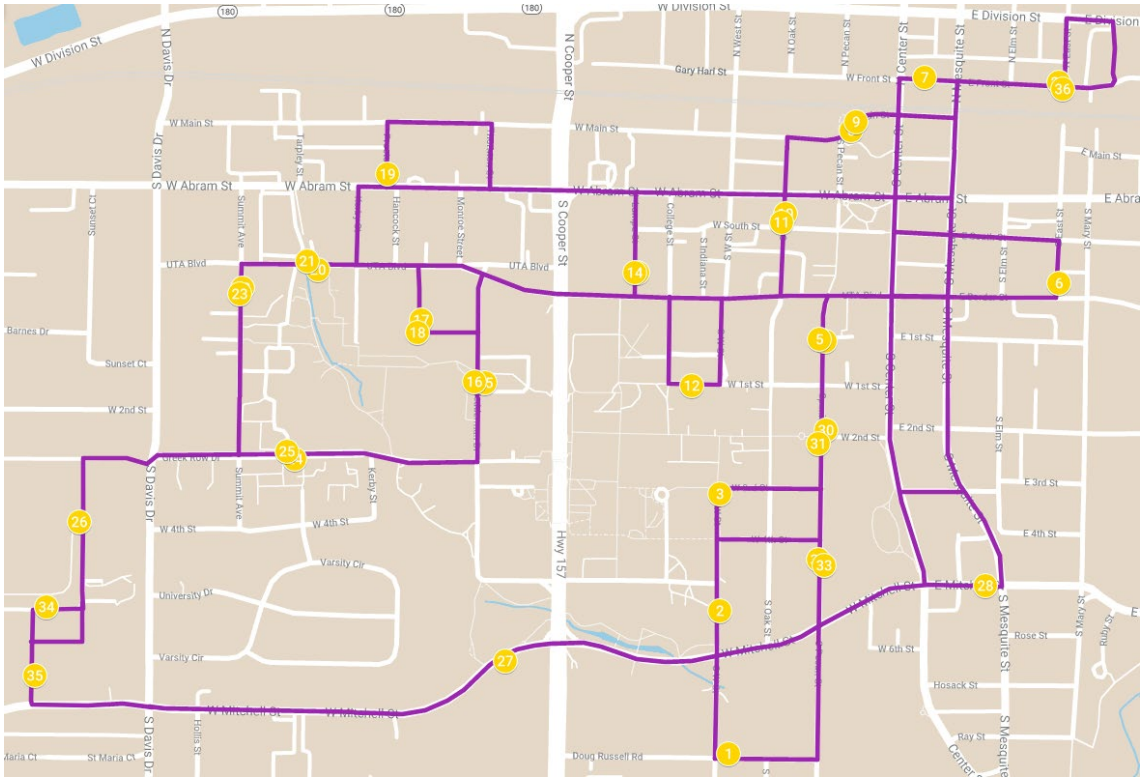

Figure A3: RAPID ODS Route

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Autonomy Insights Report

July 2021

Autonomy Heatmap Overview

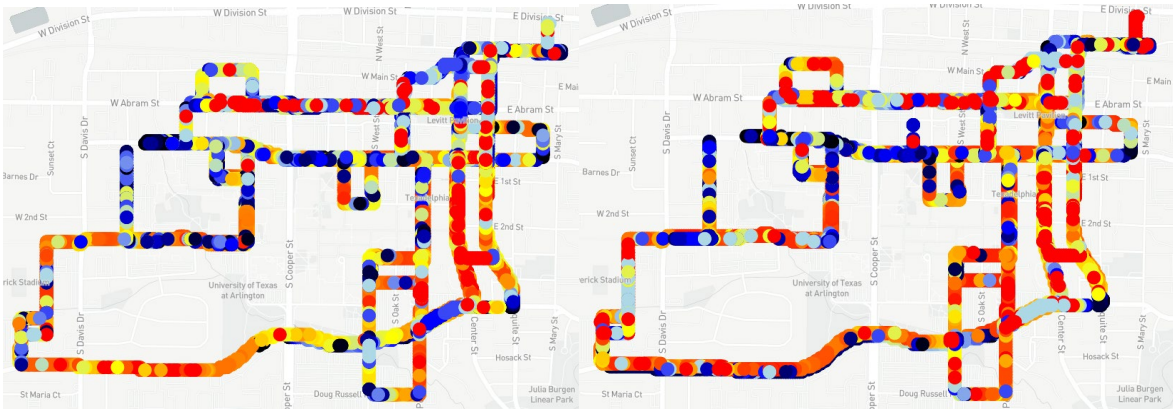

Figure 1: Autonomy Utilization Heatmap for June (Left) and July (Right) 2021

Above are the autonomy heatmaps for June and July. Circles in blue denote areas of low autonomy utilization, while areas marked in red denote areas of high autonomy utilization. Average autonomy utilization was 86% for the month of July, a substantial improvement from 80% in June. This autonomy percentage filters for times where the Autonomous Vehicle Operator (AVO) was driving through a required manual zone (such as an unprotected turn) or around a construction diversion.

Manual takeover information is listed below. Currently, we categorize takeovers that occur in the following areas.

- Passenger Stops: The AVO must manually shift into park when they have arrived at a passenger stop. This results in the autonomous system switching to manual mode.
- Require Manual Zones: These are areas/actions that are outside of the vehicle's Operation Design Domain (ODD) such as an unprotected left turn. The vehicle is programmed to come to a stop, requiring the AVO to take over.

Interventions	= 10,010
Interventions / km	= 0.37 km
Interventions at Passenger Stop	= 1273, 12.7% of total
Interventions at Require Manual Zone	= 2109, 21.1% of total

Due to rider comfort concerns primarily at other sites, autonomy was halted across all of May Mobility's sites from July 23 to August 6, 2021 out of an abundance of caution. A team of autonomy, operations, and field engineering personnel travelled to each site to diagnose the issues, test a solution, and rollout updates to the fleet. A detailed summary will be included in the August report.

Areas of Focus

Below are specific learnings from discussions with AVOs, log review, and in-person testing.

Davis Addition:

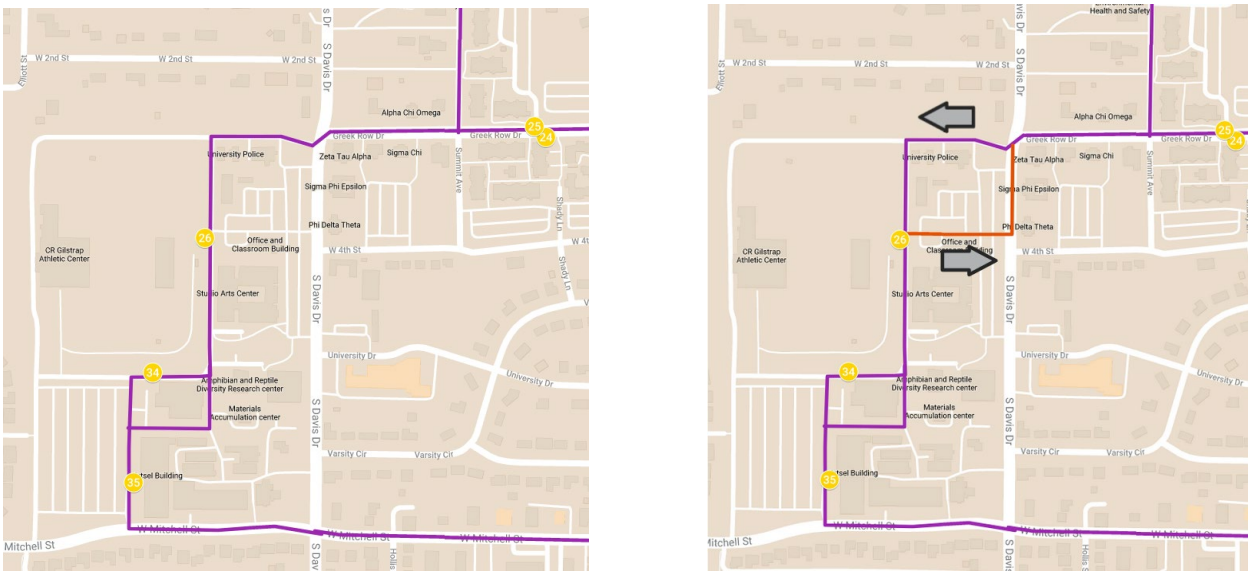

Figure 2: Additional section on Davis from Stadium to Greek Row (previous route on left; new route on right)

Previously, in order to connect the stadium stop to the rest of the route, the AV was routed along Mitchell to the east end of the route before it could make its way north and back west. This is due to the crossing at Davis & Greek Row Dr only being legal in the westbound direction. In addition, the 35mph speed limit on Davis placed it

outside of the May AV's ODD (Operation Design Domain). After looking at ridership data, a significant portion of riders originated from the stadium and terminated in the north western portion of the service area. In order to reduce wait times, a manual-only section was added (shown in Figure 2) which connects the Stadium stops to Greek Row through Davis. This manual only section will slightly reduce autonomy, but greatly improve the wait times for the AV service.

Construction along UTA:

Figure 3: Construction cones along UTA

Continued construction along most of UTA Blvd has reduced autonomy utilization along this section. As mentioned in previous reports, construction cones near our lane often result in the vehicle slowing down unexpectedly; therefore, the AVOs will need to take over. This situation is particularly challenging since, depending on their placement, the traffic cones may or may not cause a slowdown depending on if they encroach on the AV's designated lane. As a result, the AVOs opt to prioritize rider comfort and drive manually in these areas. The May autonomy development team is

currently working on the classification of and reaction to static objects in the AV's lane.

New Crosswalks:

Figure 4: New crosswalks added to Center & E South St

During the Field Engineering trip to Arlington for July, it was noted that crosswalks were added to the intersection of Center and E South St. The geometry of crosswalks are added to the route network which the vehicle uses to inform its decision making. Knowing the locations of crosswalks are particularly important for the AV as it allows the behavior system to better predict what pedestrians along the sides of the road may do. This in turn allows the vehicle to better determine the right of way when pedestrians are crossing this intersection.

For these reasons it's important to update the route network with pertinent information such as crosswalks and lane markings, and it highlights the importance of regular checks for changes in the route. We are also now training the AVOs on changes to look out for in order for the Field Engineering team to make updates as quickly as possible.

Software Updates

A new minor software update was rolled out to the Arlington fleet in the middle of July. The main improvement was to the tracking of other vehicles on multilane roads. One aspect was fixing a case where two vehicles driving closely together could be grouped into a single vehicle track. This happened if the vehicles were in a specific position to the side of and behind the AV. This resulted in unreliable predictions of the two vehicles' future paths.

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Autonomy Insights Report

August 2021

Autonomy Heatmap Overview

Figure 1: Autonomy Utilization Heatmap for July (Left) and August (Right) 2021

Above are the autonomy heatmaps for July and August. Circles in blue denote areas of low autonomy utilization, while areas marked in red denote areas of high autonomy utilization. Average autonomy utilization was relatively stable at 83.5% for the month of August, as compared to 85.7% in July. This autonomy percentage filters for times where the Autonomous Vehicle Operator (AVO) was driving through a required manual zone (such as an unprotected turn) or around a construction diversion.

Manual takeover information is listed below. Currently, we categorize takeovers that occur in the following areas.

- Passenger Stops: The AVO must manually shift into park when they have arrived at a passenger stop. This results in the autonomous system switching to manual mode.
- Require Manual Zones: These are areas/actions that are outside of the vehicle's Operation Design Domain (ODD) such as an unprotected left turn. The vehicle is programmed to come to a stop, requiring the AVO to take over.

Interventions	= 17,058
Interventions / km	= 0.2km
Interventions at Passenger Stop	= 1,094, 6.4% of total
Interventions at Required Manual Zone	= 3,857, 22.6% of total

Based on a pilot program with selected AVOs manually keeping a tally of the cause for common interventions, th e project team developed a computer script that can categorize these interventions automatically. This process is in place and is the source of the intervention data presented above. Additionally, the May team is working on creating a log button on the AVO vehicle screen that would allow the AVO to quickly flag disengagements from autonomous mode to manual mode for uncommon situations.

Areas of Focus

Below are specific learnings from discussions with AVOs, log review, and in - person testing.

Construction on Lampe Street:

Figure 2: Autonomy utilization on UTA before (left) and after (right) construction on Lampe St cleared

Construction on Lampe Street cleared at the end of August. Before, construction cones and signs blocking UTA Boulevard westbound resulted in the AVOs manually taking over to drive around the obstructions. The above autonomy heat maps show the autonomy util ization on UTA before and after the obstructions at UTA & Lampe

cleared. Small improvements such as this help to improve autonomy utilization through fewer interventions and longer autonomy segments.

Foliage on Mitchell & Davis:

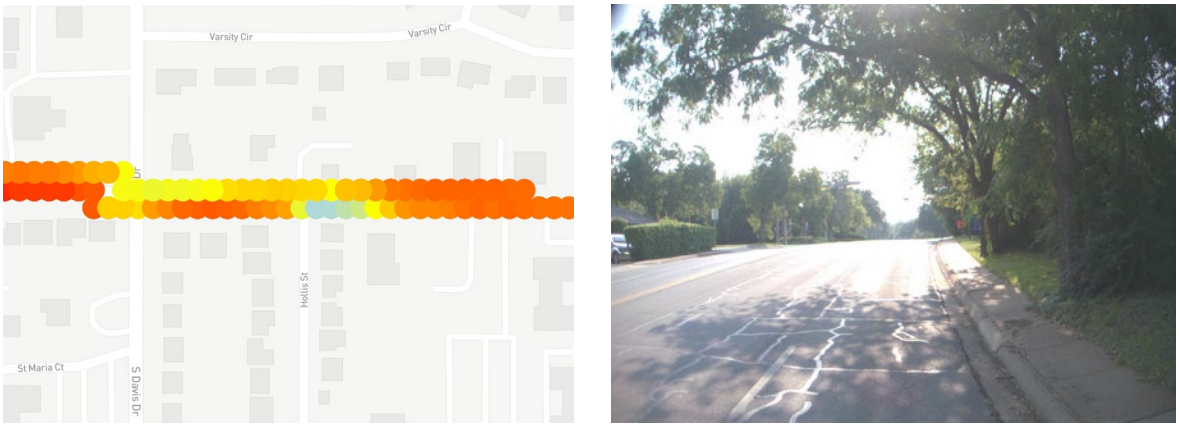

Figure 3: Reduce d autonomy in yellow (left), Overhanging trees on Mitchell & Davis

As mentioned in previous reports, foliage that encroaches on the AV's lane will cause the vehicle to slow or come to a stop as it passes. In this particular case, the overhead trees appear to be too close to the top of the AV when viewed at a distance. Because of this, the AV will slow down until it becomes confident that it can pass safely under the perceived obstacle. AVOs have been taking over recently to improve rider comfort as the slo wing has increased due to increased growth. The project team is working with UTA to get these trees trimmed to avoid this problem in the future.

Increased traffic near the Business Building:

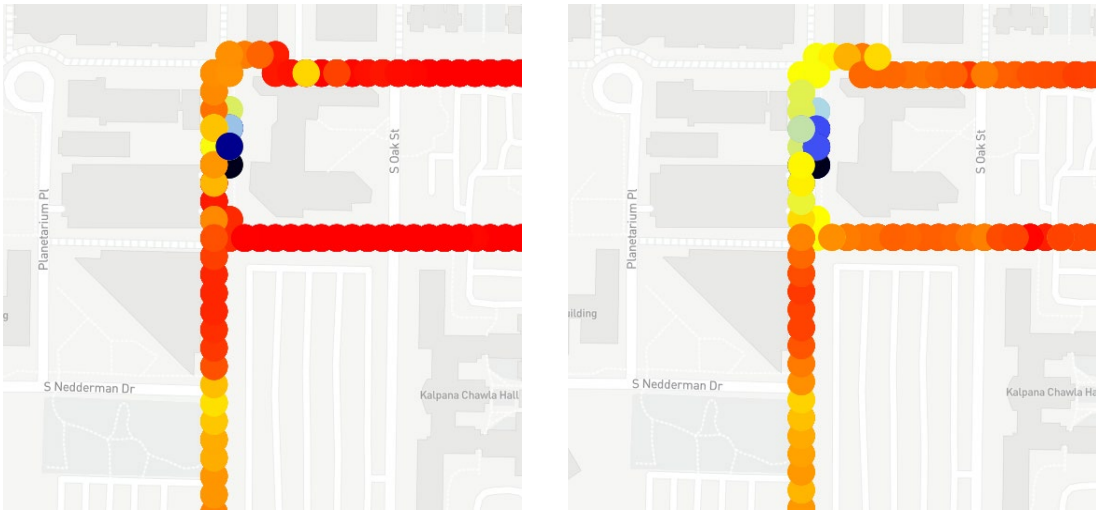

Figure 4: Autonomy utilization near the Business Buil ding terminal

As classes came back into session, pedestrian foot traffic increased near the eastern terminal at the Business Building. With this, vehicle traffic has also increased, often resulting in situations where the AVO needs to take over to get aro und parked vehicles. This can be seen with the reduction in autonomy near the AV stop on the top left of the images. This expectation of increased vehicle traffic is one of the reasons we moved the AV terminals to a new location in order to decrease conges tion.

Software Updates

Autonomy was paused in Arlington, as well as all other May Mobility deployment sites, from July 23 to August 6, 2021, due to an overly conservative reactive stop zone that triggered rapid deceleration when other vehicles passed the autonomous vehicle and changed lanes into the autonomous vehicle's lane. This rapid deceleration occurred even in situations when the passing vehicle left sufficient space to merge in front of the autonomous vehicle safely. We determined that these rapid decelerations, because they could be unexpected by a trailing vehicle, posed a potential risk of rear - end collision and, thus, paused autonomous operations while

resolving the issue. We have addressed this error by shrinking the reactive stop zone to cover only close cut - ins that present a risk rather than normal passing behavior. We ran extensive testing of the updated stop zone, including testing in a wide range of passing situations and emergency stop situations (in our local controlled test environments). We returned the fleet to autonomy after our tests determined there was no longer a risk of rapid deceleration in these cases.

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Arlington RAPID

Autonomy Insights Report

September 2021

Autonomy Heatmap Overview

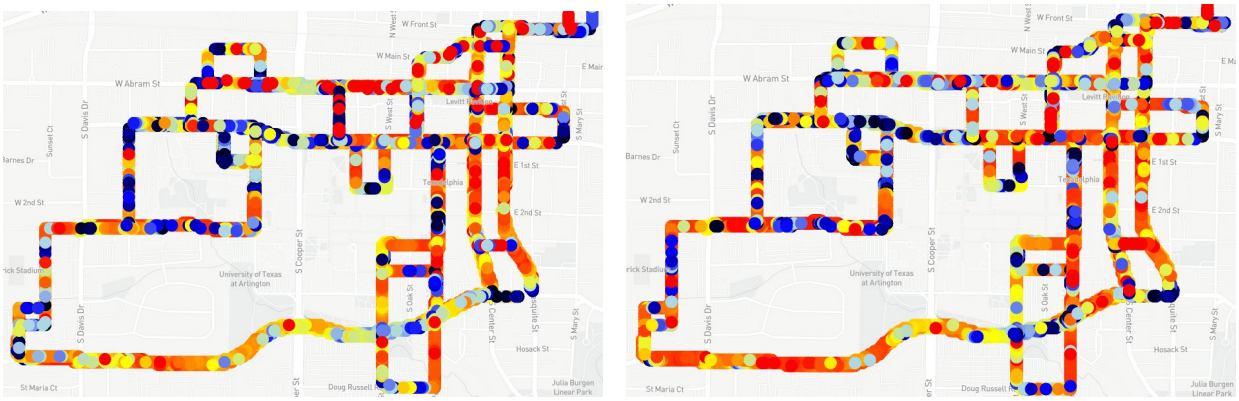

Figure 1: Autonomy Utilization Heatmap for August (Left) and September (Right) 2021

Above are the autonomy heatmaps for August and September 2021. Circles in blue denote areas of low autonomy utilization, while areas marked in red denote areas of high autonomy utilization. Average autonomy utilization reached an all-time high at 88.5% for the month of September, as compared to 83.5% in August. This autonomy percentage filters for times where the Autonomous Vehicle Operator (AVO) was driving through a required manual zone (such as an unprotected turn) or off route due to a construction diversion.

Manual takeover information is listed below. Currently, we categorize takeovers that occur in the following areas.

- Passenger Stops: The AVO must manually shift into park when they have arrived at a passenger stop. This results in the autonomous system switching to manual mode.
- Require Manual Zones: These are areas/actions that are outside of the vehicle's Operation Design Domain (ODD) such as an unprotected left turn. The vehicle is programmed to come to a stop, requiring the AVO to take over.

Interventions	= 23,490
Kilometers / Interventions	= 0.28km
Interventions at Passenger Stop	= 1,605, 6.8% of total
Interventions at Require Manual Zone	= 6,186, 26.3% of total

Areas of Focus

Below are specific learnings from discussions with FAs, log review, and in-person testing.

Elm St. Addition:

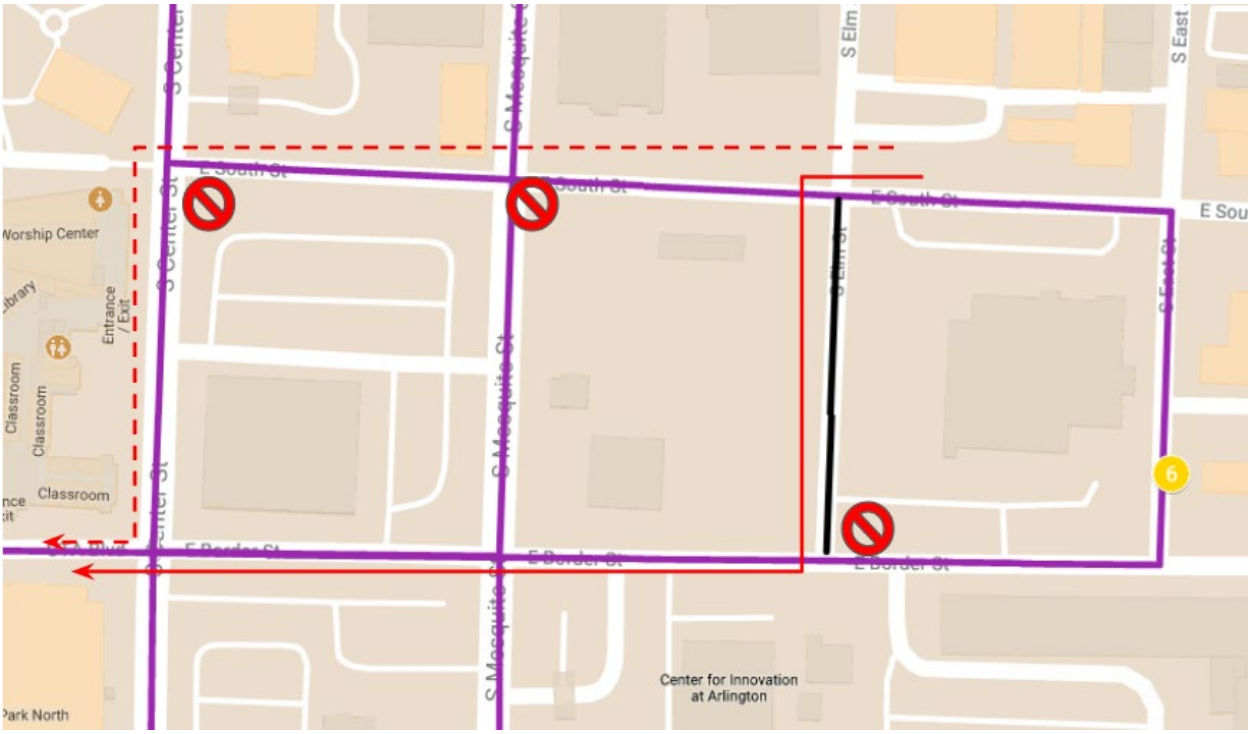

Figure 2: Original (dotted red) and the new (solid red) path between Post Office and West Garage Terminals

With the addition of the Post Office terminal in the previous month, AVOs noted that the addition of Elm Street to the route would result in one less intervention while hovering between the Post Office and West Garage terminals. This additional road was mapped and tested during September and is targeted for release to the fleet in October. The old path denoted with a dotted red line has two manual-only zones, where the new path denoted by a solid red line has just one.

Lampe Reopen:

Figure 2: Autonomy utilization on Lampe St. during August (Left) and September (right)

The south end of Lampe Street reopened at the end of August, resulting in the entire length open to be driven in autonomy. Previously dropoffs and pickups at Lot 52 (on Lampe) would result in at least one manual takeover due to the need to make a u-turn to avoid construction. After manually changing lanes, the autonomy system requires a short distance to switch paths and for the AVO to re-engage autonomy, which explains the very limited and sporadic autonomy utilization in previous months.

Mitchell:

Figure 3:Autonomy utilization on Mitchell in August (left) and September (right)

Mitchell Street has been a challenge for the AV as it is a narrow road with limited buildings to provide precise localization. After fine-tunings to the lane placement in the route map and AVO training, the western section of Mitchell St. has had >90% autonomy on average throughout the month of September.

Software Updates

There were no software updates to the Arlington Fleet during the month of September.

9/3/2021 Incident Review

On 9/3/2021 a May Shuttle experienced a curb rub incident while making a right turn onto Mitchell from Spaniolo. After our engineering and technical support teams reviewed the vehicle logs, camera footage, and route network, it was determined that the lane placement needed adjustment at this turn to increase the space between the vehicle and curb. This was rolled out immediately following the incident.

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Autonomy Insights Report

October 2021

Autonomy Heatmap Overview

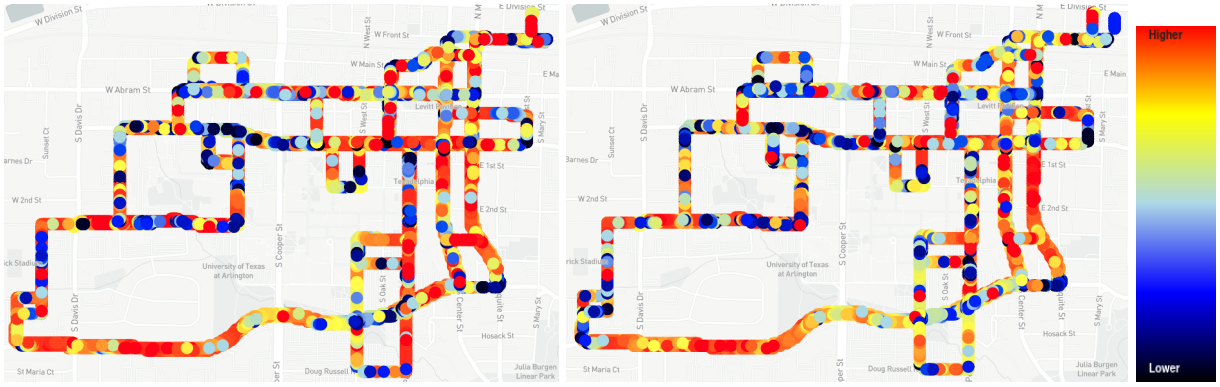

Figure 1: Autonomy Utilization Heatmap for September (Left) and October (Right) 2021

Above are the autonomy heatmaps for September and October. Circles in blue denote areas of low autonomy utilization, while areas marked in red denote areas of high autonomy utilization. Average autonomy utilization was relatively stable at 87.6% for the month of October, as compared to 88.5% in September. This autonomy percentage filters for times where the Autonomous Vehicle Operator (AVO) was driving through a required manual zone (such as an unprotected turn) or around a construction diversion.

Manual takeover information is listed below. Currently, we categorize takeovers that occur in the following areas.

- Passenger Stops: The AVO must manually shift into park when they have arrived at a passenger stop. This results in the autonomous system switching to manual mode.
- Require Manual Zones: These are areas/actions that are outside of the vehicle's Operation Design Domain (ODD) such as an unprotected left turn. The vehicle is programmed to come to a stop, requiring the AVO to take over.

Interventions	= 22,304
Km / Intervention	= 0.30km
Interventions at Passenger Stop	= 1,920, 8.6% of total
Interventions at Require Manual Zone	= 6,334, 28.3% of total

Areas of Focus

Below are specific learnings from discussions with AVOs, log review, and in-person testing.

Routing Past Business Building:

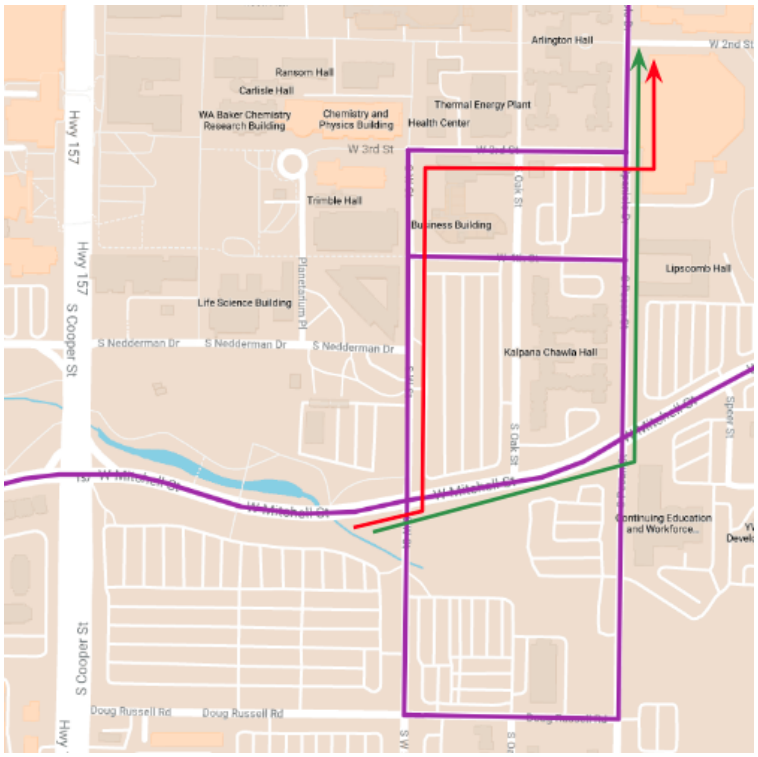

Figure 2: Old (red) and new (green) routing from Mitchell to Spaniolo

AVOs reported that while driving from Mitchell EB to Spaniolo NB, the AV would drive along South West Street instead of taking a left directly onto Spaniolo. Not only does this poor routing increase ETAs, but it also takes the AV through the much busier area around the Business Building. The issue was quickly resolved in the May Mobility route map and will be released in a software update in November.

Arlie Crosswalk:

Figure 3: Crosswalk on Abram in front of the Arlie

There is a crosswalk on Abram in front of the Arlie apartment building that has a flashing red light that can be triggered by a pedestrian. Normally this light is not illuminated. During testing and the first few months of the deployment, this light had not been seen to be triggered. In October an AVO reported that the light was triggered and subsequently took over, as the AV would not slow down for this light. This section was soon set to manual-only in the route network as our system is only able to handle traffic lights where the right of way is indicated by a constant green light.

Oak and Main:

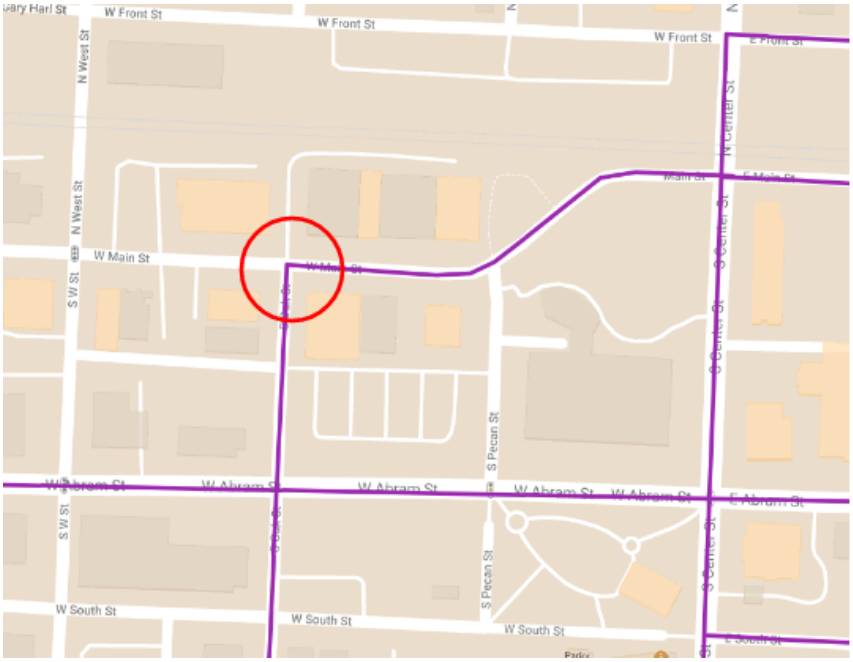

Figure 4: Intersection of Oak and Main

The intersection of Main St. and Oak St. was recently updated to an all-way stop. Previously this intersection included stop signs for Oak St. and no stop signs for Main St., therefore, the AVOs needed to take over to perform the unprotected turn from Main onto Oak and vice versa. Once this route update is tested and released to the fleet in late November, this intersection will be fully autonomous.

Software Updates

During the first week of October, a new software release (version 7.0) was rolled out to the Arlington fleet. Due to a curb strike immediately following this software update, the fleet was reverted back to the previous release (version 6.6) while autonomy engineers performed onsite testing.

The root cause was investigated by the autonomy team and fixed in an upcoming software release. This will be extensively tested in Ann Arbor and Arlington before being incrementally released to the fleet.

Arlington RAPID

Autonomy Insights Report

November 2021

Autonomy Heatmap Overview

Figure 1: Autonomy Utilization Heatmap for October (Left) and November (Right) 2021

Above are the autonomy heatmaps for October and November. Circles in blue denote areas of low autonomy utilization, while areas marked in red denote areas of high autonomy utilization. Average autonomy utilization was 88.8% for the month of November, as compared to 87.6% in October. This autonomy percentage filters for times where the Autonomous Vehicle Operator (AVO) was driving through a required manual zone (such as an unprotected turn) or off route (such as driving around a construction diversion).

Manual takeover information is listed below. Currently, we categorize takeovers that occur in the following areas.

- Passenger Stops: The AVO must manually shift into park when they have arrived at a passenger stop. This results in the autonomous system switching to manual mode.
- Require Manual Zones: These are areas/actions that are outside of the vehicle's Operation Design Domain (ODD) such as an unprotected left turn. The vehicle is programmed to come to a stop, requiring the AVO to take over.

Interventions	= 27,212
Km / Intervention	= 0.28km
Interventions at Passenger Stop	= 2,074, 7.6% of total
Interventions at Require Manual Zone	= 6,805, 25.0% of total

Areas of Focus

Below are specific learnings from discussions with AVOs, log review, and in-person testing.

Elm Street Addition:

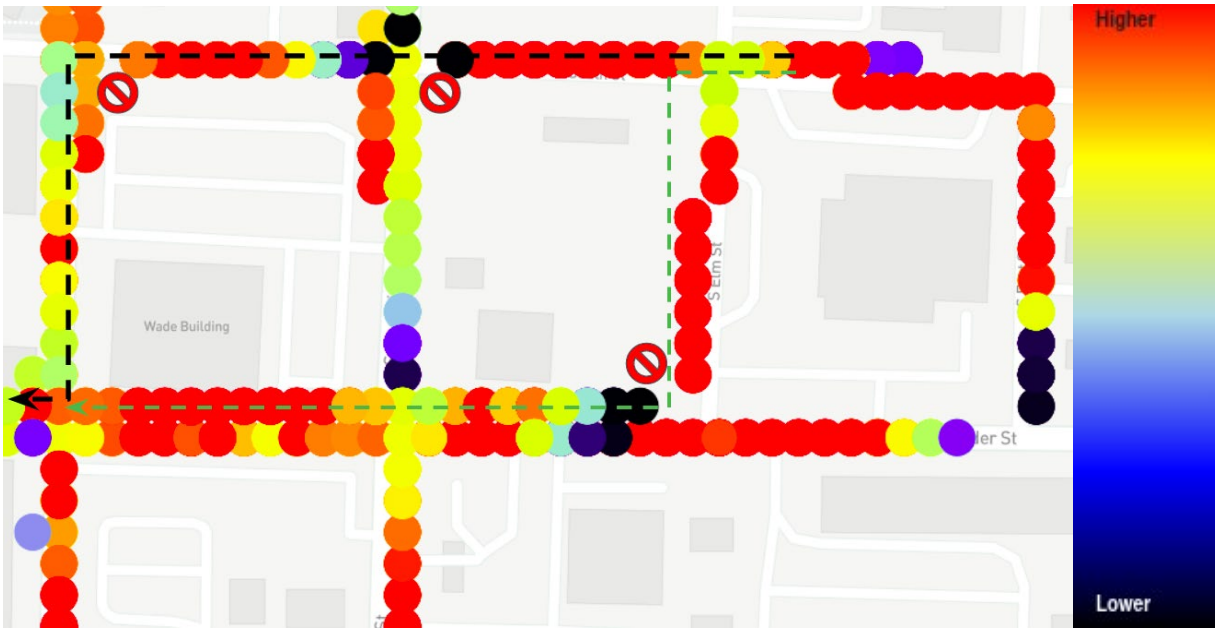

Figure 2: Old (black) and new (green) routing past the Post Office terminal

In September, Elm St SB was added to the route in order for vehicles to go from the Post Office terminal to the west side of UTA Blvd with only 1 require manual zone instead of 2. Previously, the AV would be routed along W South St. with manual takeovers at Mesquite St and Center St. Now, the AV is routed down Elm St with a single manual takeover turning right from Elm to Border St.

Figure 3: Turn from W South St to Elm St

There is a noticeable reduction in autonomy utilization on the turn from W South to Elm St. AVOs reported that during the day, vehicles would often park one spot before the official street parking started. When a vehicle is parked in the space shown above, it intersects with the implied (not painted) crosswalk. Because of this, the AV will slow or stop as it sees an object in a crosswalk very close to its intended path. Our behavior system currently errs on the side of caution and allows all objects regardless of classification to activate a crosswalk.

S West St Barriers:

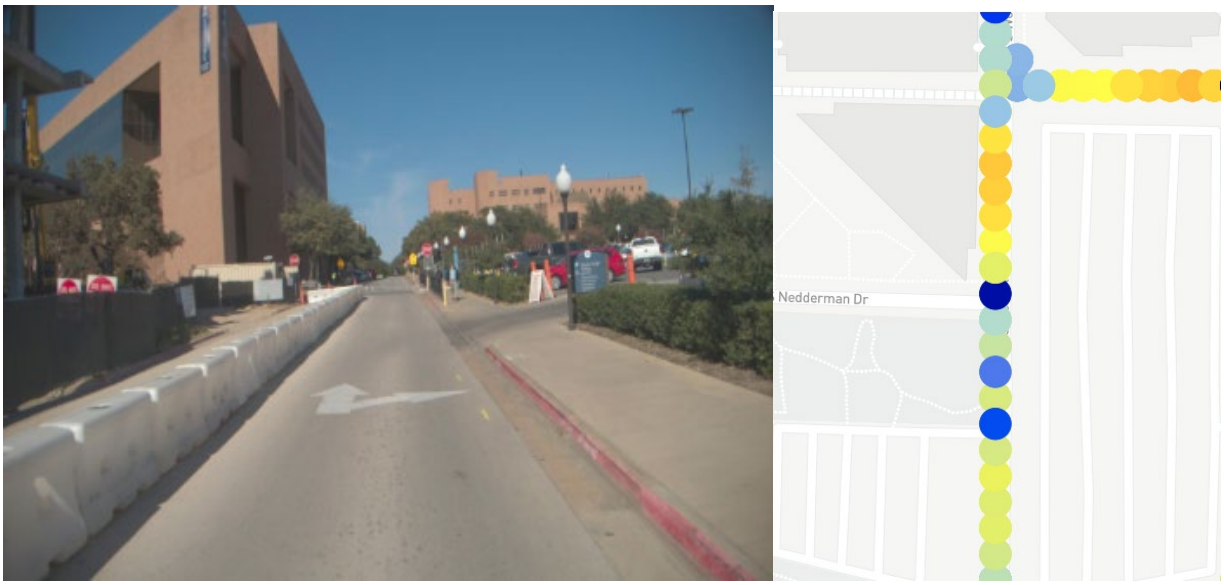

Figure 4: Construction barriers on S West St (Left) and corresponding autonomy heat map (Right)

As mentioned in previous reports, construction barriers and cones placed in the road can be difficult for the AV to pass without slowing down with our currently autonomy system. In our current system, barriers that are close to the road and very long are seen as one large obstacle. As parts of the barriers go in and out of view, it's possible for its velocity to momentarily to be detected as non-zero, thus the AV will begin to slow in anticipation. Updates to the route network can be made to adjust the lane position and to suggest that this obstacle is static, however these updates will be nullified if the barrier is moved to a new position in the road.

Software Updates

There were no software updates for the month of November.

Arlington RAPID

Autonomy Insights Report

December 2021

Autonomy Heatmap Overview

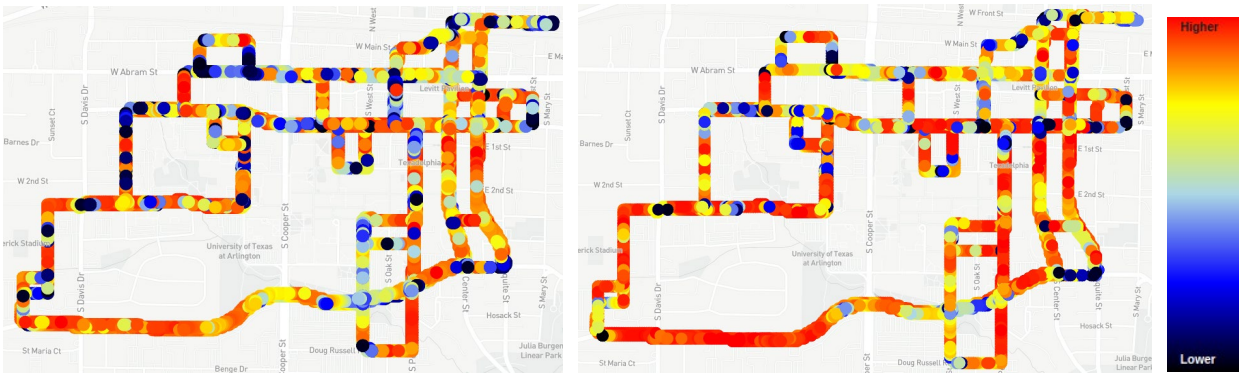

Figure 1: Autonomy Utilization Heatmap for November (Left) and December (Right) 2021

Above are the autonomy heatmaps for November and December. Circles in blue denote areas of low autonomy utilization, while areas marked in red denote areas of high autonomy utilization. Average autonomy utilization was 92.4% for the month of December, as compared to 88.8% in November. This autonomy percentage filters for times where the Autonomous Vehicle Operator (AVO) was driving through a required manual zone (such as an unprotected turn) or off route (such as driving around a construction diversion).

Manual takeover information is listed below. Currently, we categorize takeovers that occur in the following areas.

- Passenger Stops: The AVO must manually shift into park when they have arrived at a passenger stop. This results in the autonomous system switching to manual mode.
- Require Manual Zones: These are areas/actions that are outside of the vehicle's Operation Design Domain (ODD) such as an unprotected left turn. The vehicle is programmed to come to a stop, requiring the AVO to take over.

Interventions	= 27,147
Km / Intervention	= 0.34km
Interventions at Passenger Stop	= 1,973, 9% of total
Interventions at Require Manual Zone	= 7,630, 34% of total

Areas of Focus

Below are specific learnings from discussions with FAs, log review, and in-person testing.

UTA and Cooper Intersection:

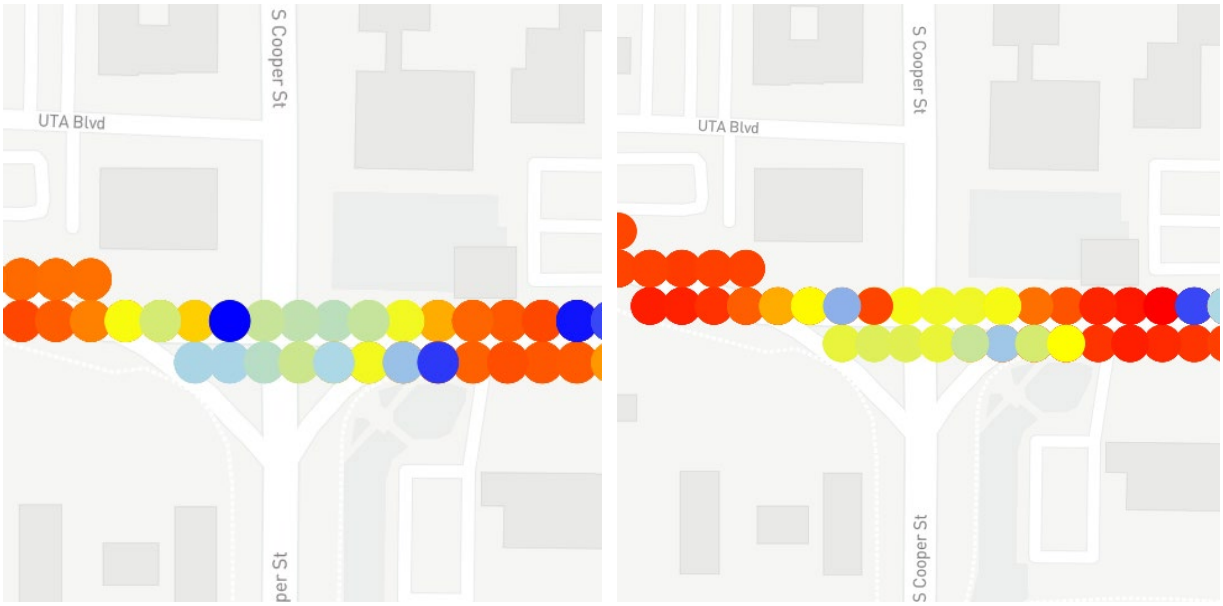

Figure 2: Autonomy Utilization at UTA and Cooper for November (left) and December (right) 2021

A new software update (version 7.3) was released to Arlington in the middle of December. An overview of that release is described at the bottom of this document. One outcome of this software release was improved performance through busy intersections. AVOs often needed to take over through the UTA and Cooper intersection. This was due to the AV incorrectly predicting that crossing vehicles would creep forward into the intersection. This can still happen in software version 7.3, but the issue has greatly reduced in frequency, as seen in the above autonomy heatmaps.

Roadside Objects:

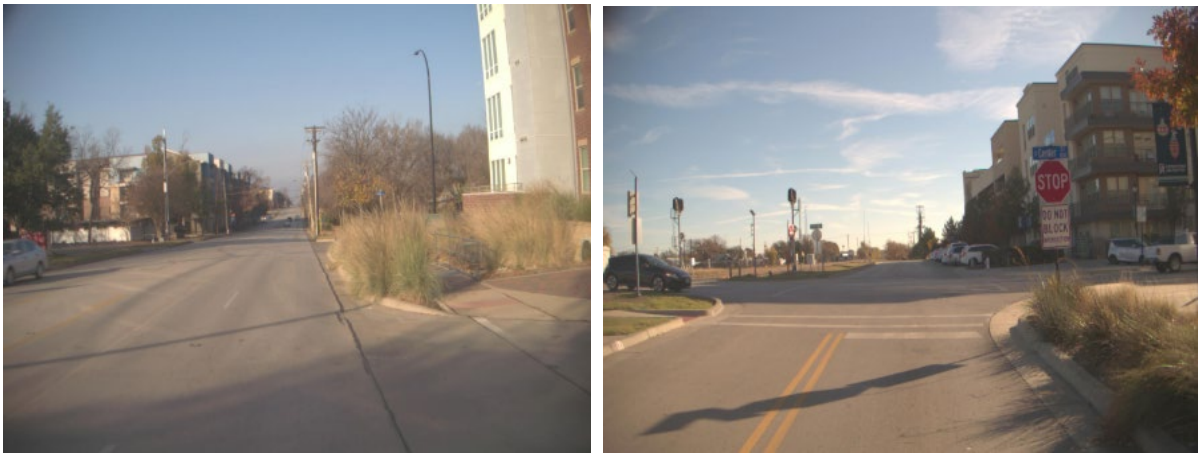

Figure 3: Foliage near roads continues to be a challenge in sections of the route

As mentioned in previous reports, bushes and other foliage near the side of the road present a challenge to pass in autonomy. The AV will detect this vegetation as an object partially in the road and come to a stop, requiring an AVO intervention. As total intervention numbers come down in Arlington, interventions for foliage in or very close to the side of the road become a greater share. Detection and smooth avoidance of objects such as this are currently in development.

Parked Vehicles:

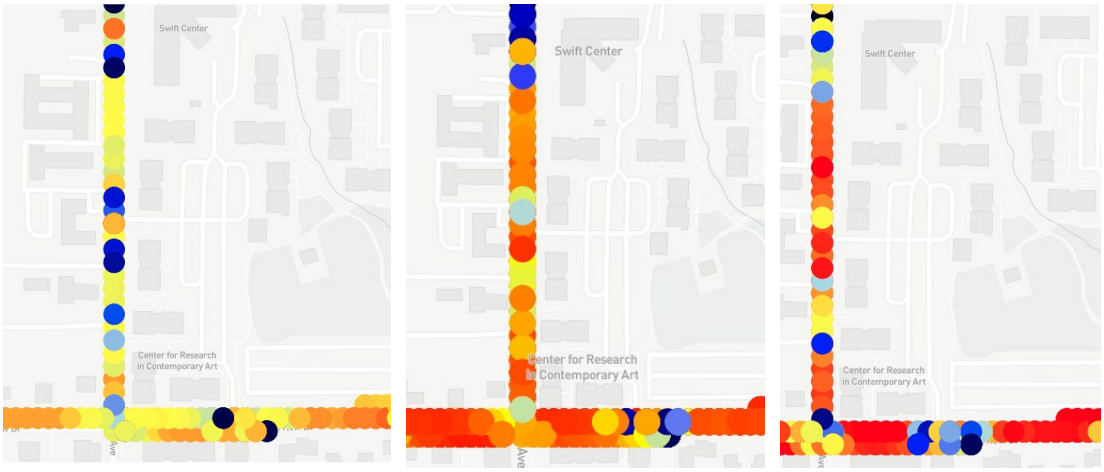

Figure 4: Comparing autonomy near parked vehicles from the start of the deployment in April 2021, November 2021, and December 2021

At the start of the deployment, navigating around parked cars was a challenge for the AV. This was improved upon in later software versions and in 7.3. With version 7.3, the autonomy software can identify these vehicles and smoothly offset the AV to the side in order to create space between the AV and the parked vehicles.

Software Updates

On December 21, 2021, software version 7.3 was released to the Arlington Fleet. The major changes are listed below:

- Improvements to the curve controller will help the AV follow curves more accurately.
- The chance of two objects very close together being grouped together as one was reduced. This improves the AV's ability to predict what agents in the environment will do in the future.
- Improvements to in-lane offset maneuvers, which are useful in getting around objects that are near or partially in the AV's lane.

Issues During Rollout

After the first vehicle was updated to 7.3, the vehicle was not able to receive dispatches from Via. This was quickly discovered to be due to a missing step in the software rollout procedures. A new key needed to authenticate with a May Mobility server to allow communication with Via needed to be generated. This was not caught in site testing as we do not use the Via dispatching service during testing.

This issue did not impact the service as vehicles are updated one at a time to ensure uncaught issues ground the entire fleet. Our software rollout guides have been updated to prevent this issue from happening in the future.

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Arlington RAPID

Autonomy Insights Report

January 2022

Autonomy Heatmap Overview

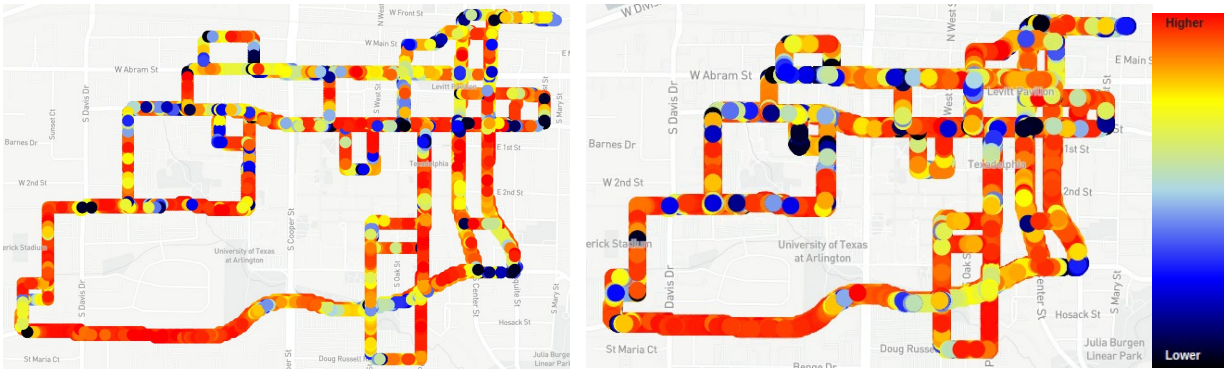

Figure 1: Autonomy Utilization Heatmap for Dec. 2021 (Left) and Jan. 2022 (Right)

Above are the autonomy heatmaps for December and January. Circles in blue denote areas of low autonomy utilization, while areas marked in red denote areas of high autonomy utilization. Average autonomy utilization was 93.6% for the month of January, as compared to 92.4% in December. This autonomy percentage filters for times where the Autonomous Vehicle Operator (AVO) was driving through a required manual zone (such as an unprotected turn) or off route (such as driving around a construction diversion).

An intervention for one of the following reasons is considered a planned intervention, where we always expect the AVO to take control of the shuttle. An intervention for any other reason is an unplanned intervention.

- Passenger Stops: The AVO must manually shift into park when they have arrived at a passenger stop. This results in the autonomous system switching to manual mode.
- Require Manual Zones: These are areas/actions that are outside of the vehicle's Operation Design Domain (ODD) such as an unprotected left turn. The vehicle is programmed to come to a stop, requiring the AVO to take over.

	December 2021	January 2022
Interventions	22,147	18,763
Km / intervention	0.34	0.42
Km / unplanned intervention	0.6	0.8
Interventions at Passenger Stop	1,973 - 9%	1,514 - 8%
Interventions at Require Manual Zone	7,630 - 34%	7,383 - 39%

Areas of Focus

Below are specific learnings from discussions with AVOs, log review, and in-person testing.

Insight 1:

Arlington saw continued autonomy improvements at pain points in the route due to the rollout and increased AVO comfort with software release 7.3, features of which were described at the end of the December Autonomy Insights Report.

Prior to release 7.3, the shuttle would frequently predict other vehicles to creep forward into intersections as the shuttle passed, but this intent prediction was improved with the new software release. This can be seen through further improvement in autonomy utilization at the UTA Blvd and Cooper St intersection, which has been one of the most difficult for the shuttles.

The December autonomy insights report mentioned that as software release 7.3 reduces the total number of interventions, the expectation was that interventions for roadside objects, such as bushes or trees, would become a higher percentage of the total number of interventions. Heat maps from January, however, show that on Mitchell EB, where there historically have been a number of interventions near roadside objects, there is already improved autonomy performance around these static objects from the updates in software release 7.3.

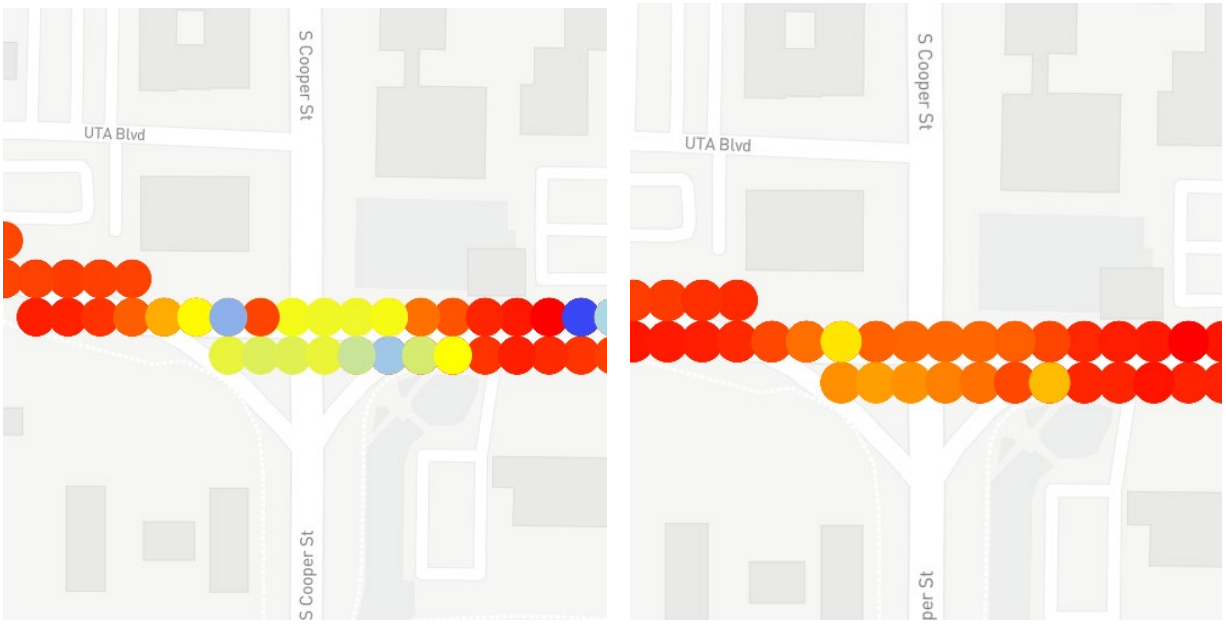

Figure 2: Autonomy map at UTA and Cooper for Dec. 2021 (left) and Jan. 2022 (right)

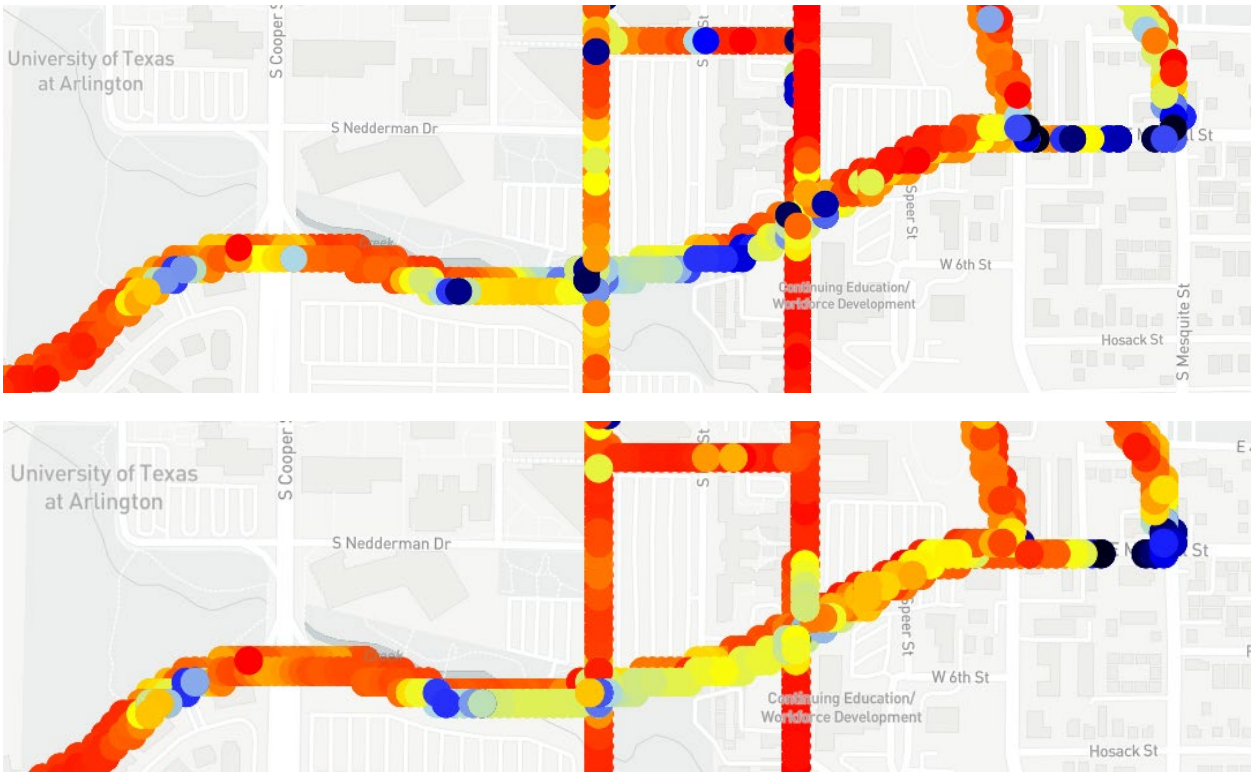

Figure 3: Autonomy map of Mitchell for Dec. 2021 (top) and Jan. 2022 (bottom)

Insight 2:

On previous software versions, there was a frequent issue wherein the shuttle would slow down significantly due to pedestrians walking on the sidewalk. Site staff mentioned that this issue was greatly improved with software release 7.3. This behavior occurs when the shuttle slowly drives behind a pedestrian on the sidewalk, due to the large buffer that our autonomy system gives to pedestrians and other vulnerable road users. While this behavior used to be observed for a single pedestrian, site staff said they rarely received call-ins for this behavior in January.

This behavior, when it was common, led to many AVO interventions in order to maintain a high standard for rider comfort, and to be courteous to other drivers, so that the shuttle was not driving unduly slowly on the road.

The shuttle continues to exhibit similar behavior when there are large groups of pedestrians on the sidewalk, but we can expect this behavior to improve with future software releases as our logic for pedestrian interactions is refined.

Insight 3:

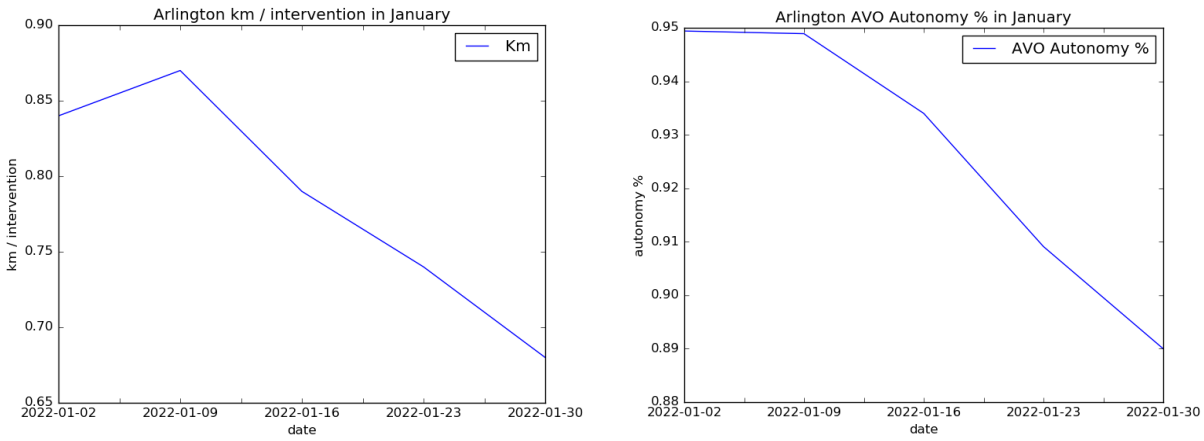

Figure 4: Arlington km / intervention (left) and AVO Autonomy % (right) for the month of January

Although the site saw improved autonomy numbers over previous months (especially the two weeks at the beginning of the month that had nearly 95% AVO Autonomy), weather conditions made it difficult to sustain the same autonomy percentages over the entire month. The AVO Autonomy % dropped slightly from nearly 95% down to 89% over the course of January. Site staff primarily attributed this to two factors.

First, the rain Arlington experienced during January was on-and-off throughout the day, and varied over the service area. This meant that there were places where AVOs were still able to operate in autonomy on the route, but there were also a number of times and locations where AVOs had to drive manually for comfort reasons, as our shuttle's autonomy performance reduces in heavy rain.

The varying weather conditions were handled well by AVOs and site staff, but frequent switching from autonomy to manual led to slightly lower autonomy numbers overall.

Secondly, site staff mentioned that in the days after the rain stopped, puddles left in the road could splash up and cause the shuttle's sensors to believe an object was nearby, so AVOs were advised to drive manually through these areas with large puddles. This also contributed to slightly lower autonomy percentages in January than may be expected during periods with better weather conditions.

Software Updates

There were no major or minor software updates in January.

Arlington RAPID

Autonomy Insights Report

February 2022

Autonomy Heatmap Overview

Figure 1: Autonomy Utilization Heatmap for Jan (Left) and Feb. 2022 (Right)

Above are the autonomy heatmaps for January and February. Circles in blue denote areas of low autonomy utilization, while areas marked in red denote areas of high autonomy utilization. Average autonomy utilization was 87.72% for the month of February, as compared to 93.6% in January. This autonomy percentage filters for times where the Autonomous Vehicle Operator (AVO) was driving through a required manual zone (such as an unprotected turn) or off route (such as driving around a construction diversion).

An intervention for one of the following reasons is considered a planned intervention, where we always expect the AVO to take control of the shuttle. An intervention for any other reason is an unplanned intervention.

- Passenger Stops: The AVO must manually shift into park when they have arrived at a passenger stop. This results in the autonomous system switching to manual mode.
- Require Manual Zones: These are areas/actions that are outside of the vehicle's Operation Design Domain (ODD) such as an unprotected left turn. The vehicle is programmed to come to a stop, requiring the AVO to take over.

	January 2022	February 2022
Interventions	18,763	16,892
Km / intervention	0.42	0.34
Km / unplanned intervention	0.8	0.54
Interventions at Passenger Stop	1,514 - 8%	977 - 6%
Interventions at Require Manual Zone	7,383 - 39%	5,162 - 31%

Areas of Focus

Below are specific learnings from discussions with AVOs, log review, and in-person testing.

Insight 1:

After improved autonomy performance in January, Arlington saw a slight decrease in autonomy performance in February, which can be attributed to a few different factors. In particular, construction on a number of streets around Arlington is a large inhibitor to autonomy since our vehicles utilize a static map in order to understand their surroundings. As a result, new construction projects led to AVOs driving the shuttle manually to safely guide the vehicle and the passengers through the construction zone.

One location where this issue was particularly apparent was on Summit Ave. as shown in Figure 2. The autonomy utilization on Summit Ave. was very high in January, but new construction in February led to significantly reduced autonomy utilization.

At the north end of Summit Ave., near the Swift Center, there was a route fix made at the beginning of February that should improve autonomy utilization in that area and will be deployed to the fleet in the next software release toward the end of March.

Site staff also reported construction on Greek Row, Abram, and Front St. which all led to reduced autonomy performance over the previous month.

Figure 2: Autonomy map on Summit Ave. for Jan. (left) and Feb. 2022 (right)

Insight 2:

Similarly to the previous month, weather conditions in February continued to impact autonomy utilization. During every week, temperatures dipped below freezing at least once, which was often accompanied by precipitation. AVOs are generally instructed to operate the shuttles manually when the weather changes to moderate levels of precipitation, but in freezing conditions, when the road surface can be difficult to navigate in general, our AVOs drive manually the entire time, which greatly reduces autonomy utilization.

Hopefully, as the weather continues to warm up and precipitation becomes less frequent, there will be fewer weather-related breaks in autonomy at the Arlington site.

One other point of note: the Arlington site had two brand new AVOs start this past month, which tends to come with a learning curve as new AVOs get comfortable with the technology and the transitions between autonomy and manual driving.

Insight 3:

At the beginning of last month, members of our autonomy team visited the Arlington site to test the 8.0 software release, which is expected to be released as production software in early April. Overall the feedback was very positive as the autonomy team felt that the new software fixes a number of current issues with our shuttle's autonomy, while also providing better insight into the root causes of other existing issues so that they can be addressed in future software releases.

Among the new features in the 8.0 software release are:

- Improved traffic light detection which should improve our performance at intersections
- Improved in-lane maneuvering so the shuttle can better drive past small objects sticking out into the road like trash cans or parked cars
- Better interactions with pedestrians and other Vulnerable Road Users (VRUs) in crosswalks that should make shuttle behavior feel more natural and comfortable for both passengers and pedestrians
- Fewer instances of the vehicle losing autonomy due to being overwhelmed by having too many agents in the environment

Software Updates

There were no major or minor software updates in February.

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Arlington RAPID

Autonomy Insights Report

March 2022

Autonomy Heatmap Overview

Figure 1: Autonomy Utilization Heatmap for Feb (Left) and Mar. 2022 (Right)

Above are the autonomy heatmaps for February and March (1st - 18th). Circles in blue denote areas of low autonomy utilization, while areas marked in red denote areas of high autonomy utilization. Average autonomy utilization was 87.5% for the month of March, as compared to 87.7% in February. This autonomy percentage filters for times when the Autonomous Vehicle Operator (AVO) was driving through a required manual zone (such as an unprotected turn) or off route (such as driving around a construction diversion).

An intervention for one of the following reasons is considered a planned intervention, where we always expect the AVO to take control of the shuttle. An intervention for any other reason is an unplanned intervention.

- Passenger Stops: The AVO must manually shift into park when they have arrived at a passenger stop. This results in the autonomous system switching to manual mode.
- Require Manual Zones: These are areas/actions that are outside of the vehicle's Operation Design Domain (ODD) such as an unprotected left turn. The vehicle is programmed to come to a stop, requiring the AVO to take over.

	February 2022	March 2022
Interventions	16,892	12,620
Km / intervention	0.34	0.36
Km / unplanned intervention	0.8	0.57
Interventions at Passenger Stop	977 - 6%	749 - 6%
Interventions at Require Manual Zone	5,162 - 31%	3,881 - 31%

Areas of Focus

Below are specific learnings from discussions with AVOs, log review, and in-person testing.

Construction on Front St:

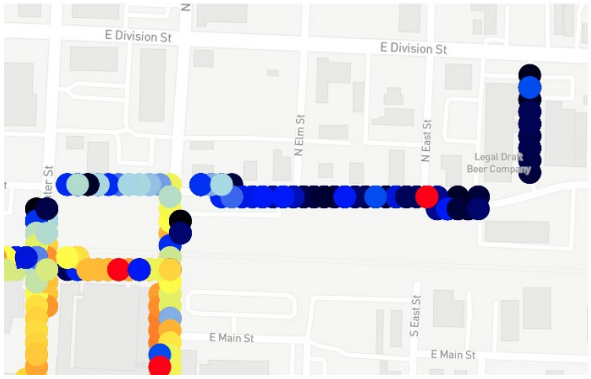

Figure 2: Autonomy utilization along Front St.

Autonomy utilization decreased through March as construction along Front Street prevented the AV from being driven autonomously. Currently, the AV is programmed to drive on a fixed set of pre-mapped roads. If a spot is known to be under construction for a long time, that section of the route can be disabled as long as there are alternative paths for the AV to take in the route map. This would require a software update to the vehicle, so it's only feasible for long-term closures. The May

team is currently working on the infrastructure to perform this kind of route adjustment within 24 hours.

Mitchell St.:

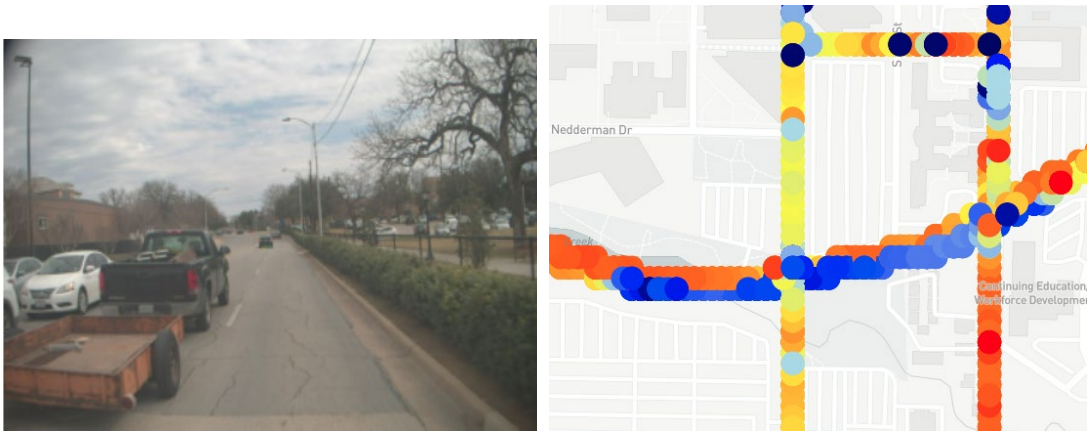

Figure 3: Narrow lanes (left) and autonomy utilization (right) on Mitchell

Narrow lanes such as those on Mitchell continue to be a challenge for the autonomy stack. AVOs report that most interventions in this area are due to the vehicle slowing down unnecessarily, as it thinks there is not enough space to get through. The Autonomy team will be watching for improvements, as the new autonomy software (version 8.0) set to release in April should help in these situations. Specifically, the vehicle is more adept at executing small nudges to either side of the lane center to create space between itself and others in the environment.

Stadium Turnaround:

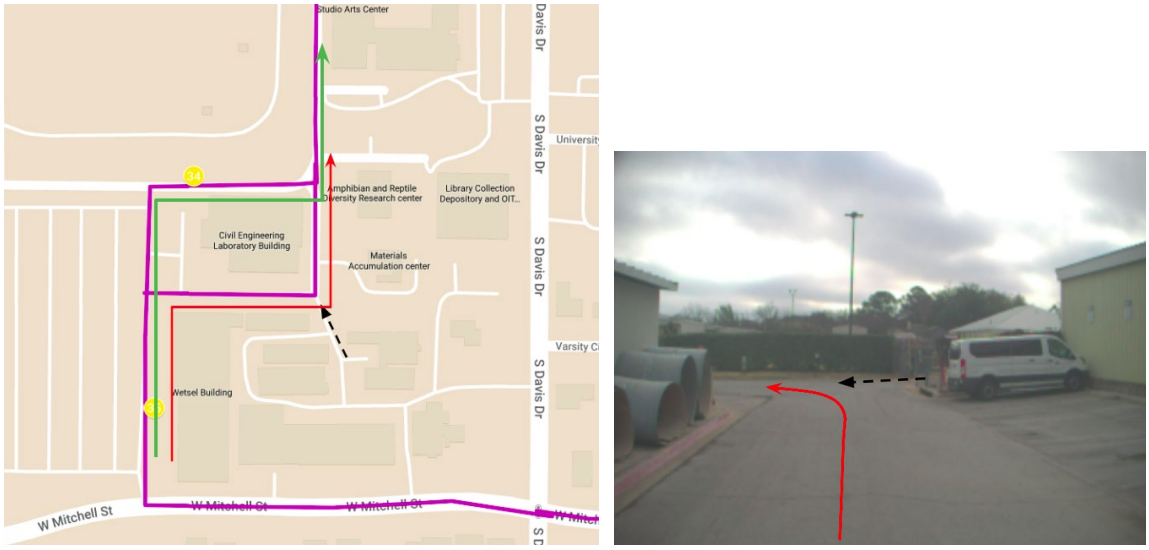

Figure 4: Other vehicles' path (broken black), old routing (red), and new routing (green) when passing the stadium

Currently, the AVs use the loop around the Civil Engineering Lab (shown above) to connect to the north side of the route and to turn from WB to EB Mitchell Street. Vehicles departing the parking lot at the southeast corner often do not yield when leaving this blind exit (marked in the above image with a black dashed arrow). This resulted in requiring the AVOs to take over manually in this section. As a permanent fix, the routing will be adjusted to allow the road marked in green to be available for the AV to drive through. This will negate the need to drive past this blind exit.

Software Updates

A minor software revision (7.4.0) was released in March. The primary autonomy improvement is the ability for the AV to depart stops autonomously. AVOs shift into Park when at a passenger stop which drops them into manual mode. Now, the vehicle will stay in autonomous mode when shifted into Park from Auto, and subsequently from Park back into Drive.