Create and Use Field Boundaries

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Boundary Overview

Boundaries are a foundational piece of precision agriculture. When created correctly and accurately, boundaries can be a very powerful tool and provide tremendous value to an operation. Boundaries tell the operator and machine the size, shape, and working area of a field. Whether hand drawn in Operations Center for field detection purposes or driven to achieve Autonomy quality for use with autonomous solutions, boundaries offer a great deal of insights to an operation and are required for many technologies to function.

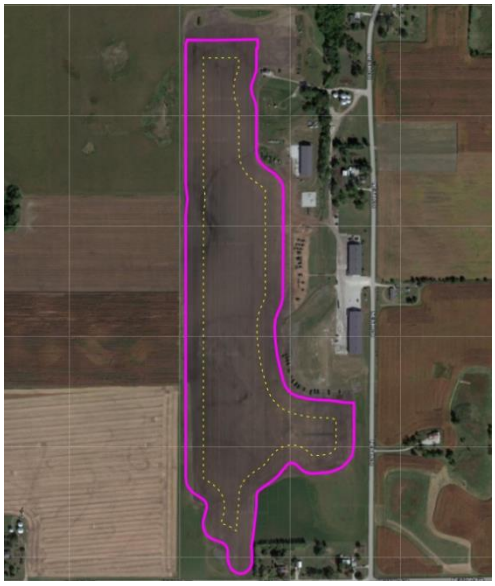
Boundary Definitions

Exterior Boundaries are used to define the outer perimeter of the workable area of the field. Boundaries tell the machine and operator the size and shape of the field. This boundary also is key in mapping field location, utilizing machine guidance, and executing work. Exterior boundaries are essential, whether just starting to implement precision ag technology in an operation or preparing for autonomy. There is value that comes from boundary creation for every customer. Exterior boundaries appear pink within the display and Operations Center. This showcases that the boundary is impassable, and work should only occur within the created shape. A great example of the capabilities of an exterior boundary are seen with Section Control. Work is only completed within the boundary and sections are turned off as they cross outside of the boundary.

Exterior boundaries can be created in different ways – driven using a receiver and display, created from previous coverage, hand drawn in Operations Center, or imported from another system. More information on each creation type is included later in this document.

An exterior headland is associated with an exterior boundary and tells the machine where end of row turns should occur. Headlands are dashed yellow in the display and Operations Center. Headlands are crucial for technologies like ATTA, AutoPath, and Autonomy.

There are several types of headlands. The first is a driven headland which is created by driving a custom path in the field using a display and receiver. Once driven, that headland can be saved and shared to Operations Center. The two other headland types shown below can be created in the display or within Operations Center.



Constant Offset

Enter the width of the desired headland and the system will automatically offset that distance from the external boundary to create the headland.

This headland type is required for Autonomy.

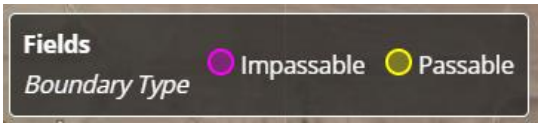
Top and Bottom Offset

Input the heading angle followed by the width of the desired headland. The system will offset that distance from the external boundary at each end of the field according to the heading angle.

Interior Boundaries are used to mark the perimeter of a non-operational area in a field.

There are two types of interior boundaries:

1. An impassable boundary is an area of the field that should not be crossed by a machine and implement and is not farmed. Impassable boundaries are pink within the display and Operations Center. An example would be a tree line, power lines, or a ditch.
2. A passable boundary is an area of the field that can be crossed by a machine and implement but the operational practice does not occur when within that area. Passable boundaries are solid yellow within the display and Operations Center. Interior passable boundaries are often used with Section Control to prevent application of product inside of the marked area. Think of a shallow waterway that can be driven through but should not be sprayed.

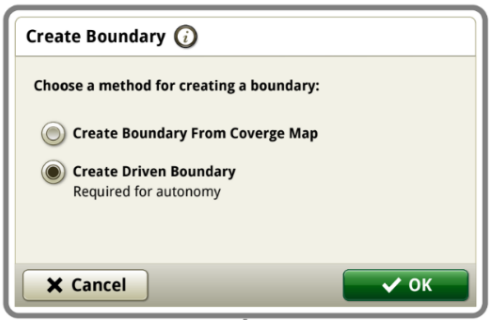


An interior headland is created and paired with an interior impassable boundary. This type of headland is often used with ATTA and compatible guidance tracks to establish a turn area within the field to complete work more efficiently. These headlands can be established using constant or driven creation methods.

Boundary Creation Methods

Boundaries can be created in multiple ways:

1. Driven
   Customers can drive boundaries using a machine equipped with a receiver and display. Using this creation method allows customers to precisely outline the outer edge of the working area of the field. In the display, navigate to Fields and Boundaries, identify the desired Client Farm Field, choose to create boundaries, and select “create driven boundary”. Driven boundaries are required to achieve a verified level of accuracy and system requirements needed for use with autonomy.



   Many customers use a Gator equipped with the required technology to map boundaries. This allows for very precise movements around obstacles, curves, and corners to map the most accurate representation of the working area. Ensure that TCM Calibration has been completed prior to recording.

   In the example on the left, a ‘safety rod’ or ‘buffer bar’ has been added to the front of the Gator. This gives the operator a visual reference as they drive and record a field boundary, of where any implement overhang, like the planter marker, will be located when traveling past an obstacle near the edge of the field.

   The operator must position the Gator to avoid the rod contacting the obstacle. When the operator does this, the boundary is recorded a safe distance from the obstacle to prevent damage during later operations completed using that boundary.

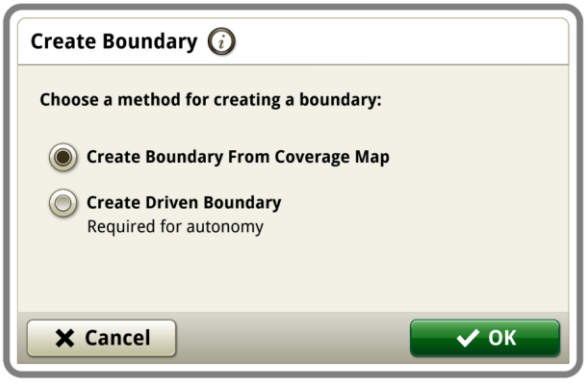
   This method is HIGHLY recommended when driving a field boundary to prevent machine contact with objects along the border. More information can be found in the best practices section and the appendix.

2. From Coverage

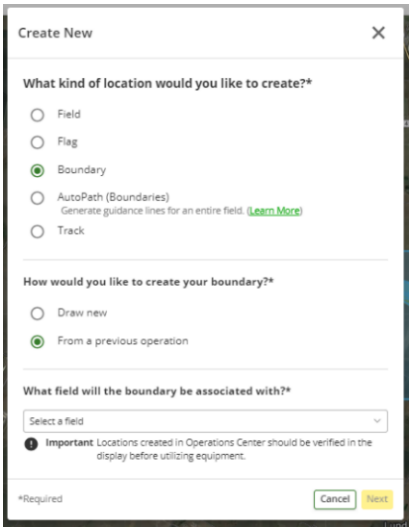
Boundaries can be created from past coverage in the display or in Operations Center.

In the display, navigate to Fields and Boundaries, identify the desired Client Farm Field, choose to create boundaries, and select “create boundary from coverage map”. Select which past operation in that field should be used to create the boundary. The field boundary will be established from the outer edge of coverage logged in that operation.

In Operations Center, navigate to Land, click the Add icon, choose to create a new boundary, and select “from a previous operation”. Select the field where the coverage exists and choose from a list of past operations completed in that field. The field boundary will be established from the outer edge of coverage logged in that operation.



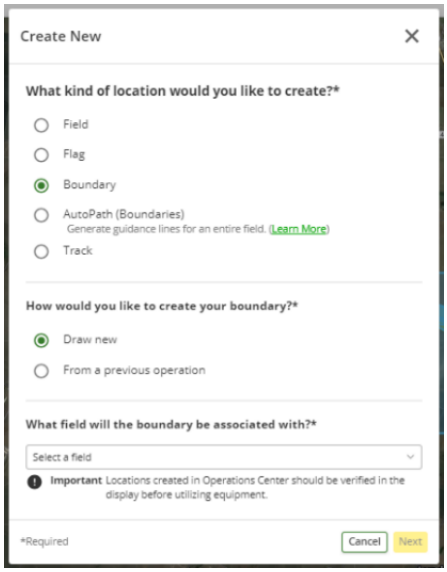
From coverage in the display



From coverage in Operations Center

3. Hand drawn in Operations Center

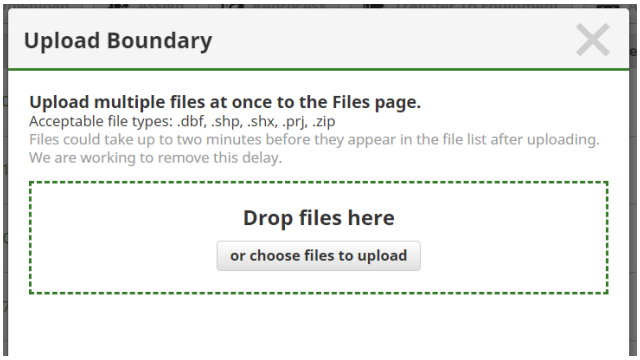
In Operations Center, navigate to Land, click the Add icon, choose to create a new boundary, and select “draw new”. Select the field that you want to create a boundary for. Use the computer mouse to create the shape around the field edge.



Keep in mind that the map in Operations Center is not a live view of the geographical area. Additionally, the map is in reference to meters which is not accurate enough to reflect some changes that can be at the centimeter scale. This creation method is a great way to identify and mark field areas for an organization, but it is not considered accurate enough to use with most technologies.

4. Imported from a legacy or third-party source

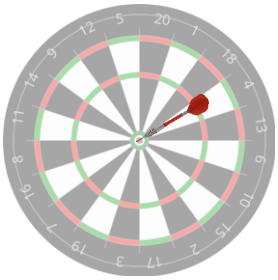
   If a boundary was created using a legacy John Deere display or a third-party source, a shape file can be imported into Operations Center. First you need to export the file that includes the boundary from the other system using a USB. Then use the “Upload Boundary” button on the Operations Center Files page. Upload the shape file from the USB into Operations Center. Once it has been recognized and uploaded, the file type will show as “setup data” and the boundary will appear in Land.



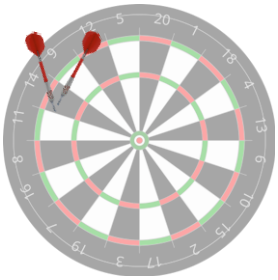
   Each of these creation methods offer a different level of accuracy of the data points that make up the boundary. This means that there are different recommended uses and technologies supported for each creation method. This will be explained more later in this resource.

Correction Modes

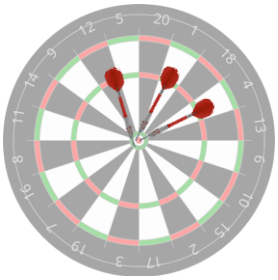
Before looking deeper into boundary quality, it is important to understand signal types. Signal types or correction modes dictate the level of accuracy and repeatability possible for the boundary. Think about playing a game of darts. Accuracy is how close you can get to the bullseye. Repeatability is how many times you can place a dart in the exact same place on the board consecutively. A highly successful dart player has both accuracy and repeatability. They can hit the bullseye every single time.



Accurate



Repeatable



Accurate & Repeatable

For a farmer, accuracy and repeatability are just as important when it comes to preparing, planting, protecting, and harvesting crops. As a farmer records a boundary, they want the line to track exactly where they intended. The reality is that whether hand drawn, created from coverage, or driven, each boundary creation method offers a different level of accuracy. Below is a table that showcases the difference between each signal type.

	SF1	SF2	SF3	Radio RTK	SF-RTK
Pull In Time	10 minutes	90 minutes	30 minutes	Less than 1 minute	8 minutes
Accuracy	+/- 15 cm	+/- 5 cm	+/- 3 cm	+/- 2.5 cm*	+/- 2.5 cm
Repeatability	none	none	9 months	long-term repeatability	long-term repeatability**
Receiver Compatibility	StarFire™ 3000 StarFire™ 6000 StarFire™ 7000 StarFire™ 7500	StarFire™ 3000	StarFire™ 6000	StarFire™ 3000 StarFire™ 6000 StarFire™ 7000 StarFire™ 7500	StarFire™ 7000 StarFire™ 7500

*Within 12 miles of the Base Station
**Refer to sales manual for geographical limitations

Important Notes

- Do not mix and match correction signals. Doing this results in decreased accuracy of field work.
- The same correction mode must be used when creating the boundary and when using the boundary. For example, if a boundary that was created using RTK is loaded into a machine to be used with an operation running SF1, it will only be as good as SF1. The exception to this rule is SF3 and SF-RTK. These signals can be mixed throughout a crop cycle.
- If using Radio RTK, refer to this video to learn how to add, edit, and view Base Station information. You will see how to correctly associate the Base Station with the field and enable “Automatic Base Station Switching” to keep the Base Station up to date when moving between fields.

Boundary Quality

John Deere is developing solutions to support customers wherever they are on their technology journey. Continued work will go into developing further enhancements to boundary creation to better the overall experience for all customers. Let's dig into the boundary quality levels, how to create each type, and the recommended use cases for each.

<table>
<tr><th>Creation Source</th><th>Creation Method</th><th>Recommended Uses</th><th>Boundary Quality</th></tr>
<tr><td>Unknown</td><td>Imported from competitive system
Created using legacy displays/software</td><td>Use with Discretion</td><td rowspan="6">Not Autonomy Capable</td></tr>
<tr><td rowspan="2">Operations Center</td><td>Hand Drawn</td><td rowspan="3">• Maps
• Reporting
• Field detection
• Weather
• Logistics
• Predictive Ground Speed Automation</td></tr>
<tr><td>From Coverage</td></tr>
<tr><td rowspan="3">Display</td><td>From Coverage</td></tr>
<tr><td>Driven using SF1 or SF2</td><td rowspan="2">All previous uses plus:

• Section Control
• AutoTrac (Boundary Track)
• AutoTrac Turn Automation
• AutoTrac Implement Guidance
• AutoPath (Rows)
• AutoPath (Boundaries)
• Machine Sync</td></tr>
<tr><td>Driven using SF3</td></tr>
<tr><td>Driven using RTK or SF-RTK
(without autonomy requirements met)</td><td></td><td></td></tr>
<tr><td>Driven using RTK or SF-RTK
(with autonomy requirements met)</td><td>All previous uses plus:

• Autonomy</td><td>Autonomy</td></tr>
</table>

Autonomy

Autonomy boundaries achieve the level of accuracy and system requirements that deem them usable for the level of safety and precision needed by autonomy. Autonomy boundaries are required for autonomous operations.

Autonomy boundaries can be used with Premium 3.0, Automation 4.0, and G5 Advanced features but are not required.

Requirements

Display	Gen 4 V2 (Integrated or Universal) G5 / G5 Plus (Integrated or Universal)
Display Software	24-2 or newer
Machine or Implement Receiver*	StarFire™ 7000 or StarFire™ 7500
Correction Mode**	Radio RTK or SF-RTK

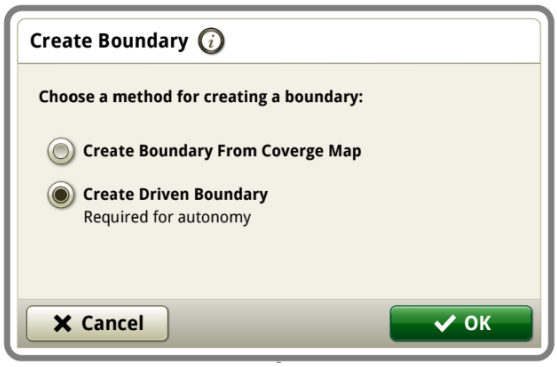
**Autonomy Boundaries can be recorded using either a StarFire™ 7000 or StarFire™ 7500. Autonomous machines require a StarFire™ 7500 to run autonomy.*

***Shared signal can be used to record an Autonomy Boundary. Refer to the appendix to understand further shared signal requirements to achieve an Autonomy Boundary.*

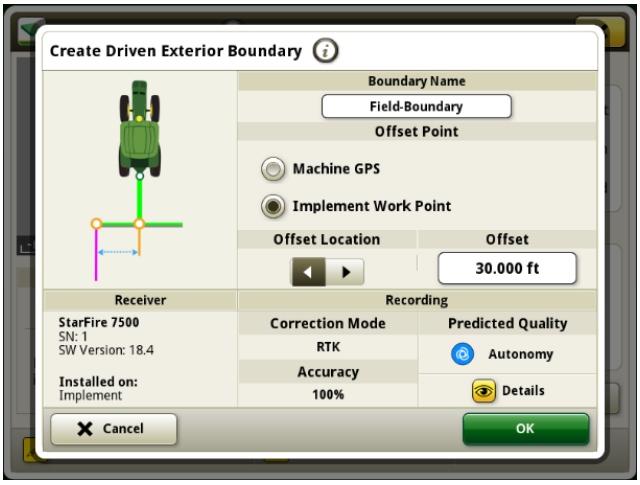
Creating an Autonomy Boundary

Refer to the best practices and troubleshooting section for further assistance when creating an Autonomy Boundaries.

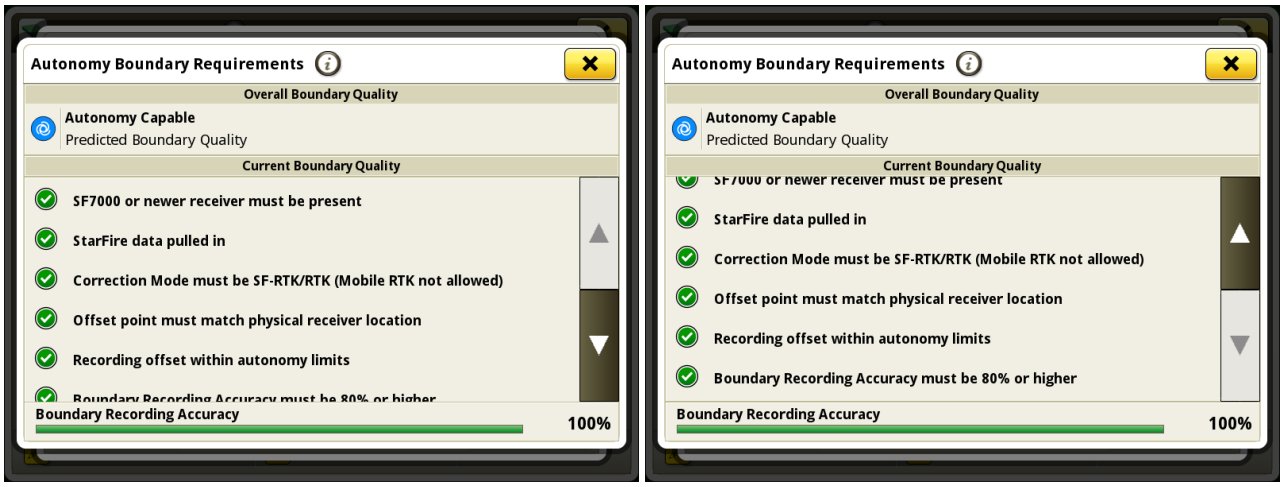
1. Begin creating a boundary
    - Drive to the location in the field where you want to start recording the boundary.
    - To record an Autonomy boundary, the driven creation method must be used. All other creation methods will result in a Not Autonomy Capable boundary.



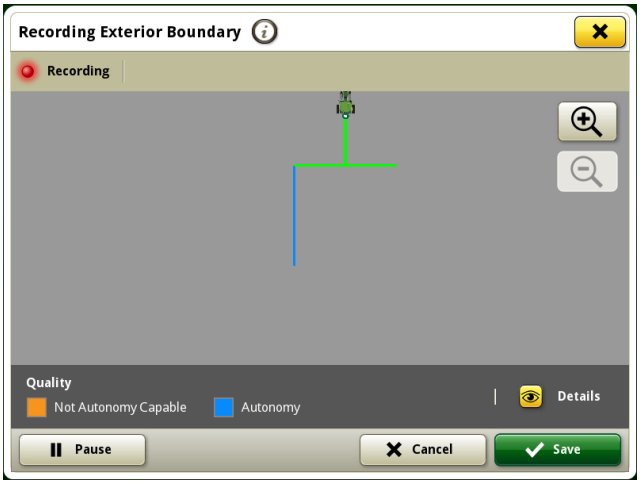
2. Complete setup and verification steps prior to recording



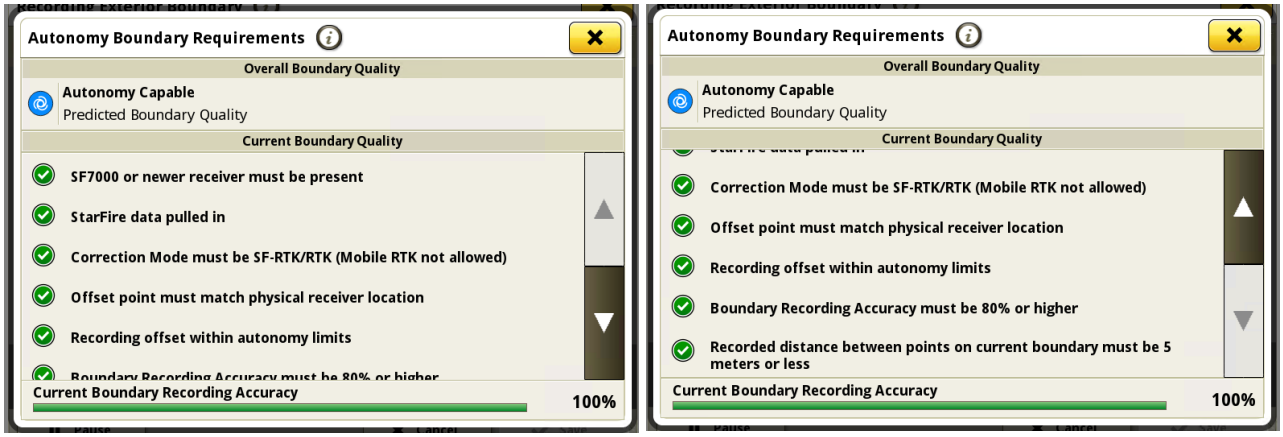
- Input a boundary name.
- Determine if you are using a machine or implement mounted receiver for recording. Ensure that the receiver is mounted on that selected location – machine or implement. The correct selection must be made so that an accurate reference point is used during recording.
- Set a left or right offset if needed and input the correct offset measurement. The offset is based on where the center of the receiver is located to the outermost point of the machine/implement - where the boundary should be placed while recording. Input zero into the offset measurement if no offset is being used and the boundary should be placed at the center of the receiver location.
    - If using a machine receiver, the offset should be ½ the machine width measurement. The overall entered offset must be less than 4 meters (13 feet).
    - If using an implement receiver, the offset should be ½ the working width measurement. The overall entered offset must be less than 16 meters (52 feet).
    - Refer to the best practices section for more information about using a ‘buffer bar’ when recording.
- The Receiver and Correction Mode information will automatically populate based on the Offset Point selection that was made.
- Accuracy is referring to the overall boundary recording accuracy, not the signal accuracy that is found in the receiver settings. Boundary recording accuracy factors in different data inputs that allow the system to adequately determine each points’ reference location when recording. This percentage can also be found on the details page by clicking the details button.
- Ensure that the predicted quality shows “Autonomy”.
    - If predicted quality shows “Not Autonomy Capable”, click the details button to review the specific system requirements and fix any qualifications that do not show a green check mark prior to recording. If the predicted quality is Not Autonomy Capable, the boundary will not be able to achieve Autonomy quality while recording.
    - Prior to recording, the details page shows the predicted quality based on current prerequisites met.



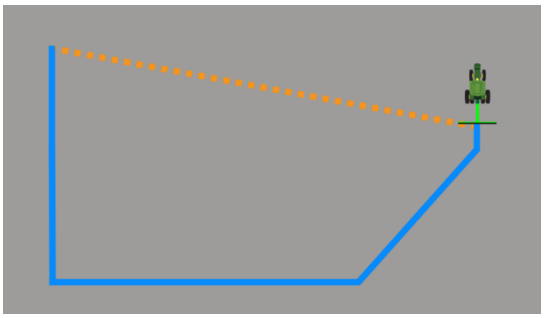
3. Record the boundary
    - Begin driving the boundary. Keep in mind that you can review the details page at any time to ensure all system requirements remain checked.



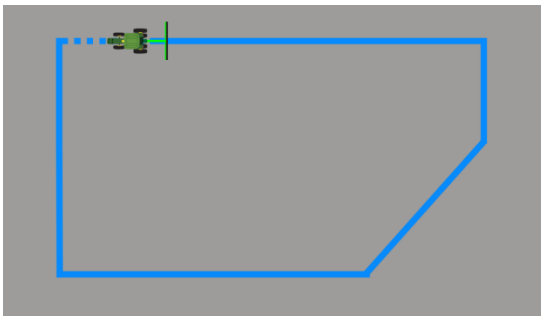
    - If at any time, a portion of the boundary falls to Not Autonomy Capable, that portion will be mapped as orange. The entire boundary will then be classified as Not Autonomy Capable, and the boundary will not be able to be used for autonomous solutions. If this occurs, use the details page to understand what requirement is no longer met.
    - While recording, the “current boundary quality” checklist only highlights the status of the boundary in that current moment. It is not a cumulative overview for the entire boundary.



- While recording, a dashed line will showcase a connection from the current point to the starting point.
    - If the dashed line is orange, the distance between points is greater than 5 meters and/or prerequisites are not met
    - If the dashed line is blue, the distance between points is less than 5 meters and all prerequisites are met.

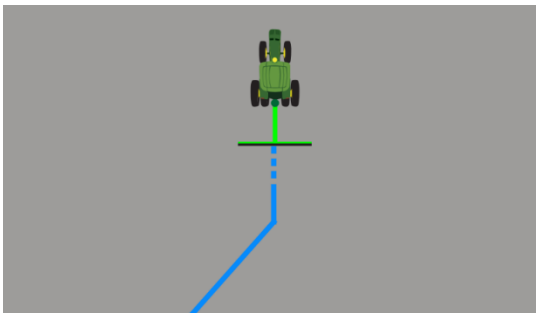


If saved at this time, the orange portion of the boundary would be Not Autonomy Capable meaning the entire boundary would be Not Autonomy Capable.

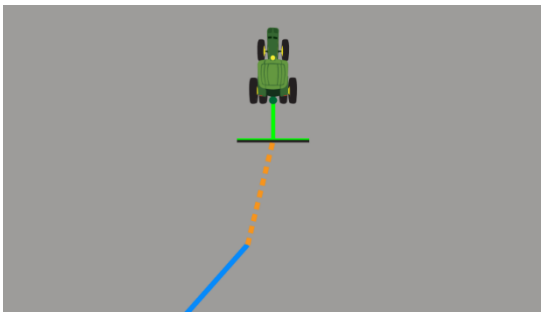


If the dashed line is blue, the distance between points is less than 5 meters and all prerequisites are met. If saved at this time, that portion of the boundary would be classified as Autonomy.

- This same dashed line will appear when using the pause/resume functionality.
    - If the dashed line is orange, the distance between points is greater than 5 meters and/or prerequisites are not met.
    - If the dashed line is blue, the distance between points is less than 5 meters and all prerequisites are met.

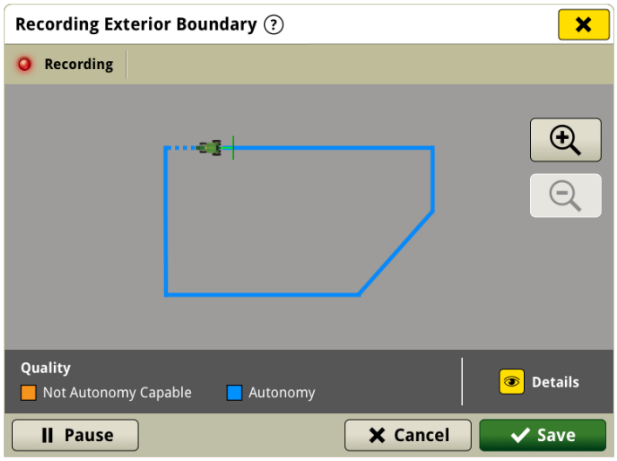


If you resume recording at this time, the blue portion of the boundary would be classified as Autonomy.

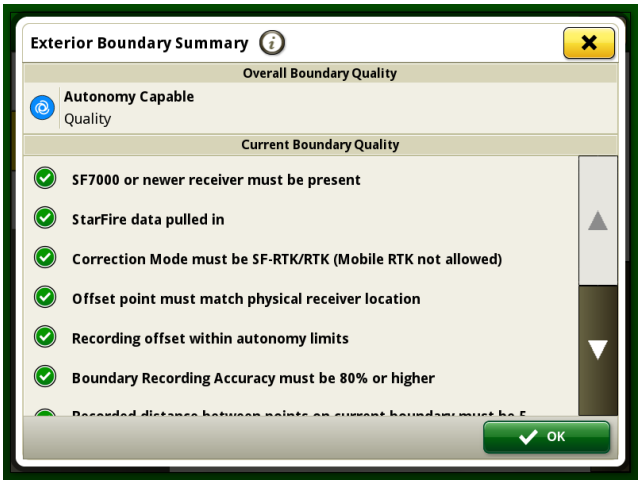


If you resume recording at this time, the orange portion of the boundary would be Not Autonomy Capable. If trying to achieve an Autonomy Boundary, return to a 5 meter distance from the pause point before resuming (indicated by blue dashes).

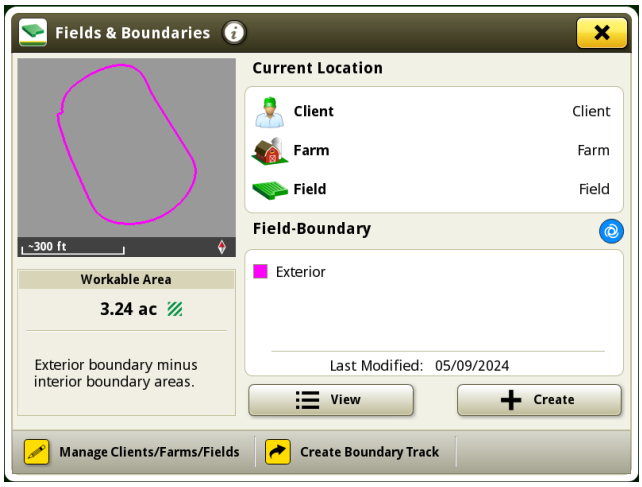
4. Review the map and details page prior to saving
    - After saving the boundary, the quality map showing the blue and/or orange colors will no longer be accessible.
        - Consider taking a photo of the map if there are Not Autonomy Capable portions so when preparing to rerecord to achieve Autonomy quality, those portions can be investigated further.

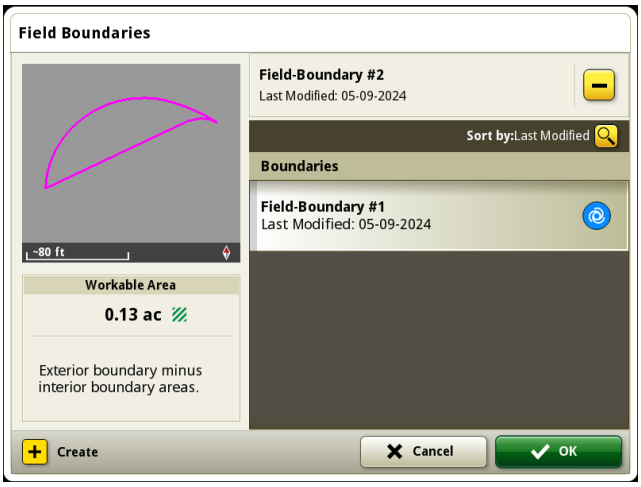


- After recording is saved, the boundary summary page showcases the cumulative quality and system requirements for the entire boundary. Once this boundary summary is closed, the checklist for that boundary will no longer be accessible.
    - Consider taking a photo of the summary page prior to exiting if there are system requirements that do not have green checkmarks. This checklist can be investigated further when preparing to rerecord and achieve an autonomy boundary next time.



5. Review the boundary quality on the display
    - Autonomy quality is only associated to the exterior boundary. Any interior boundaries that fall within that boundary set will also be usable by autonomy; no system requirements need to be met for interior boundaries.

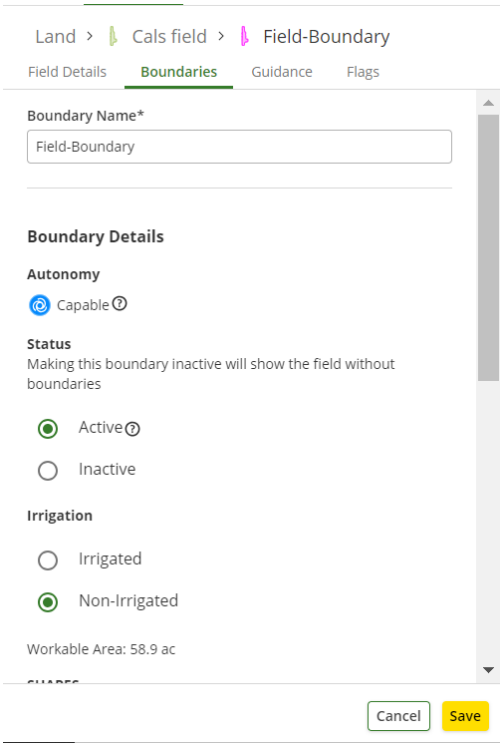




After saving a boundary, a blue Autonomy icon will be the indicator that the boundary achieves Autonomy quality requirements and is compatible for use with autonomous solutions.

Within the Field Boundaries page, the blue Autonomy icon will indicate which boundaries are Autonomy boundaries. If the icon is not present, the boundary is Not Autonomy Capable.

6. Review the boundary quality in Operations Center
    - The Autonomy or Not Autonomy Capable quality icon will also be associated to boundaries within Operations Center.



Some boundary edits can be made within Operations Center and **will not** impact the boundary quality:

- Changing the boundary name
- Shrinking the boundary as long as no new areas outside the initial boundary are included in the new boundary area

If the boundary was Autonomy capable initially, these changes will result in the boundary remaining Autonomy capable.

<u>IMPORTANT</u>: Moving or adding points outside of the original boundary will result in the boundary becoming Not Autonomy Capable. A warning message will appear to notify the user that saving will change the boundary to Not Autonomy Capable and will not be able to be reverted.

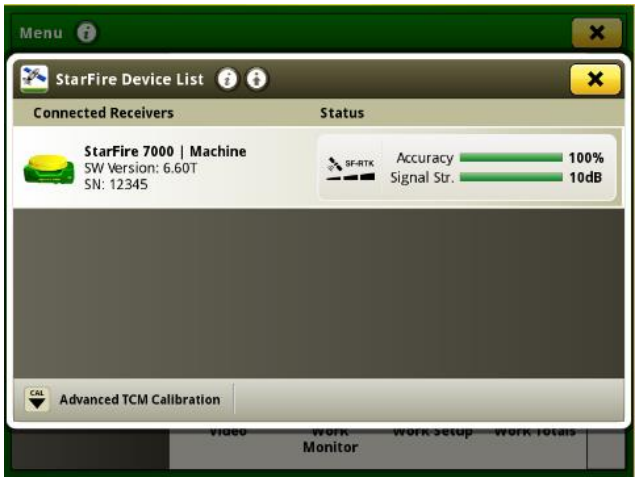
Best Practices and Troubleshooting

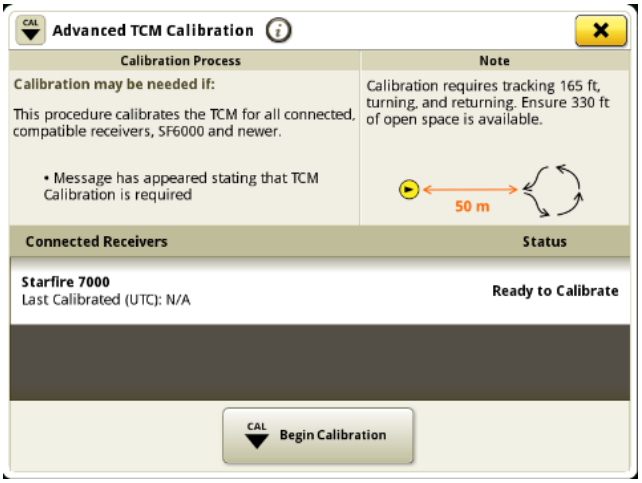
1. It is important to correctly utilize a ‘buffer bar’ if using a Gator to map boundaries. There are two recommendations that should be used when mapping boundaries for Automation or Autonomy.

- **All boundary users** - Account for the difference between the working width and physical width when recording. Measure your implements, determine the implement with the greatest difference between these two measurements, and set the buffer bar according to that value. Use that buffer bar to stay away from any obstacles like fences, buildings, tree lines, etc. This is a best practice for all boundaries created for Automation and Autonomy. This will ensure that the entire physical width remains clear of obstacles that are near the boundary. Refer to the appendix for further assistance with taking these measurements.
- **Autonomy boundary users** - Autonomous machines create a buffer zone 1.5 meters around the outside of the boundary as an added perimeter of safety for the machine. It is meant to protect the machine from tipping or crossing into any specific areas undetected by the camera system. This is strictly for Autonomy users. When you are creating a boundary, to use with an autonomous machine, it is recommended to record at least 1.5 meters away from:
    - areas of sloped land exceeding 11 degrees / 20 percent grade
    - holes, ditches, gullies, steep embankments, bodies of water, other drop-offs
    - dwellings, private properties, buildings, public roadways
    - wind turbines, center pivot irrigation equipment
    - anything low hanging that could interfere with the cab - cables, guywires, branches
    - propane / natural gas inlets or storage

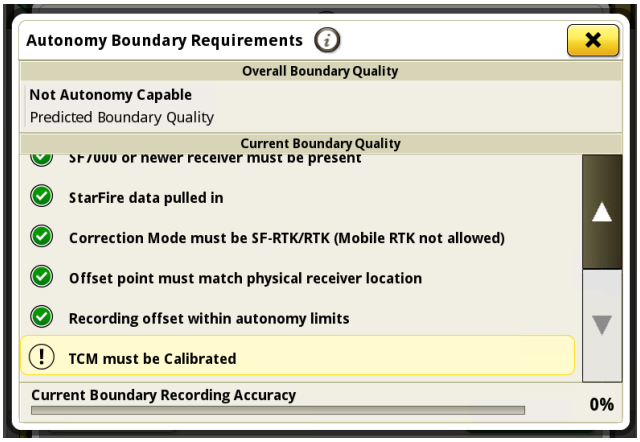
  Not all conditions that can cause a hazard are listed above. Be alert for any situation in which stability may be compromised, or hazards are not clearly visible. Make reasonable attempts to map out the hazard with Exterior or Interior Impassible Boundaries.

2. If the boundary recording accuracy is less than 80%, consider:
    - Shading can cause the boundary recording accuracy to drop below 80%. Staying 1-2 meters away from heavily shaded areas can help to maintain a high boundary recording accuracy.
    - Allow the receiver adequate time to reach full signal accuracy. This can be verified by going to the StarFire page in the Menu. Ensure that receiver accuracy has reached 100%.
    - If any changes have been made to the receiver (changed mounting direction, installed a new receiver, reconnected a receiver). Be sure to drive a short distance to collect some GPS points before recording to achieve higher boundary recording accuracy.
    - A TCM calibration is required to create an Autonomy Boundary. Go to Menu > Applications > StarFire™ > Advanced TCM Calibration.





TCM calibration is specific to machine, so moving a receiver to a different machine will require the calibration to be done again. Additionally, anytime the receiver direction is changed or location on a machine is altered, the TCM calibration will need done again. If a DTC appears in the diagnostics center showing that the TCM has not been calibrated, you will see an unmet prerequisite appear in the details page showing that TCM must be calibrated.



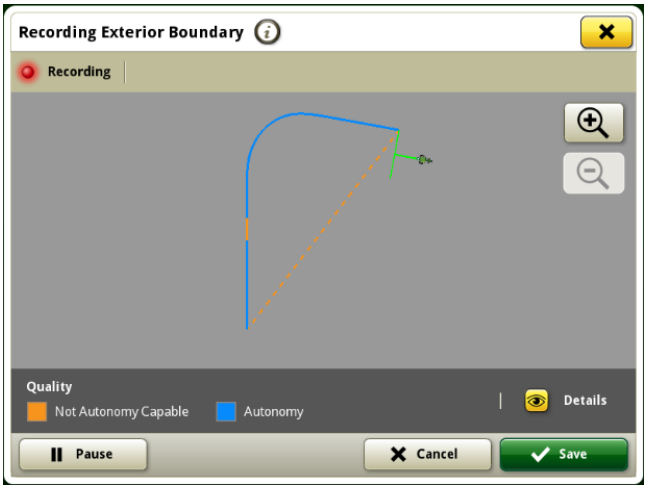
3. Within the details page, if the prerequisite “StarFire data pulled in” is not met, ensure that:
    - RTKX is enabled.
    - Mobile RTK is not being used.
    - The correction mode has not been changed while recording.
    - The base station has not been changed while recording (if using Radio RTK).
    - The receiver had adequate pull-in time.
    - Geographical fault lines can affect boundary creation.
        - Autonomy boundaries cannot be created within 30 km of fault lines. An error will showcase for the receiver.
        - Autonomy boundaries can be created within 30-100 km of fault lines but are not guaranteed. RTK is the recommended signal to use when trying to create Autonomy Boundaries in these areas.

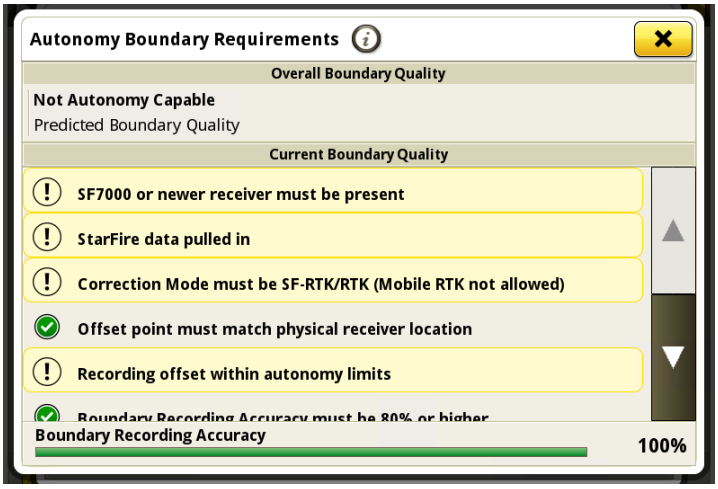
Not Autonomy Capable

As discussed earlier in the guide, the boundary is what tells the machine the bounds that it needs to remain within to complete work during an operation. It signifies the intended working area of the field. When we think about autonomy and removing an operator from the seat of a cab, it is even more essential that the boundary is of upmost accuracy. That is why additional levels of system checks are required to achieve an Autonomy quality boundary (which is outlined in the previous section).

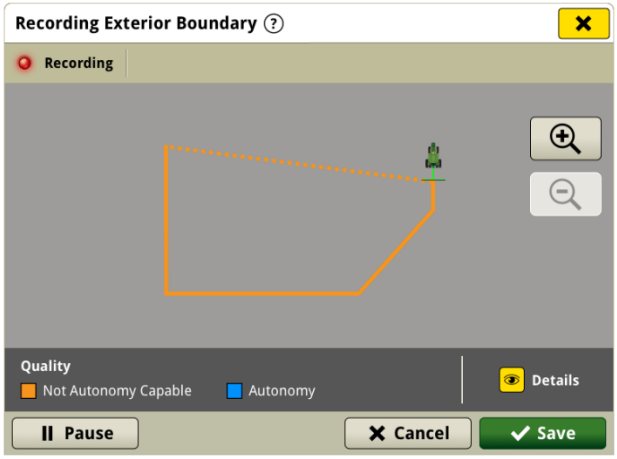
The Not Autonomy Capable boundary quality is associated with a boundary that does not include the level of data accuracy or system checks required for use with autonomous solutions. This boundary type can still be precise and accurate. For instance, think of a boundary that was driven using a G5 display, StarFire™ 7500 receiver, and SF-RTK signal. That boundary is very precise, but it is possible that due to heavy shading of a tree line, the operator could not fulfill all the boundary creation checklist items because overall boundary recording fell below 80% accuracy in that shaded area. That boundary would be classified as Not Autonomy Capable. Boundaries like this, are still able to be used for solutions like Section Control, AutoTrac, AutoPath, Turn Automation, Implement Guidance, Machine Sync, etc. They just cannot be used with Autonomy.

When creating a driven boundary, if any portion of the boundary is mapped in orange and any of the boundary recording checklist is not met, the boundary will be Not Autonomy Capable.





If creating a driven boundary using SF1, SF2, SF3, or mobile RTK signal, the entire boundary will be mapped in orange and will be Not Autonomy Capable.



Refer to the Autonomy section of this guide to better understand the recording requirements needed only if striving to achieve Autonomy quality.

Additionally, a Not Autonomy Capable quality will result from:

- creating a hand-drawn boundary in Operations Center
- using previous coverage to generate a boundary in Operations Center or on the display,

These creation methods should be used to help customers only with mapping, reporting, and field detection. These boundaries help many customers with overall logistics of the operation and monitoring field operations.

Lastly, unknown boundaries that are created and/or imported from a legacy John Deere display or a competitive system are also considered Not Autonomy Capable. These boundaries may be accurate but due to the data processing system utilized to analyze the boundary shape file, there is not a way to categorize the boundary or determine the overall accuracy of the shape. Additionally, there is not a strong way to make recommended use cases for these boundaries. Because of this, customers should use discretion when utilizing this type of boundary for precision ag practices.

This table further clarifies the Not Autonomy Capable classifications:

<table>
<tr><th>Creation Source</th><th>Creation Method</th><th>Recommended Uses</th><th>Boundary Quality</th></tr>
<tr><td>Unknown</td><td>Imported from competitive system
Created using legacy displays/software</td><td>Use with Discretion</td><td rowspan="6">Not Autonomy Capable</td></tr>
<tr><td rowspan="2">Operations Center</td><td>Hand Drawn</td><td rowspan="3">• Maps
• Reporting
• Field detection
• Weather
• Logistics
• Predictive Ground Speed Automation</td></tr>
<tr><td>From Coverage</td></tr>
<tr><td rowspan="3">Display</td><td>From Coverage</td></tr>
<tr><td>Driven using SF1 or SF2</td></tr>
<tr><td>Driven using SF3</td><td rowspan="2">All previous uses plus:
• Section Control
• AutoTrac (Boundary Track)
• AutoTrac Turn Automation
• AutoTrac Implement Guidance
• AutoPath (Rows)
• AutoPath (Boundaries)
• Machine Sync</td></tr>
<tr><td>Driven using RTK or SF-RTK
(without autonomy requirements met)</td></tr>
<tr><td>Driven using RTK or SF-RTK
(with autonomy requirements met)</td><td>All previous uses plus:
• Autonomy</td><td>Autonomy</td></tr>
</table>

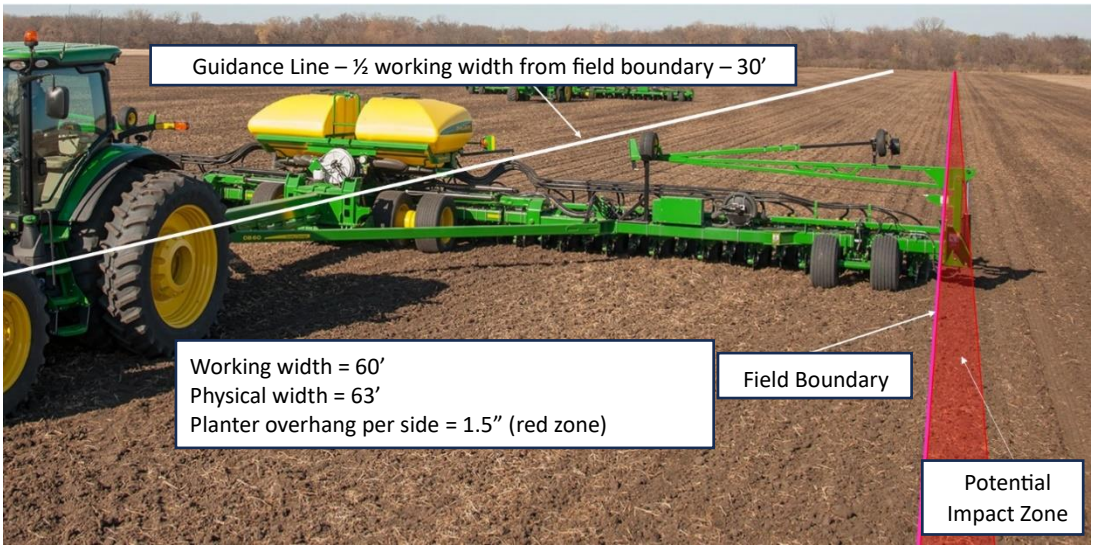
Appendix

Shared Signal Requirements

Shared Signal can be used when recording an Autonomy Boundary. It is important to note that a StarFire™ 7000 or StarFire™ 7500 must be present on both the machine and implement if using shared signal.

Machine	Implement	Can this shared signal pairing work to achieve an Autonomy Boundary?
StarFire 3000 or StarFire 6000 with SF1, SF2, or SF3	StarFire 7000 or StarFire 7500 with RTK or SF-RTK	No
StarFire 7000 or StarFire 7500 with RTK or SF-RTK	StarFire 3000 or StarFire 6000 with SF1, SF2, or SF3	No
StarFire 7000 or StarFire 7500 with RTK or SF-RTK	StarFire 7000 or StarFire 7500 with SF1	Yes – Shared Signal running off of the machine receiver
StarFire 7000 or StarFire 7500 with SF1	StarFire 7000 or StarFire 7500 with RTK or SF-RTK	Yes – Shared Signal running off of the implement receiver

Tips to Measure for a Buffer Bar



Some implements are wider than their working width. For instance, a planter may have a working width of 60’, but a physical width of 63’ due to the marker extensions. When recording a boundary, you must know and consider the extra width of the implement. Think about obstacles in/next to the edge of a field. You need to allow for that additional implement width to prevent machine damage.

To accomplish this, measure how far the marker extension protrudes from the edge of the working width.

Similarly, this customer records the boundary at the left front tire, so the boundary is recorded wherever the outside of that tire drives.