Document Revision History:

Change Date	Rev #	Author	Change Description
03/08/2013	001	S. Jordan	Initial Release
11/22/2017	002	B. Stout	Remove unnecessary checklist and provide general updates.
04/28/2022	003	T. Brown	Reduced erroneous information and re-wrote major sections, reduced pages by 10

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Overview

The RP-VITA is an extremely sophisticated robot capable of autonomously operating in a large semi-structured and dynamic environment. The RP-VITA uses a map and a rich set of sensors to understand and navigate within that environment. Therefore, the creation of the map is critical to the performance of the robot. This map is generated through a mapping procedure that takes into account various types of obstacles in the environment like doors, stairs, ramps and zones of non operation or special behavior.
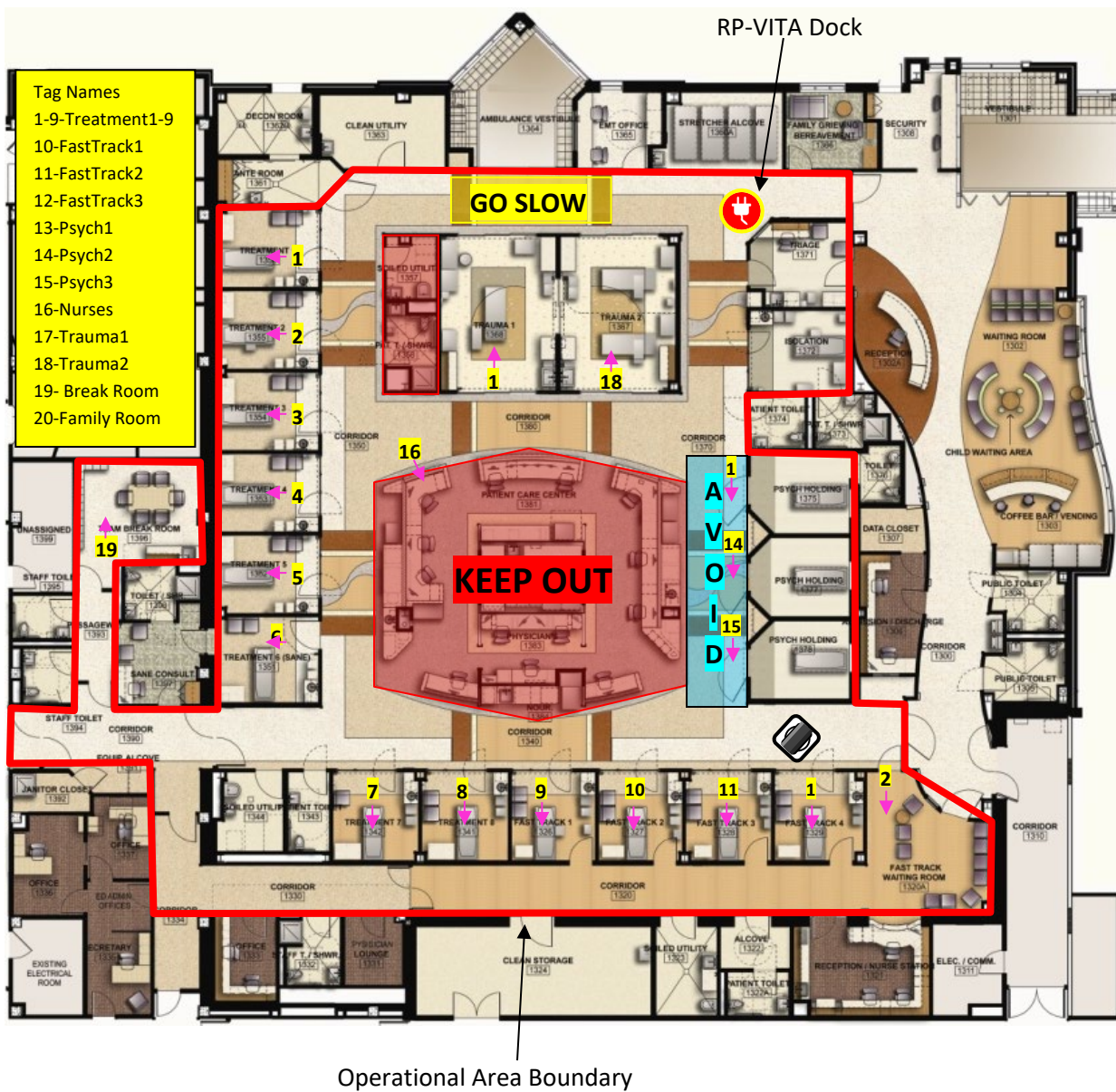
Pre-Mapping Preparation

Before beginning the map creation process a set of information must be gathered from the customer. This should be done by the Sales Engineer before delivery of the robot. The following information is key to the mapping process.

- Floorplan: A floorplan of the region the robot is to be operating in.
- Operational Area: The area that the robot will be able to AutoDrive within. The boundaries of this area should be marked on the floorplan.
- Destination Tags: All the locations that the clinical staff would like the robot to AutoDrive to. These should be marked on the floorplan.
- Destination Orientation: The desired orientation for the robot for each Destination Tag should be defined.
- Destination Tag Names: The names of all the destination locations for the robot. These names should be consistent with the names that the clinical staff currently uses.
- Zones: There are multiple types of regions that need to be identified and defined by the staff and the installation team.
    o No-Go Zone: Areas that the robot is not permitted to go
    o Avoid Zone: Areas the robot should avoid unless there is no other way to get to a destination
    o Slow Zone: Areas that the robot should go slowly in due to things like noise or expected traffic.
    o Threshold Zone: Any thresholds or transition surfaces where the robot would have difficulty traversing or would be to rough for it to cross at full speed.

The following is a good example of a well-marked floorplan

Notice that the boundary of the operational area of the robot is clearly defined. The location of the robot dock is shown. The desired keep out areas and other zones are shown. All destination locations and orientations are identified along with the desired name.


Tag Names
1-9-Treatment1-9
10-FastTrack1
11-FastTrack2
12-FastTrack3
13-Psych1
14-Psych2
15-Psych3
16-Nurses
17-Trauma1
18-Trauma2
19- Break Room
20-Family Room

RP-VITA Dock

GO SLOW

KEEP OUT

AVOID

Operational Area Boundary

Creating a Map

Maps

The RP-VITA needs a map of the operational area that it is intended to be used in. This map is created using a highly accurate, long range laser range finder located at the front of the laser gap of the robot base. The laser range finder scans in a plane that about 8" off the floor and 270 degrees around the robot and at a distance of up to 30m. The following illustration shows the laser sensor range.
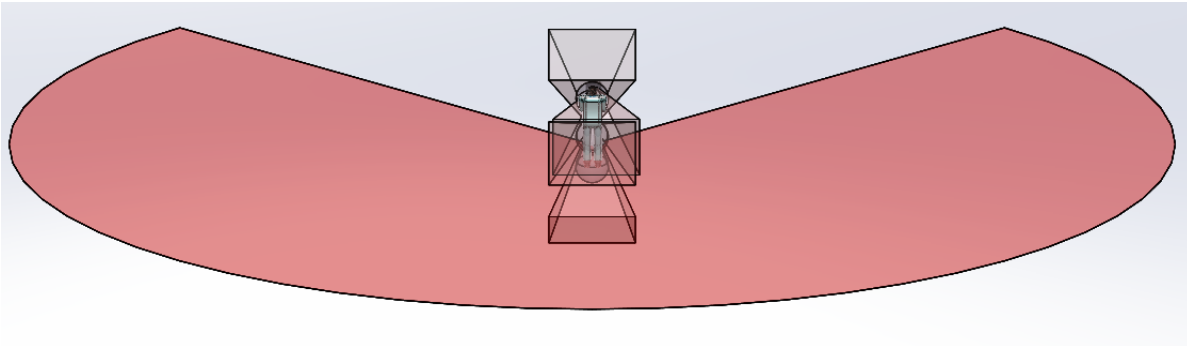
 As the robot is moved around the operational area it notes the radial range measurements it detects and marks them as obstacles in a map. These measurements are taken hundreds of times a second and the result is a highly accurate, high resolution map of all the obstacles it encountered and their relationship to each other. Here is an example of what the Laser range finder can "see". Notice that it sees the wall behind it, down the hallway and across and thru the doorway.
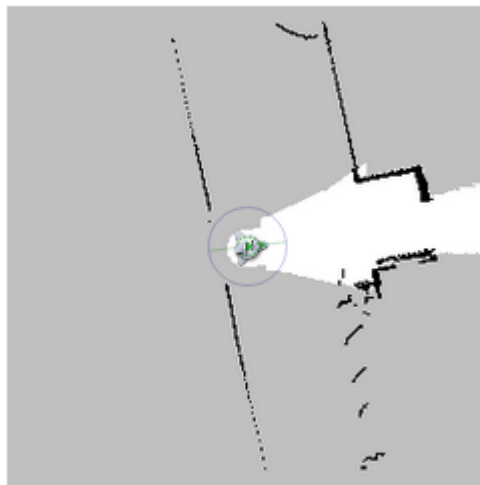
Mapping Interface

The robot's internal map is created using a web-based mapping interface that is hosted by the base.

Mapping can be done in two ways. The first is to use Kaseya to establish a remote session. Then access the mapping interface to create the map.

The second is to use a keyboard attached to the VITA and access the mapping interface on the robot and dive it around manually through that interface. However, this method can be awkward due to crude driving interface and the need to stay out of the way and keep cords etc. out of the way so that they do not incorporate into the map that is being created.

Before starting the robot network installation must be complete. The robots come from the factory preconfigured for Internet Connection Sharing. If there is a problem, refer to Appendix A for instructions on Internet Connection Sharing.

Open the Google Chrome browser. The correct webpage will automatically open. A password dialog box should appear. Enter the base username and password (aware/aware). The home page for the mapping interface should appear as shown below.
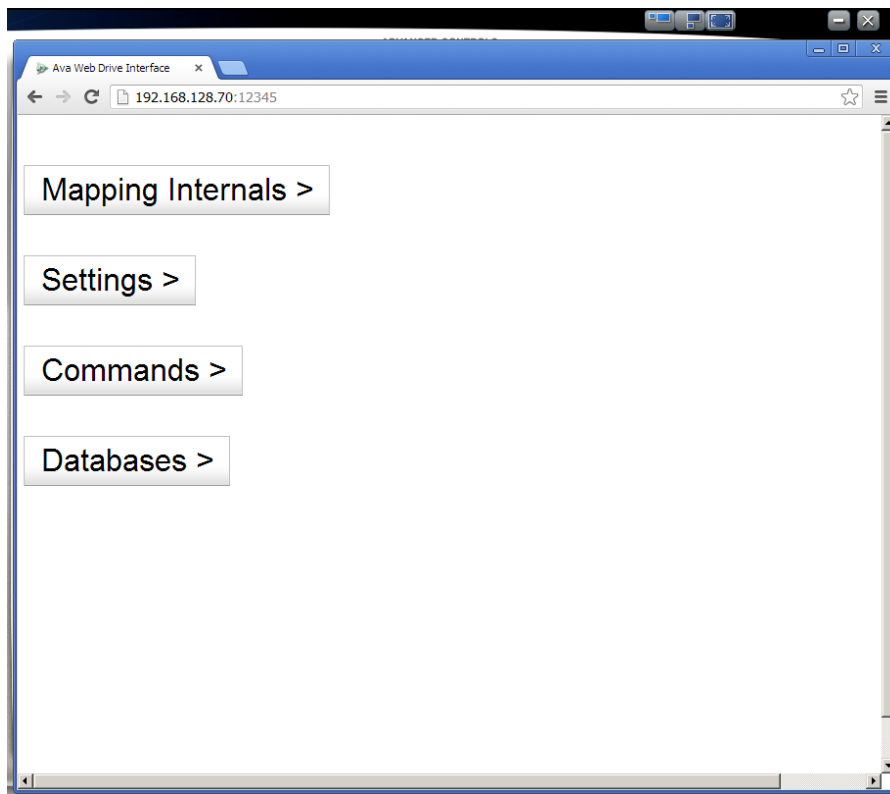
Click on the **Databases>** button. This will take you to the databases page where map databases are managed. To create a new map database, click on the **Create New Database** button shown below

A dialog box will pop up asking you to enter a name for the new database. Note database names are restricted to 14 characters. Enter the new name and click **OK**. The Current Database listing should change to the new name.

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VITA Mapping Guide
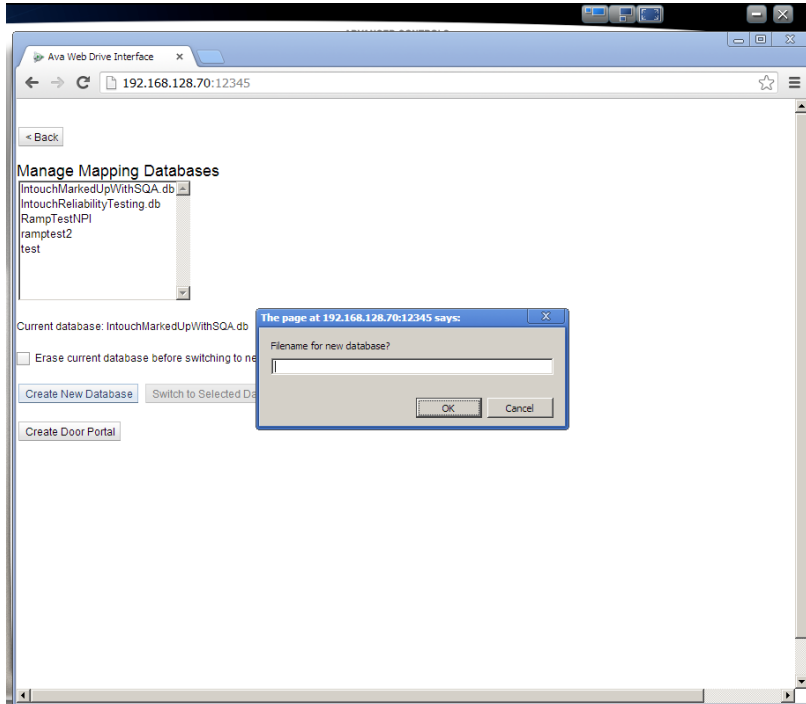
Go back to the Home page and click on the **Mapping Internals** button. This will take you to the page where you can create the new map. This interface has several functional areas as shown below.

3D Camera Window

The 3D camera window shows the live view of any one of the three range cameras. They can be selected using the dropdown menu directly below the window.

Mapping Window

The Mapping Window shows the current map in use or the state of the map that is being created. You can pan and zoom the map by grabbing the map (left click and hold) and moving it around or to zoom by hovering over the map and using the scroll wheel to zoom in and out.

Notice how the robot icon is oriented facing right along one of the major axes in the new map. Note: It will flip to facing up when you start the mapping process by clicking the **Create Map** button. Think about how you want the map to appear once it is made and position the robot so that it begins facing in the desired direction. Pick a position in the environment to be mapped so that long axis like hallways will line up with one of these major axes. That way the new map will not be tilted and hard to read. In addition, try to select a starting position that is "interesting" in that it has many features like corners etc. that can be easily recognized by the SLAM system. The robot looks at its map many times a second to determine where it thinks it is and it does this probabilistically. Therefore. the more unique the scene is the
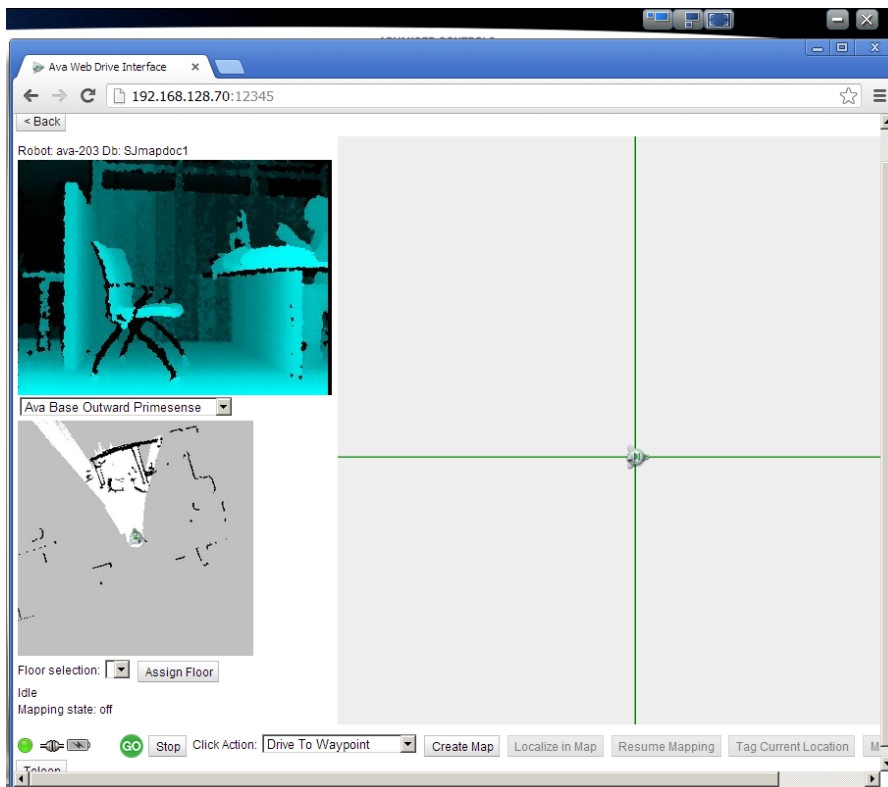

greater confidence it will have in where it is.

LPS Window

The Local Perception Space or LPS Window shows a 2D composite view of what all the sensors are seeing. The white cone shaped area in front of the robot represents the field of view of the waist mounted sensor suite (Prime Sense sensors and ultrasonic sensors). Note that there are three sets of PrimeSense and sonar sensors. They are oriented looking up, looking down and looking straight ahead. This view will represent everything that is being seen by them projected down to a plane within the field of view. Note that the grey color is unknown area, black color is an obstacle and the white area is known area and safe to drive in.

Toolbar The Toolbar has a number of buttons related to mapping and the state of the robot. For a full explanation see the iRobot Base User Manual.
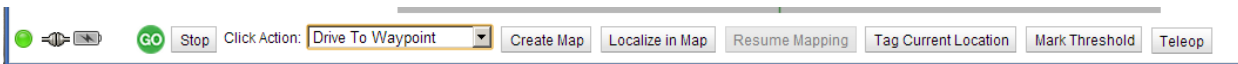
Base Status: Clicking on this button will bring up a list of robot base functional items and their status. Rolling over the button will give the overall health status. If any of the functional items are in fault the button will be red and the offending functional item's button will be red.

Connection Status Icon: If you roll over this icon the status of the base-to-torso connection will be displayed along with the latency of the connection

Stop/Go Button: This is a status indicator for the state of the E-Stop button and thus the ability to drive the robot. If you roll over it, the state of the E-Stop button and power status of the drive system is displayed.

Stop Button: The STOP button will halt any movement command

Command Drop-Down List: This command list has a number of commands for moving the robot and creating/editing map items:

Create Map: This button is used to begin the map creation process.

Localize in Map: This button is used to stop mapping and place the robot in a mode where it continuously localizes its position in the current map.

Resume Mapping: Use this button to edit an existing map.

Tag Current Location: Use this button to mark the current robot location and orientation as a destination tag.

Mark Threshold: This button will define a region that the robot will operate slowly in and change how it interprets obstacles to be more robust to vibration and pitch changes as it traverse a threshold. To set a threshold area first touch the threshold with the front of the robot then click the button and the area will be defined.

Teleop: The teleop button will allow the user to teleop via a pop-up control graphic similar to a compass rose. The graphic allows for omindirectional movement and speed control of the robot.

Start Mapping

First note the robot icon in the middle of the Mapping Window. It is on a grey plane. The grey color indicates unknown area and the robot icon is surrounded by it because it has not yet begun to map.

Click on **Create Map**. Immediately the area around the robot icon will start showing white with black lines as the laser range finder sweeps the area around the robot (see below). The white space indicates area that is now "known" and is free from obstacles. Black represents obstacles. As the robot is driven around the laser range finder will scan out more and more "known" space and obstacles. As this continues walls will be drawn as they are encountered along with other obstacles.
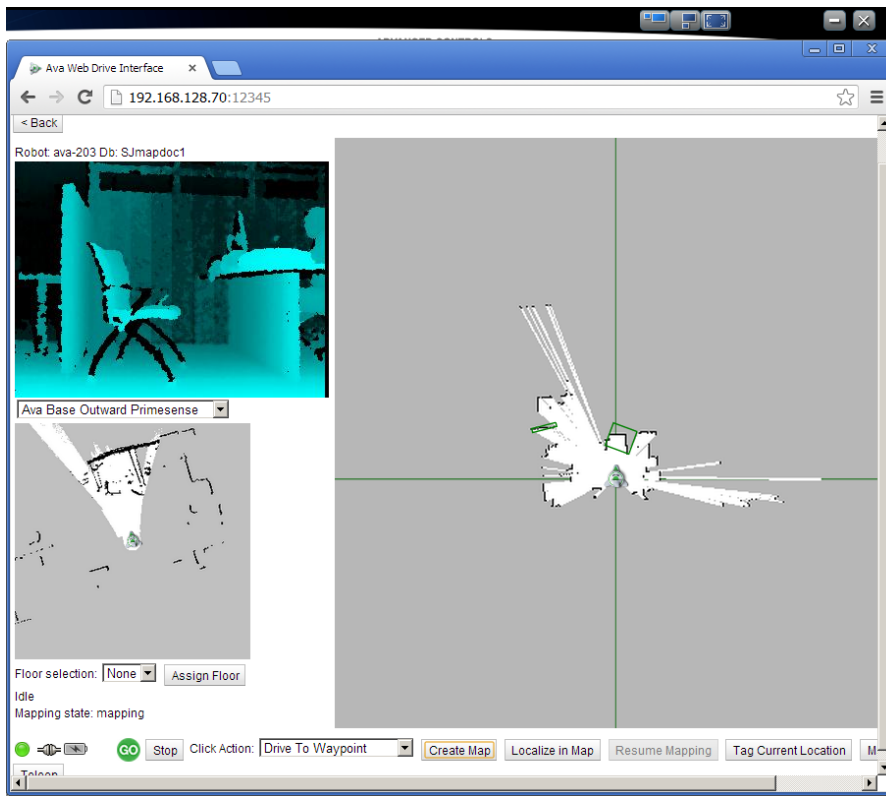
Mapping

To start creating the map you must drive around the operational area in mapping mode. However, you must follow some guidelines in the way you drive and the path you take.

Mapping Guidelines

1. Click "Create Map" with the robot perpendicular and very close to a large wall. This will help it start with a good sense of its relation to the building geometry.
2. Set the start of your map in a main hallway in the middle of the intended work zone
3. Make many small loops, spiraling outwards and returning to home as many different ways as possible.
4. Close loops first then fill out details like rooms etc.
5. Drive straight ahead and let the laser range finder sweep out the details around you.
6. Try to avoid partial loop closures where the robot can see the path to close the loop but continues on without having gone down it. This can cause confusion especially in big loops.

The overall process can be broken into several key parts.

- Map the overall area
- Map the rooms and other areas not captured in first part
- Add Zones
- Add Destination Tags
- Add Portals

Overall Mapping

Begin by looking at the floorplan to find a good place to start. This location should be at an intersection or other area that is rich with permanent features. Plan the number of loops you will make and the paths to follow keeping in mind the above guidelines. The loops should capture an ever increasing area of the operating space. This is illustrated below.

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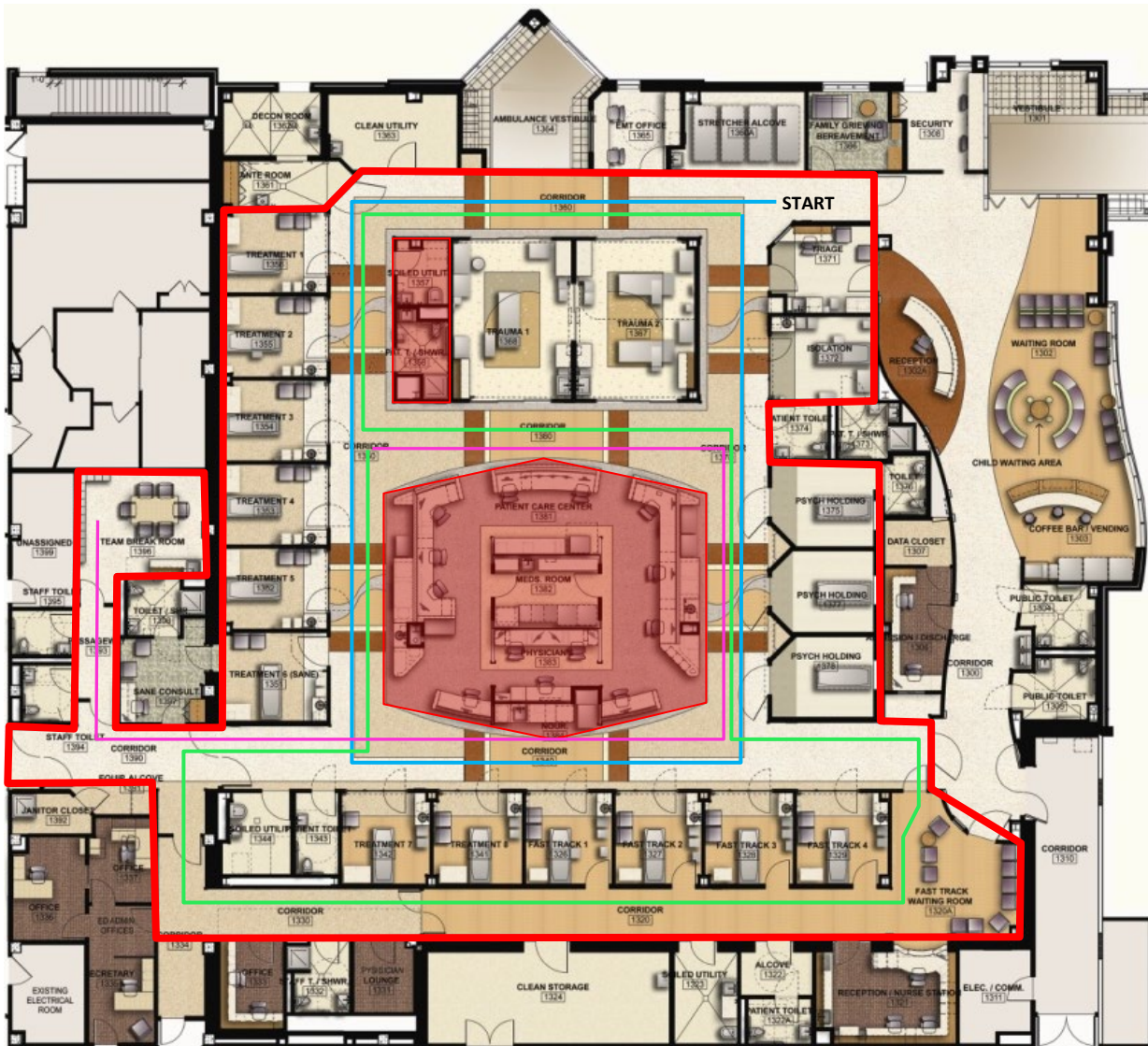
In this example we have a detailed floorplan and a well-defined operational area. We start mapping in the upper right corner of the operational area. We start by following the blue path and we close the loop back where we started. The blue path violates guideline 5 in that the loop could be closed by going through the middle corridor. But in this case the distances are small, and it should close the loop successfully. Next, we follow the green path and close the loop around a larger area at the intersection of the middle corridor and the left-hand corridor. Now we have captured most of the operational area. Next, we follow the pink path to map out any non-loop branches. Carefully note any obstacles like glass wall or doors that should show up as obstacles but may not because the laser reflection is poor.

Here is an example of making a map. First I start in a hallway that intersects with an entry. The corners of the entry provide a rich feature set for the SLAM system to identify.
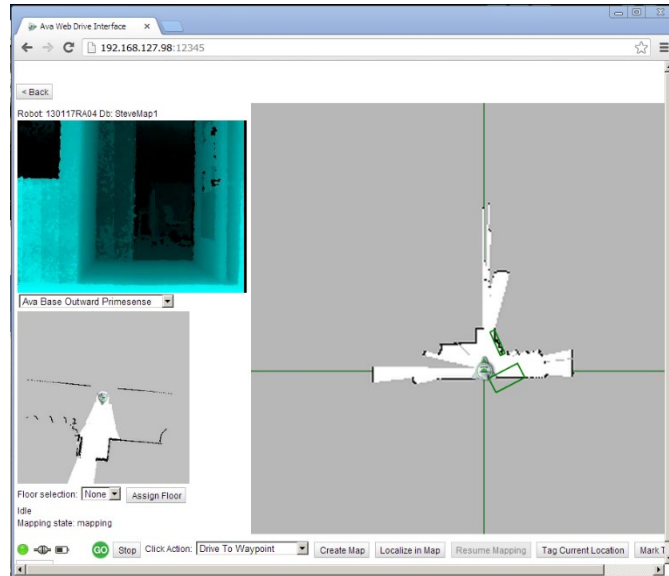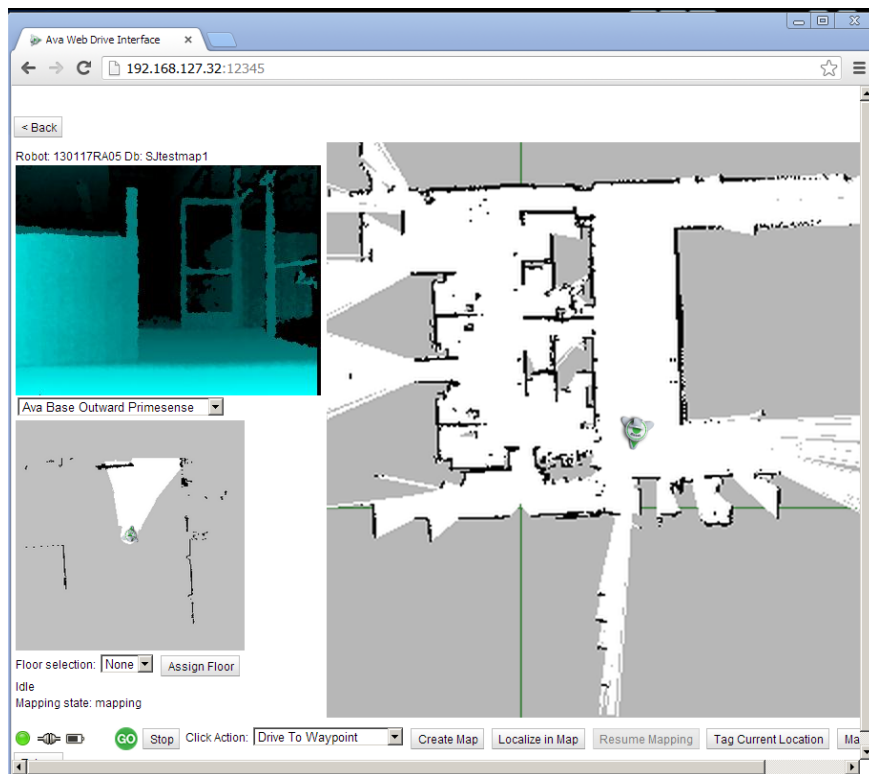

This is another screenshot showing how the map progresses as I travel on my first loop.
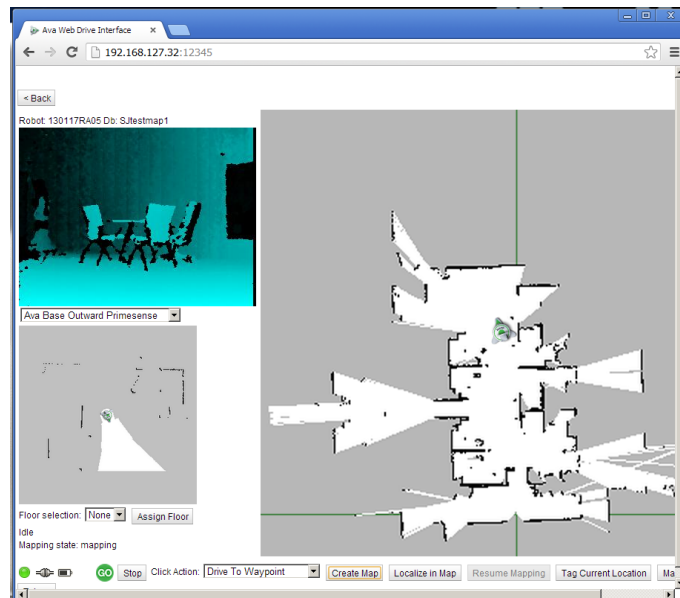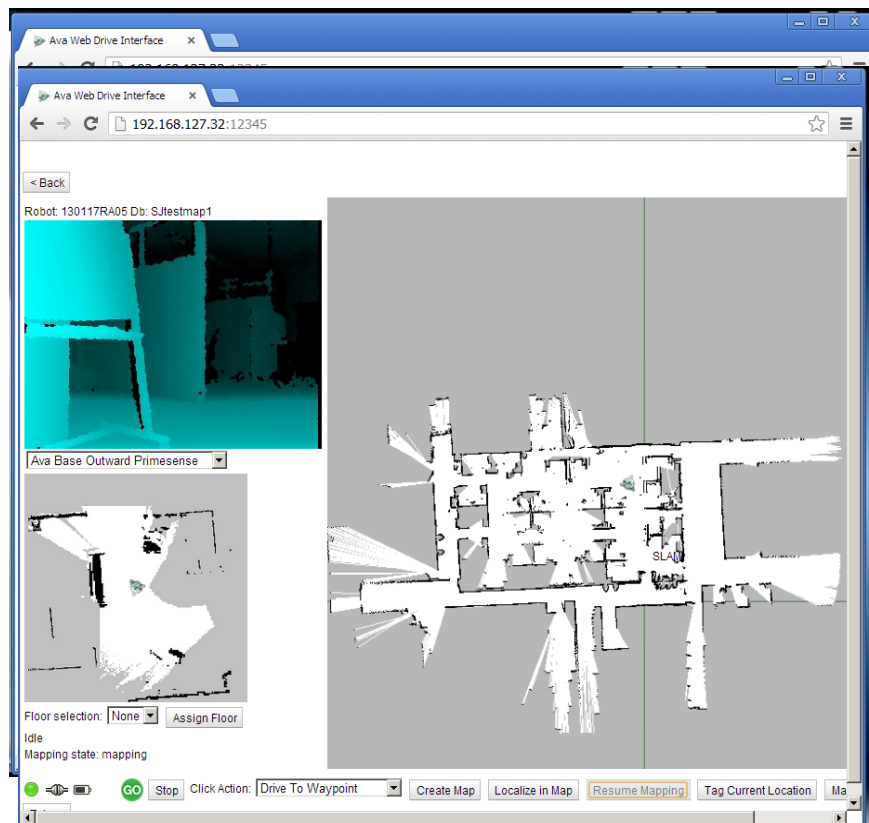
Here I have finished my first loop and am in a good position to localize in the map.

Here I am starting my second loop

Here I have finished my map and can go fill in unknown areas.

VITA Mapping Guide

Look for mistakes in the completed map and note them for clean up using the map editor. Here is an example of an error in the map and the result of that error.

Notice that the red area of the map did not register an existing glass wall. When I send the robot from one tag to another it plans a path through this area. I must use the Map Editor to fix this by making it a keep out zone in that region.

Mapping Rooms

Once the overall map has been established it is time to add more detail to the map. Enter each room in mapping mode. Depending on the size and how cluttered the room is with chairs, beds, equipment etc you may have to maneuver around to capture all the walls and permanent structures. In some cases, the room will be occupied or otherwise have access constrained. In this case if you can go to the door entryway and rotate the robot around to map as much as possible from that position. Note that during normal operation the robot can go into "unknown" space for a limited distance and still AutoDrive back onto the map so complete mapping is not required but it is desirable if at all possible. Continue mapping any dead-end paths or open spaces in the operational area that did not get captured in the overall mapping phase. **Note: If there you are going to create door portals for this environment be sure that they are all mapped as closed.**

Adding Zones

After you have mapped the rooms, you can add the zones that were identified in the pre-mapping phase. Furthermore, you should add zones to govern how routes are chosen for AutoDrive. For example, during the overall mapping phase
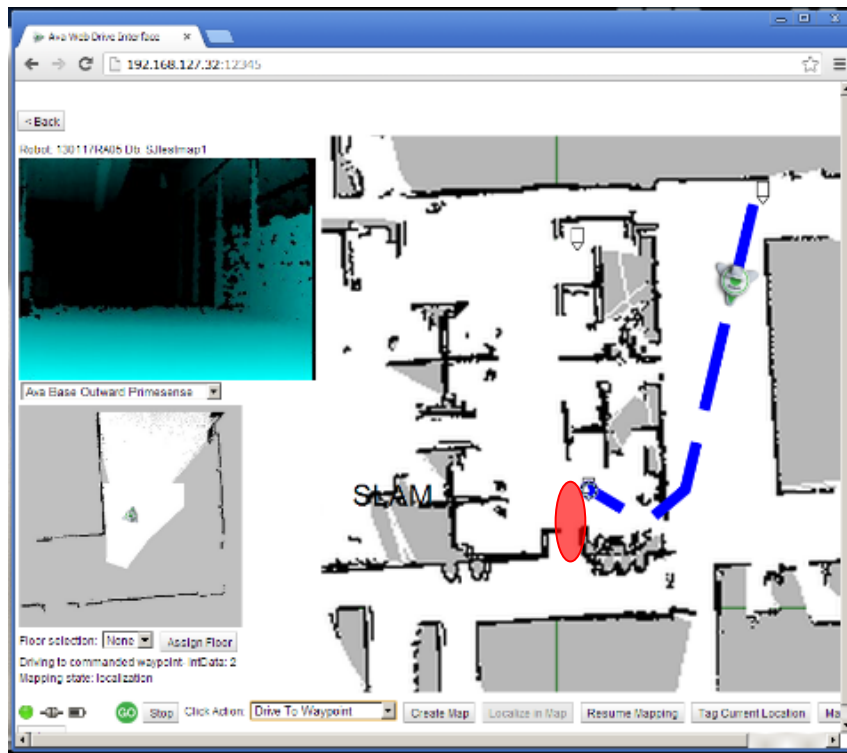

when mapping a glass wall it will not show up as an obstacle because the glass is transparent to the laser. Therefore

when the robot is planning a route for AutoDrive it could plan to go through the glass wall. It would not hit the wall because the 3D cameras would most likely pick up the frame of the glass wall or at a minimum the sonar sensors would as it got very close. The robot would then hunt around to try to get though and eventually give up and try a new route. This is hardly efficient and gives the appearance of a very dumb robot. Not what we want! This is also the case for tables or bar structures that have legs. The robot would see the legs while mapping (remember that the laser is only 8" off the ground) and mark them but the route planning could plan to go between the legs. So carefully examine the map and compare it with the environment for cases like this and mark them as no-go zones. One obstacle that can pose a collision risk for the robot is a protruding table overhang if the table is ~28" off the floor and less than 2" in thickness or made of glass. Mark these with Keep Out zones to protect the robot from any possible collision. Be sure that the zone is well aligned with the obstacle. Here is an example of adding a zone.

First click on Create Region in the drop-down menu. Then define the region by clicking on the map at each of the vertices of the polygon that makes up the region you want as shown below by the green outline in the lower part of the map.
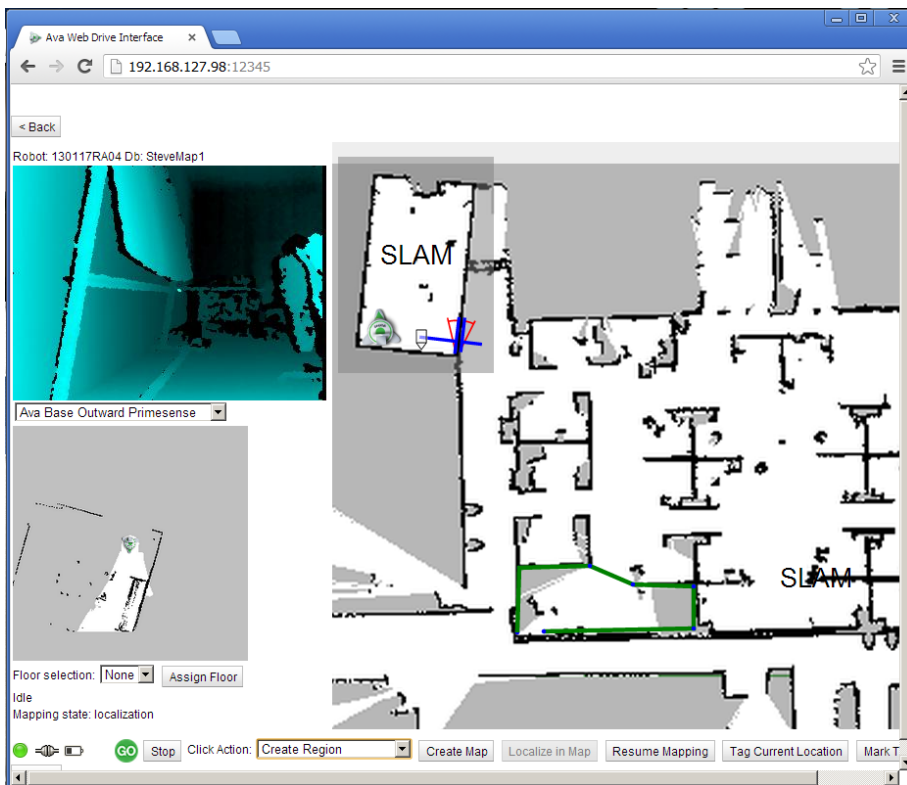
Double click on the first point to close the polygon. A pop menu will come up to name the zone. As shown.
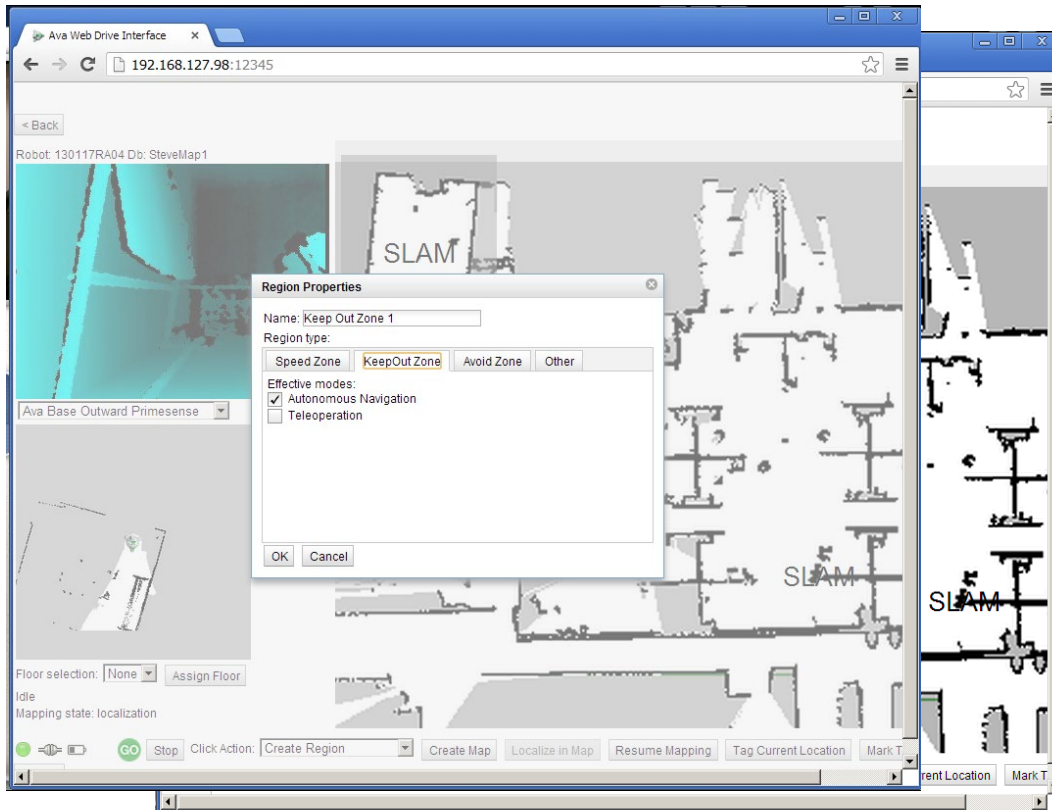
The completed region looks like this.

Adding Destination Tags

Now you can add all the destination tags to the map. The best way to do this is to drive directly to the desired location and position the robot with the desired orientation then push the **Tag Current Location** button. This will bring up a dialog box that will allow you to enter the name of the tag.

To map a dock destination tag carefully position the robot on the Dock. Click the **Tag Current Location** button. Select the dock tag in the dialog box. Put "Dock" in the name field. Dock is a reserved word and should not be used for any other tag names. Be sure to check the **Localize in map when docked** check box so that the robot will be relocalized every time it is docked. This will minimize the chance that the robot will become delocalized over time.
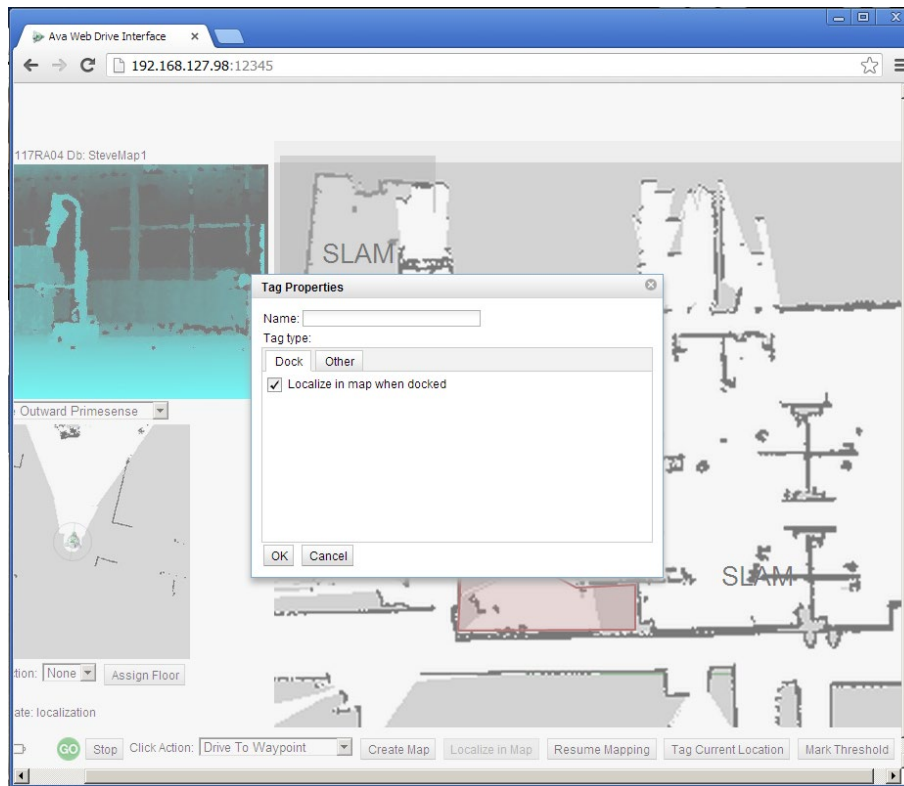
Adding Door Portals

Door portals are advanced map features that are used to allow RP-VITA to go from one area to another that is connected by a door and have the robot understand how to deal with the door in its various states like open, closed or transitioning. Door portals are used to mark a door location in the robot map and to define the type of door it is. The robot's navigation system understands the concept of a door and will behave in a predefined way for each type of door like manual or automatic. To start the process first verify that the robot is well localized. Do this by selecting the **Correct Robot Position** option from the drop-down menu in the RP-VITA mapping interface. Check the alignment of the blue laser scan graphic with the obstacles in the map. Correct as necessary.

Position the robot in front of the door to be mapped about 3 feet away. Be sure it is out of the swing radius of the door. For wide doorways make sure the robot is centered in the path you want it to take. Check to be sure the door was closed when it was mapped. If it was not closed during initial mapping use the map editor to make that area grey (unknown) then resume mapping and add it as closed. Make sure the front edge of the robot is parallel with the closed door.

Summary of the Door Portal Creation Process

1. Position the robot parallel to the door, three feet away and out of any swing radius of the door.

2. Press **Create Door Portal** on the **Databases** page of the robot mapping interface.
3. Open the door
4. Dive straight through the door and stop outside the swing radius of the door.
5. Close the door behind you
6. Create new map
7. Map room
8. Localize in new map
9. Edit the door portal extents and attributes as necessary.

The following example shows the creation of a manual door portal.

Position the robot in center of the door about 3 feet away from the door and perpendicular to the door. Be sure the LPS shows the door frame clearly as shown below.
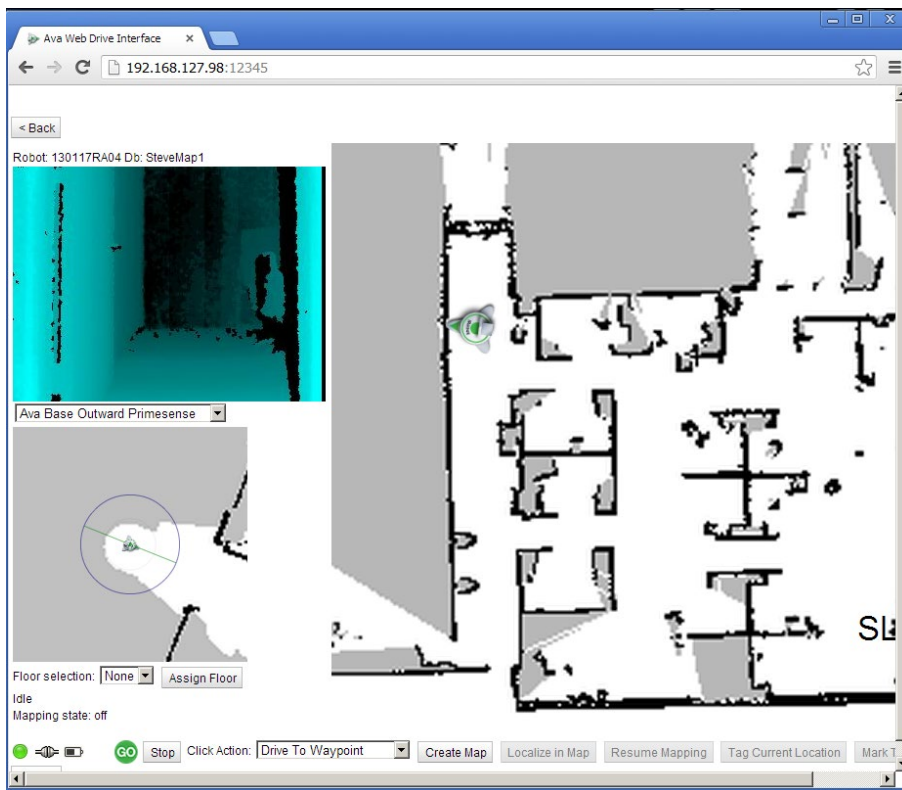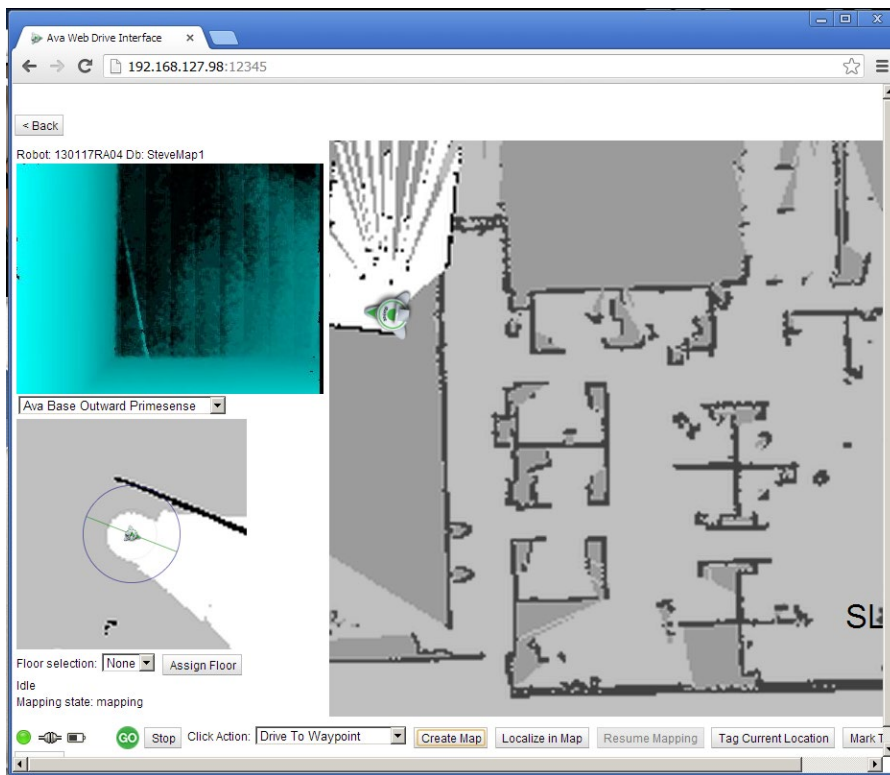
Open the door, drive straight through the door and shut the door.
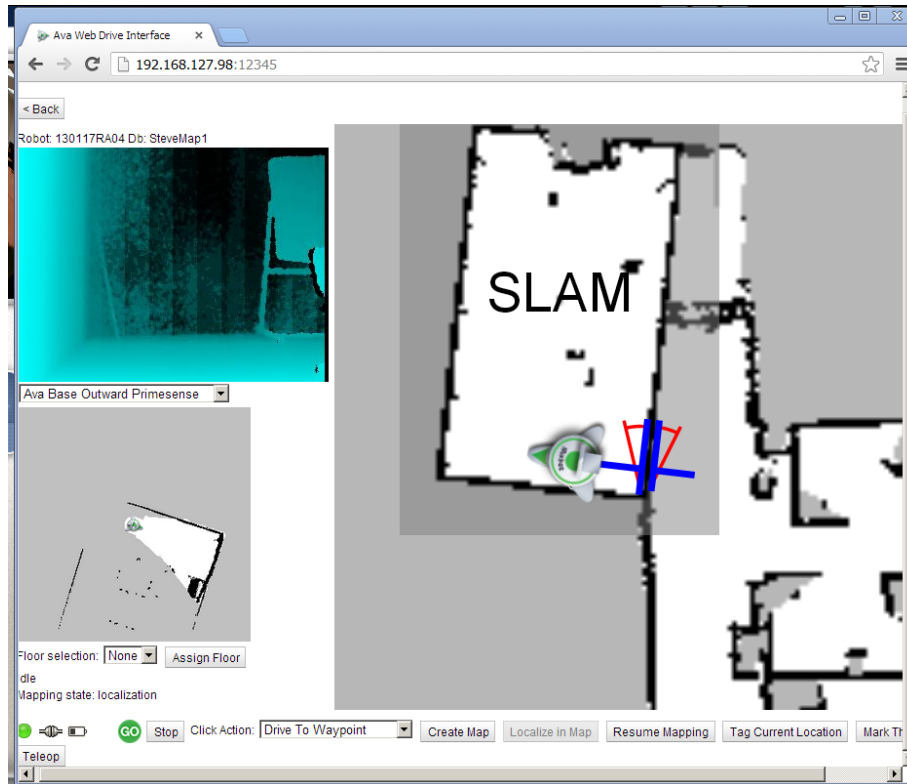
Click **Create Map** and map the new room.

Click **Localize in Map** to complete new map area. A door portal graphic should be shown between the two maps. Notice that I was not perfectly aligned perpendicular to the doorway when I began and thus the new map was not aligned very well.

Adjust both of the door portal extents to be slightly larger than the door opening. This will allow the robot to navigate into the doorway more easily.

Making an Automatic Door Portal

Summary of the Automatic Double Door Portal Creation Process

1. Position the robot parallel to the door and in the path you want it to travel (the right hand side for a double door). Be sure to position it out of the swing radius of the door.
2. Press **Create Door Portal** on the **Databases** page of the robot mapping interface.
3. Open the door
4. Dive straight through the door and stop outside the swing radius of the door.
5. Close the door behind you
6. Create new map
7. Map room
8. Localize in new map
9. Edit the door portal extents and attributes as necessary.

10. Again position the robot parallel to the door and in the path you want it to travel (the right hand side for a double door). Be sure to position it out of the swing radius of the door.
11. Press **Create Door Portal** on the **Databases** page of the robot mapping interface.
12. Open the door
13. Dive straight through the door and stop outside the swing radius of the door.
14. Close the door behind you
15. CORRECT ROBOT POSTION
16. Edit the door portal extents and attributes as necessary.

Editing a Map

The map editor no longer works as it was created using Java which is a plug-in no longer supported by major browsers. Once you have created a map, there are very few ways to modify it. You can resume mapping and map over the previous area if semi-permanent obstacles have been added. If the walls have not straightened or you map a door portal crooked, you will likely have to start mapping over again.

Validating Maps

Driving Tests

Test the map by driving around the operational area and verify that the robot responds to defined obstacles as it should. For example, if a KeepOut region is defined as not allowing tele-operation in that region verify that it will indeed do just that. Check that KeepOut regions that are used around obstacles align well with the obstacle.

AutoDrive Tests

Test the AutoDrive works well with all the destination tags and that when the destination is reached that it completes the trip in a timely manner.

Obstacles

Review the operating area and look for troublesome obstacles and be sure they are considered in the map so that the robot won't have navigation problems. For example, glass walls, bright sunlight area and protruding tabletops.

Appendix A: How to set up internet connection sharing on VITA

Set up ICS on the Torso

- Hook up keyboard to the robot
- Quit our application
- Login to the Admin account
- Right-click on the wireless network signal strength icon in the sys tray.
- Open the **Network and Sharing Center**
- Select **Change Adaptor Settings**
- Right-click on the **Wireless Network Connection**
- Select **Properties**
- Select the **Sharing** tab
- Check the top check box (Allow network users to connect through…)
- Select "Base" in the Home Networking Connection dropdown menu.
- Select **Settings**
- Select the "iRobot" service
- Click on **Edit**
- Enter 172.20.1.15 in the name or IP Address field
- Enter: 12345 in the **External Port** field
- Enter: 80 in the **Internal Port** field
- Click **OK**
- Click **Add**

  Add Map Editor Service

- Click **Add**
- Enter Map Editor in the **Description** field
- Enter 172.20.1.15 in the **Name or IP Address** field
- Enter: 12344 in the **External Port** field
- Enter: 82 in the **Internal Port** field
- Click **OK**
- Click **OK**
- Click **OK**

Get Torso IP address

- Open a Command Window
- Enter >ipconfig
- Note the IP Address

The robot base routing configuration should be set from the factory and this step should not be necessary!

Set up Base Routing

- Putty into the base at 172.20.1.15
- Login as root: usr=root/pwd=awareroot
- Edit /etc/network/interfaces file add: gateway 20.1.1.20 to the "Payload" interface
- Add the gateway to the route table with this command:
    >*route add default gw 20.1.1.20 dev eth1* (base adaptor)

Test the Connection

- Test by opening Chrome on your LTCS (make sure you are on the same network)
- Type in the robot IP address from above.
- Should open the map interface web page.