



Route Data Definition Format (RDDF) Interface Configuration Documentation

The Route Data Definition Format (RDDF) is a comma-delimited text file that contains six required parameters for each waypoint, along with several optional parameters.

The required data parameters include:

- number of each waypoint
- latitude and longitude of each waypoint
- lateral boundary offset of each segment (ft)
- maximum speed of each segment (mph)
- recorded time

Each waypoint marks the start of a segment. The first waypoint is number 1 and subsequent waypoints follow in sequence. Latitude and longitude are specified in decimal degrees with seven decimal places. The applicable datum is WGS 84 (<http://earth-info.nga.mil/GandG/wgs84/>). The accuracy of the waypoint locations is \pm 15 cm. The 7th decimal figure does not connote an additional degree of accuracy. Segments with unspecified maximum speed are indicated by 999.

The optional parameters include: AVIL command, brake, minimum meatball, steering gain, PID gains, playback speed, and playback direction; in addition, there are markers for the origin and end points. If an optional field is used, it remains active until changed by a subsequent waypoint entry (e.g., if waypoint number 3 sets the reverse option, but waypoint 4 does not set either the reverse or forward options, then the vehicle will continue in reverse).

The format of a waypoint entry structure is:

#, lat, lon, lbo, speed, time{, optional attributes separated by commas}

Waypoint parameter specifications are detailed in the RDDF Parameter Specifications section.

Sample Waypoints and Corresponding RDDF Entries

Figure 1 shows sample RDDF entries, based on the waypoint data in Table 1.



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Table 1: Sample Waypoint Parameters

#	Lat	Lon	LBO	Max speed	Time	Options
1	54.104419	28.331488	14	2.1	1.00	orig, steergain=2.8, meatball=25
2	54.104478	28.331472	14	6.8	4.40	
5	54.104626	28.331554	14	8	9.81	
6	54.104677	28.331675	14	8.9	12.48	
7	54.104725	28.331876	14	8.8	0.01	meatball=55
53	54.104615	28.331463	14	4	127.81	
54	54.104653	28.331621	14	2.2	0.01	
55	54.104691	28.331779	14	0	155.76	Reverse, steergain=3.4, meatball=4
56	54.104665	28.331689	14	2	160.38	
58	54.104586	28.331334	14	4	0.01	
59	54.104547	28.331157	14	4	0.01	
60	54.104508	28.330980	14	4	191.42	end, steergain=2.8, meatball=25



```

1,54.104419,28.331488,14,2.1,1.00, orig, steergain=2.8, meatball=25
2,54.104478,28.331472,14,6.8,4.40
...
5,54.104626,28.331554,14,8,9.81
6,54.104677,28.331675,14,8.9,12.48
7,54.104725,28.331876,14,8.8,0.01, meatball=25
...
53,54.104615,28.331463,14,4,127.81
54,54.104653,28.331621,14,2.2,0.01
55,54.104691,28.331779,14,0,155.76,Reverse, steergain=3.4, meatball=45
56,54.104665,28.331689,14,2,160.38
...
58,54.104586,28.331334,14,4,0.01
59,54.104547,28.331157,14,4,0.01
60,54.104508,28.330980,14,4,191.42, end, steergain=2.8, meatball=25
  
```

Figure 1: Sample RDDF Entries

RDDF Parameter Specifications

Table 2: Waypoint Number

#	Required
	Waypoint number.
Usage:	{value}
Values:	Sequential integers

Warning

Duplicated or skipped Waypoint numbers may cause unintended behavior.

Table 3: Waypoint Latitude & Longitude

Lat	Required
	Waypoint Latitude
Lon	Required
	Waypoint Longitude
Usage:	{value}
Values:	Decimal degrees with seven decimal places. Accuracy of the waypoint location is ±15cm. The 7th decimal figure does not connote an additional degree of accuracy. The applicable datum is WGS 84 (http://earth-info.nga.mil/GandG/wgs84/).

Table 4: LBO



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LBO Required
 Lateral Boundary Offset (LBO)
 Usage: {value}
 Values: feet

Table 5: Recorded Speed

Speed Required
 Recorded Speed
 Usage: {value}
 Values: miles per hour
 999 indicates unspecified recorded speed

Table 6: Time

Time Required
 Recorded time
 Usage: {value}
 Values: seconds

Table 7: Execute AVIL Command

exec Executes an immediate AVIL command.
 Applied when the point has been achieved, i.e. at the end of the
 waypoint segment.
 Usage: exec="{AVIL_command}"
 Entire AVIL command should be placed in quotes and not contain
 quotes. Follows AVIL command syntax.
 Values: None
 Example: exec="throttle 100"

Table 8: Brake

brake Sends an immediate command to the vehicle brakes. This will be
 overwritten by future pathing commands, but the brakes are
 applied at this point.
 Applied when the point has been achieved, i.e. at the end of the
 waypoint segment.
 Usage: brake={value}
 Values: 0 - 100 (percentage)
 Example: Brake=90

Table 9: Meatball

meatball Minimum distance of the meatball from the vehicle.
 The vehicle steering follows and steers toward the meatball. The



actual meatball distance is controlled by a variety of factors, including desired speed, curves in the course, LBO, and pathing error.

A short meatball distance (e.g., 25 ft) causes the vehicle to be very responsive for steering; this can result in instability, but is advisable if there are frequent sharp turns.

A long meatball distance (e.g., 200 ft) causes the vehicle to have very stable steering, but low maneuverability.

Usage: meatball={value}
 Values: feet
 Example: Meatball=35

Table 10: Steering Gain

steergain Overall gain and responsiveness of the steering system.
 Usage: steergain={value}
 Values: 2.8 – 3.0 = slower response
 3.2 = nominal
 3.4 – 3.6 = faster response
 Example: steergain=3.2

Table 11: Proportional Gain

speedpidP Proportional gain of the PID speed control.
 Setting is determined based on vehicle engine responsiveness and mass.
 Applied when aiming at the endpoint, i.e. at the beginning of the waypoint segment.
 Usage: speedpidP={value}
 Values: 0 = nominal
 May be integers or decimal and positive or negative.
 For PID overviews and tuning methods see
http://en.wikipedia.org/wiki/PID_controller#Loop_tuning ,
<http://robotics.stackexchange.com/questions/167/what-are-good-strategies-for-tuning-pid-loops/174#174>, and
<http://saba.kntu.ac.ir/eecd/pcl/download/PIDtutorial.pdf>
 Example: speedpidP=3

Table 12: Integral Gain

speedidl Integral gain of the PID speed control.
 This setting is seldom used; it should only be used when a longer term error will occur (e.g., climbing a hill).
 Setting is determined based on vehicle engine responsiveness and



mass.
 Applied when aiming at the endpoint, i.e. at the beginning of the
 waypoint segment.

Usage: speedpid={value}

Values: 0 = nominal

May be integers or decimal and positive or negative.

For PID overviews and tuning methods see

http://en.wikipedia.org/wiki/PID_controller#Loop_tuning ,

<http://robotics.stackexchange.com/questions/167/what-are-good-strategies-for-tuning-pid-loops/174#174>, and

<http://saba.kntu.ac.ir/eecd/pcl/download/PIDtutorial.pdf>

Example: speedpid=0

Table 13: Differential Gain

speedpidD Differential gain of the PID speed control.

Setting is determined based on vehicle engine responsiveness and mass. When the proportional gain is set high for responsiveness, this setting can decrease resulting oscillation and system overshooting.

This is usually a factor of 10 less than proportional gain.

Applied when aiming at the endpoint, i.e. at the beginning of the
 waypoint segment.

Usage: speedpid={value}

Values: 0 = nominal

May be integers or decimal and positive or negative.

For PID overviews and tuning methods see

http://en.wikipedia.org/wiki/PID_controller#Loop_tuning ,

<http://robotics.stackexchange.com/questions/167/what-are-good-strategies-for-tuning-pid-loops/174#174>, and

<http://saba.kntu.ac.ir/eecd/pcl/download/PIDtutorial.pdf>

Example: speedpid=.3

Table 14: Fixed Speed

fixedspeed Fixed speed for segment playback.

This overrides the recorded speed, but will not exceed the maximum speed setting. Used for safety and performance considerations.

Applied when aiming at the endpoint, i.e. at the beginning of the
 waypoint segment.

Usage: fixedspeed={value}

Values: miles per hour

Example: fixedspeed=7



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Table 15: Actual Speed

actualspeed Playback segment at recorded speed.
Applied when aiming at the endpoint, i.e. at the beginning of the
waypoint segment.
Usage: actualspeed
Values: None
Example: actualspeed

Table 16: Reverse

reverse Playback segment in reverse gear.
Applied when aiming at the endpoint, i.e. at the beginning of the
waypoint segment.
Usage: reverse
Values: None
Example: reverse

Table 17: Forward

forward Playback segment in forward gear.
Applied when aiming at the endpoint, i.e. at the beginning of the
waypoint segment.
Usage: forward
Values: None
Example: forward

Table 18: Origin Point

orig Sets first point in the course.
Usage: orig
Values: None
Response: orig

Table 19: End Point

end Sets last point in the course.
Usage: end
Values: None
Response: end

Route Layout Description for the DARPA Grand Challenge 2005

Each leg of the route is defined by two factors: a set of waypoints and the lateral boundary offset. The track line connects the two waypoints and defines the middle of the leg segment. The outer boundary of the segment is defined by the lateral boundary offset, which is the perpendicular distance from the track line to the boundary edge. In

addition, the boundary is defined by a circular arc centered on the waypoint with a radius equal to the lateral boundary offset. This is shown in Figure 2.

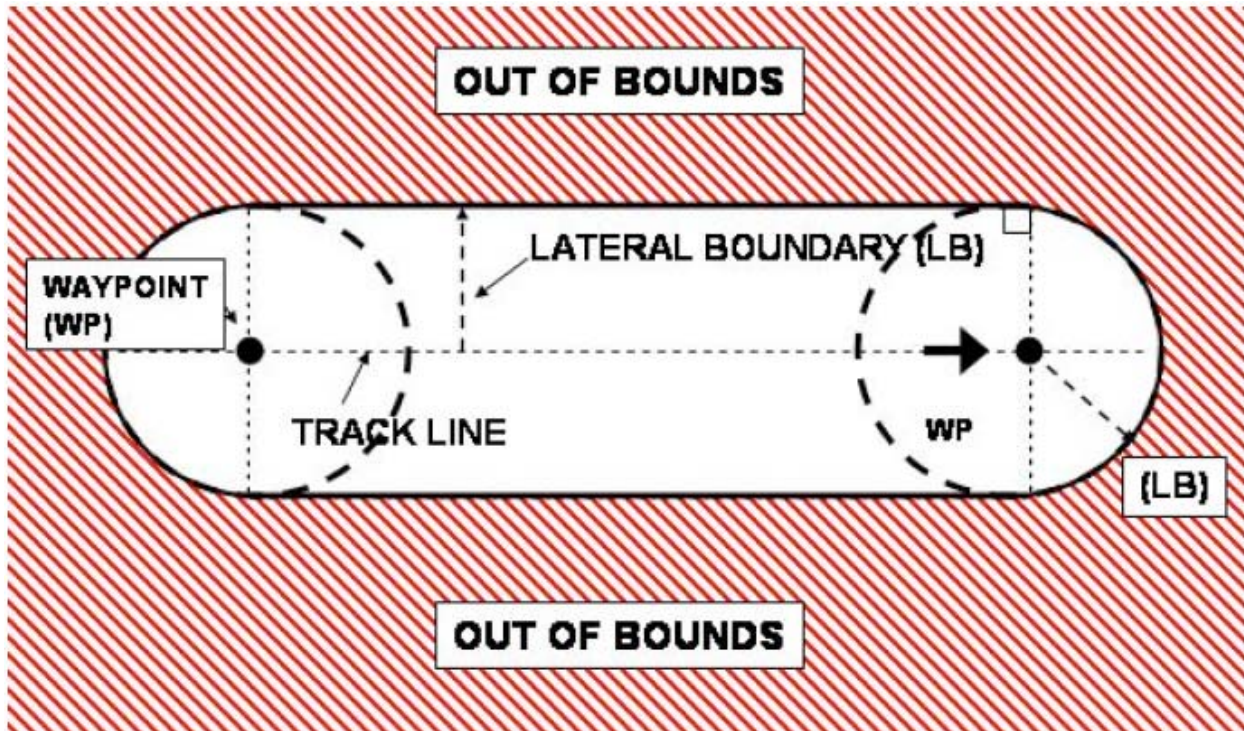


Figure 2: Leg Segment Definition

Leg segments are connected at a waypoint, which they both share. It is possible for a new segment to change direction, change lateral boundary offset, or change both. The vehicle is considered to be “in bounds” if it falls within the boundary of any leg segment. The outer boundary of the route is defined by the least restrictive leg segment boundary. Several situations are shown below to illustrate this point.

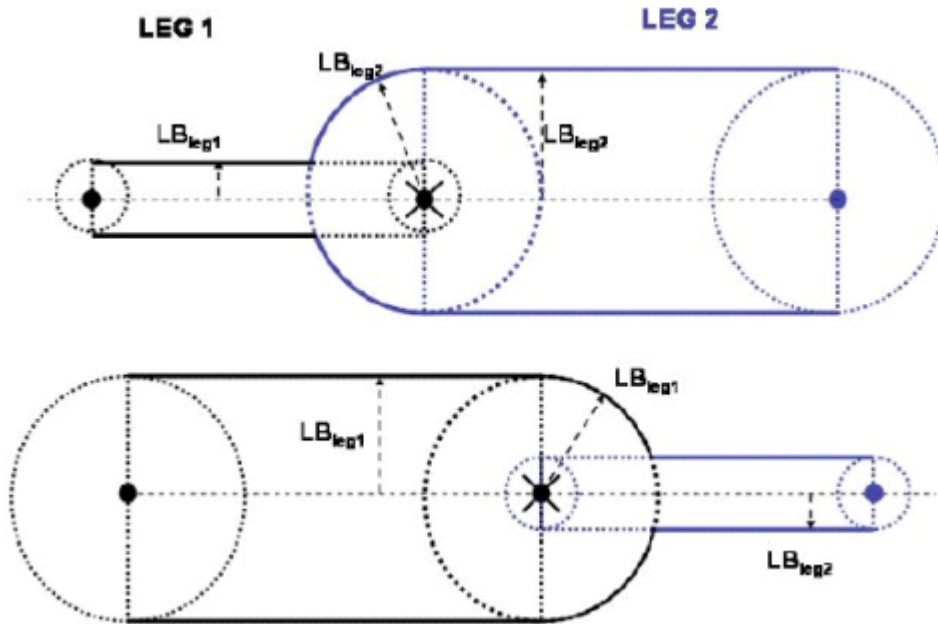


Figure 3: Changing Lateral Boundary

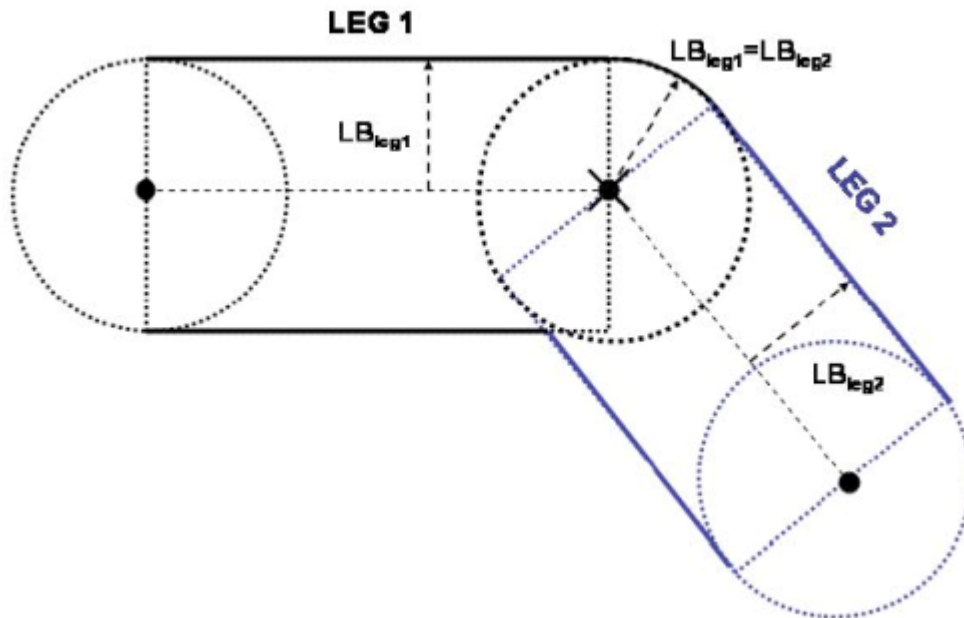


Figure 4: Change in Direction (Lateral Boundary Unchanged)

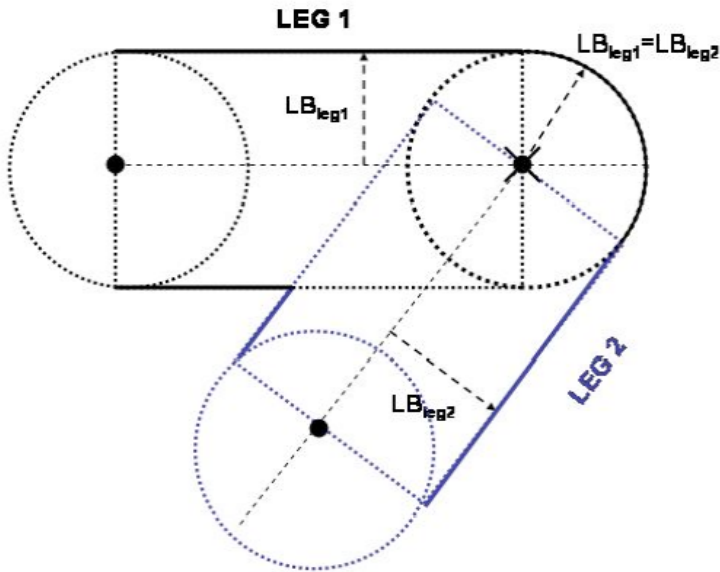


Figure 5: Large Change in Direction (Lateral Boundary Unchanged)

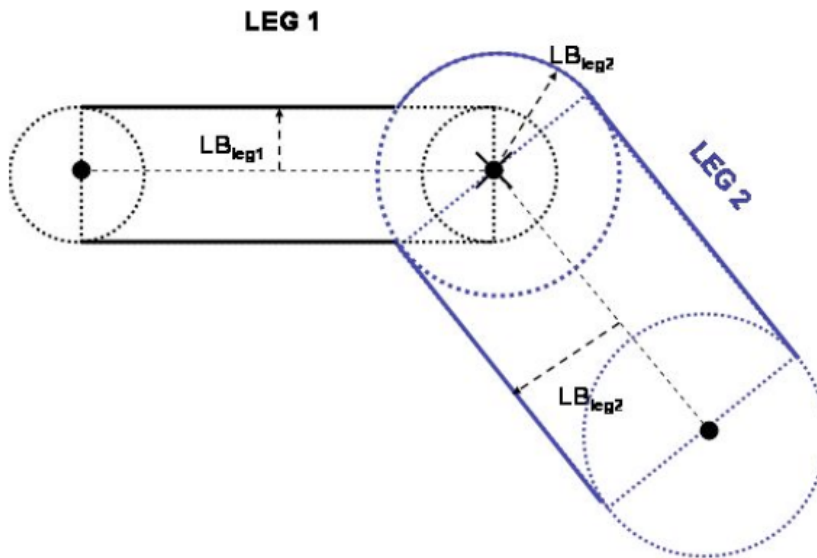


Figure 6: Change in Direction and Lateral Boundary

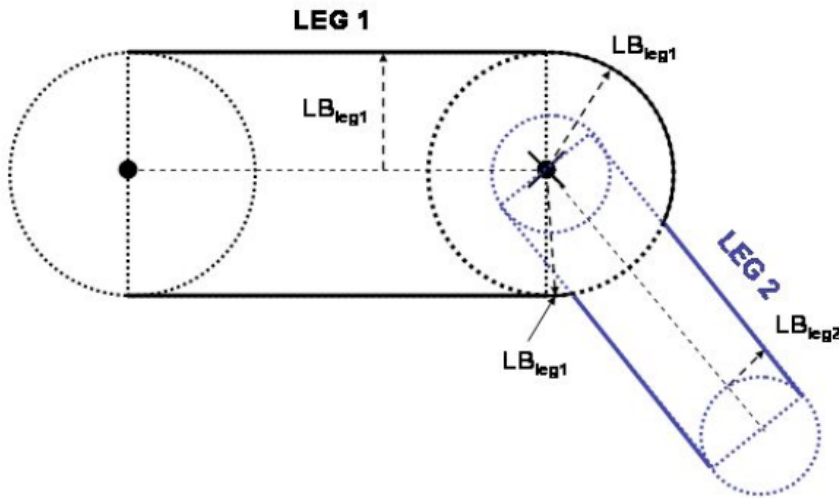


Figure 7: Change in Direction and Lateral Boundary

Sample MDF

MDF_name Sample_MDF_Rev_1.2
 RNDF Sample_RNDF_Rev_1.2
 format_version 1.0
 creation_date 5/18/2006
 checkpoints
 num_checkpoints 18
 1
 2
 3
 2
 3
 2
 3
 4
 2
 4
 2
 14 /*parking spot*/
 5
 10
 17 /*parking spot*/
 6
 7



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```

8
end_checkpoints
speed_limits
num_speed_limits 14
1 10 25
2 0 20 /*undefined minimum speed*/
3 10 20
4 10 20
5 10 15
6 15 20
7 15 20
8 10 15
9 10 15
10 10 20
11 10 10
12 10 15
13 10 20
14 5 10
end_speed_limits
end_file
  
```

Sample RNDF

```

RNDF_name Sample_RNDF_Rev_1.1      1.1.4 38.875673 -77.201373
num_segments 13                    end_lane
num_zones 1                        lane 1.2
format_version 1.0                 num_waypoints 6
creation_date 5/15/2006            lane_width 12
segment 1                          left_boundary broken_white
num_lanes 2                        exit 1.2.4 3.1.1
segment_name Michigan_Ave          exit 1.2.6 4.1.1
lane 1.1 "/*no exits, passing lane*/" 1.2.1 38.875343 -77.205619
num_waypoints 4                    1.2.2 38.875438 -77.204198
lane_width 12                      1.2.3 38.875528 -77.202959
left_boundary double_yellow        1.2.4 38.875602 -77.201871
right_boundary broken_white        1.2.5 38.875616 -77.201664
1.1.1 38.875413 -77.205045         1.2.6 38.875676 -77.200830
1.1.2 38.875471 -77.204189        end_lane
1.1.3 38.875585 -77.202593        end_segment
  
```



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```

segment 2
num_lanes 1 /*one-way*/
segment_name California_Drive
lane 2.1
num_waypoints 5
checkpoint 2.1.2 7
stop 2.1.5
exit 2.1.5 1.2.1
2.1.1 38.869226 -77.205381
2.1.2 38.871627 -77.207098
2.1.3 38.872136 -77.206181
2.1.4 38.873611 -77.205682
2.1.5 38.875293 -77.205711
end_lane
end_segment
segment 3
num_lanes 2
segment_name Indiana_Rd
lane 3.1
num_waypoints 14
lane_width 12
left_boundary double_yellow
checkpoint 3.1.2 8
checkpoint 3.1.6 4
stop 3.1.3
stop 3.1.14
exit 3.1.3 13.1.10
exit 3.1.3 13.2.1
exit 3.1.7 10.1.6
exit 3.1.7 10.2.3
exit 3.1.14 9.1.1
3.1.1 38.875550 -77.201790
3.1.2 38.874445 -77.201748
3.1.3 38.873190 -77.201704
3.1.4 38.872996 -77.201698
3.1.5 38.871750 -77.201662
3.1.6 38.870386 -77.201625
3.1.7 38.869335 -77.201592
3.1.8 38.869113 -77.201591
3.1.9 38.868168 -77.201558
3.1.10 38.867975 -77.201450
3.1.11 38.867857 -77.201336
3.1.12 38.867758 -77.201302
3.1.13 38.867064 -77.201394
3.1.14 38.866388 -77.201487
end_lane
lane 3.2
num_waypoints 13
lane_width 12
left_boundary double_yellow
checkpoint 3.2.8 9
stop 3.2.10
exit 3.2.6 10.1.6
exit 3.2.6 10.2.3
exit 3.2.10 13.1.10
exit 3.2.10 13.2.1
exit 3.2.13 1.2.5
3.2.1 38.866399 -77.201421
3.2.2 38.867074 -77.201327
3.2.3 38.867767 -77.201226
3.2.4 38.867961 -77.201359
3.2.5 38.868150 -77.201515
3.2.6 38.869115 -77.201540
3.2.7 38.869354 -77.201542
3.2.8 38.870691 -77.201585
3.2.9 38.872009 -77.201620
3.2.10 38.872998 -77.201657
3.2.11 38.873187 -77.201663
3.2.12 38.874599 -77.201706
3.2.13 38.875577 -77.201723
end_lane
end_segment
segment 4
num_lanes 2
segment_name New_York_Rd
lane 4.1
num_waypoints 7
lane_width 12
left_boundary double_yellow
checkpoint 4.1.3 1
checkpoint 4.1.6 2
stop 4.1.4
stop 4.1.7
exit 4.1.4 13.1.8
  
```



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```

exit 4.1.4 13.2.3
exit 4.1.7 10.1.4
exit 4.1.7 10.2.5
4.1.1 38.875622 -77.200759
4.1.2 38.875027 -77.200698
4.1.3 38.874115 -77.200634
4.1.4 38.873192 -77.200569
4.1.5 38.873010 -77.200554
4.1.6 38.871478 -77.200436
4.1.7 38.870081 -77.200333
end_lane
lane 4.2
num_waypoints 7
lane_width 12
left_boundary double_yellow
checkpoint 4.2.2 10
stop 4.2.4
exit 4.2.4 13.1.8
exit 4.2.4 13.2.3
4.2.1 38.870158 -77.200276
4.2.2 38.871366 -77.200372
4.2.3 38.872202 -77.200444
4.2.4 38.873010 -77.200499
4.2.5 38.873193 -77.200513
4.2.6 38.874666 -77.200627
4.2.7 38.875650 -77.200690
end_lane
end_segment
segment 5
num_lanes 1 /*one-way*/
segment_name Nevada_St
lane 5.1
num_waypoints 2
exit 5.1.2 2.1.1
5.1.1 38.869166 -77.204268
5.1.2 38.869153 -77.205225
end_lane
end_segment
segment 6
num_lanes 2
segment_name Colorado_Circle /*west
side of traffic circle*/

```

```

lane 6.1
num_waypoints 13
lane_width 12
left_boundary broken_white
stop 6.1.13
exit 6.1.7 5.1.1
exit 6.1.13 8.1.1
6.1.1 38.871336 -77.203633
6.1.2 38.871298 -77.203866
6.1.3 38.871215 -77.204026
6.1.4 38.871075 -77.204165
6.1.5 38.870949 -77.204187
6.1.6 38.869849 -77.204171
6.1.7 38.869290 -77.204160
6.1.8 38.868104 -77.204130
6.1.9 38.867249 -77.204110
6.1.10 38.867110 -77.204077
6.1.11 38.867007 -77.203998
6.1.12 38.866907 -77.203885
6.1.13 38.866797 -77.203637
end_lane
lane 6.2
num_waypoints 13
lane_width 12
right_boundary broken_white
exit 6.2.13 7.1.1
6.2.1 38.871288 -77.203633
6.2.2 38.871245 -77.203857
6.2.3 38.871121 -77.204049
6.2.4 38.871006 -77.204135
6.2.5 38.870320 -77.204140
6.2.6 38.869298 -77.204112
6.2.7 38.868062 -77.204086
6.2.8 38.867248 -77.204064
6.2.9 38.867121 -77.204031
6.2.10 38.867031 -77.203960
6.2.11 38.866933 -77.203846
6.2.12 38.866853 -77.203675
6.2.13 38.866825 -77.203545
end_lane
end_segment
segment 7

```



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```

num_lanes 1 /*one-way*/
segment_name Oklahoma_Circle /*east
side of traffic circle*/
lane 7.1
num_waypoints 12
checkpoint 7.1.8 6
exit 7.1.6 10.2.1
exit 7.1.12 6.1.1
exit 7.1.12 6.2.1
7.1.1 38.866823 -77.203270
7.1.2 38.866928 -77.203032
7.1.3 38.867053 -77.202896
7.1.4 38.867215 -77.202833
7.1.5 38.868121 -77.202838
7.1.6 38.869047 -77.202857
7.1.7 38.869286 -77.202864
7.1.8 38.870296 -77.202886
7.1.9 38.870961 -77.202919
7.1.10 38.871175 -77.203066
7.1.11 38.871274 -77.203252
7.1.12 38.871319 -77.203476
end_lane
end_segment
segment 8
num_lanes 2
segment_name Texas_Rd
lane 8.1
num_waypoints 2
stop 8.1.2
exit 8.1.2 9.2.1
8.1.1 38.866680 -77.203516
8.1.2 38.866344 -77.203509
end_lane
lane 8.2
num_waypoints 2
stop 8.2.2
exit 8.2.2 7.1.1
8.2.1 38.866370 -77.203363
8.2.2 38.866685 -77.203370
end_lane
end_segment
segment 9

```

```

num_lanes 2
segment_name Louisiana_Rd
lane 9.1
num_waypoints 2
lane_width 12
left_boundary double_yellow
stop 9.1.2
exit 9.1.2 8.2.1
9.1.1 38.866323 -77.201585
9.1.2 38.866300 -77.203235
end_lane
lane 9.2
num_waypoints 3
lane_width 12
left_boundary double_yellow
checkpoint 9.2.2 5
stop 9.2.3
exit 9.2.3 3.2.1
9.2.1 38.866270 -77.203351
9.2.2 38.866279 -77.202522
9.2.3 38.866291 -77.201586
end_lane
end_segment
segment 10
num_lanes 2
segment_name Tennessee_Rd
lane 10.1
num_waypoints 7
lane_width 12
left_boundary double_yellow
stop 10.1.5
stop 10.1.7
exit 10.1.3 4.2.1
exit 10.1.5 3.1.8
exit 10.1.5 3.2.7
exit 10.1.7 7.1.7
10.1.1 38.870720 -77.199015
10.1.2 38.870604 -77.199307
10.1.3 38.870122 -77.200111
10.1.4 38.869885 -77.200463
10.1.5 38.869323 -77.201379
10.1.6 38.869220 -77.201690

```



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```

10.1.7 38.869211 -77.202720
end_lane
lane 10.2
num_waypoints 8
lane_width 12
left_boundary double_yellow
stop 10.2.2
exit 10.2.2 3.1.8
exit 10.2.2 3.2.7
exit 10.2.4 4.2.1
exit 10.2.8 13.1.1
10.2.1 38.869167 -77.202723
10.2.2 38.869178 -77.201670
10.2.3 38.869258 -77.201403
10.2.4 38.869859 -77.200425
10.2.5 38.870065 -77.200114
10.2.6 38.870355 -77.199643
10.2.7 38.870543 -77.199311
10.2.8 38.870671 -77.198981
end_lane
end_segment
segment 11
num_lanes 1 /*one-way*/
segment_name Kansas_St /*parking lot
exit road*/
lane 11.1
num_waypoints 4
lane_width 10
stop 11.1.4
exit 11.1.4 7.1.11
11.1.1 38.871928 -77.203138
11.1.2 38.871703 -77.203132
11.1.3 38.871432 -77.203086
11.1.4 38.871293 -77.203103
end_lane
end_segment
segment 12
num_lanes 1 /*one-way*/
segment_name Nebraska_St /*parking
lot entrance road*/
lane 12.1
num_waypoints 2
lane_width 10
stop 12.1.2
exit 12.1.2 14.0.2 /*into zone 14*/
12.1.1 38.872978 -77.202819
12.1.2 38.872297 -77.202805
end_lane
end_segment
segment 13
num_lanes 2
segment_name Virginia_Rd
lane 13.1
num_waypoints 11
lane_width 12
left_boundary double_yellow
checkpoint 13.1.6 3
stop 13.1.7
stop 13.1.9
exit 13.1.7 4.2.5
exit 13.1.7 4.1.5
exit 13.1.9 3.2.11
exit 13.1.9 3.1.4
exit 13.1.11 12.1.1
13.1.1 38.870844 -77.198884
13.1.2 38.871935 -77.198945
13.1.3 38.872943 -77.199001
13.1.4 38.873051 -77.199045
13.1.5 38.873125 -77.199164
13.1.6 38.873146 -77.199409
13.1.7 38.873125 -77.200427
13.1.8 38.873116 -77.200662
13.1.9 38.873103 -77.201554
13.1.10 38.873093 -77.201816
13.1.11 38.873076 -77.202697
end_lane
lane 13.2
num_waypoints 9
lane_width 12
left_boundary double_yellow
checkpoint 13.2.8 11
stop 13.2.2
exit 13.2.2 4.1.5
exit 13.2.2 4.2.5

```




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BUL-041

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exit 13.2.9 10.1.1
13.2.1 38.873072 -77.201548
13.2.2 38.873085 -77.200661
13.2.3 38.873085 -77.200425
13.2.4 38.873107 -77.199406
13.2.5 38.873107 -77.199260
13.2.6 38.873034 -77.199100
13.2.7 38.872921 -77.199054
13.2.8 38.871897 -77.198998
13.2.9 38.870849 -77.198941
end_lane
end_segment
zone 14 /*zones & segments have
unique identifiers.*/
num_spots 6
zone_name Central_Parking_Lot
perimeter 14.0
num_perimeterpoints 6
exit 14.0.5 11.1.1 /*out of zone 14*/
14.0.1 38.872271 -77.203339
/*perimeterpoint order reversed from
Rev 1.0*/
14.0.2 38.872258 -77.202804
14.0.3 38.872264 -77.202315
14.0.4 38.871959 -77.202309
14.0.5 38.871948 -77.203136
14.0.6 38.871947 -77.203331
end_perimeter
spot 14.1
spot_width 16
checkpoint 14.1.2 12
14.1.1 38.872151 -77.202972
14.1.2 38.872103 -77.202971
end_spot
spot 14.2
spot_width 16
checkpoint 14.2.2 13
14.2.1 38.872152 -77.202907
14.2.2 38.872104 -77.202906
end_spot
spot 14.3
spot_width 16
checkpoint 14.3.2 14
14.3.1 38.872152 -77.202843
14.3.2 38.872104 -77.202840
end_spot
spot 14.4
spot_width 16
checkpoint 14.4.2 15
14.4.1 38.872152 -77.202772
14.4.2 38.872105 -77.202770
end_spot
spot 14.5
spot_width 16
checkpoint 14.5.2 16
14.5.1 38.872153 -77.202708
14.5.2 38.872106 -77.202707
end_spot
spot 14.6
spot_width 16
checkpoint 14.6.2 17
14.6.1 38.872153 -77.202645
14.6.2 38.872106 -77.202643
end_spot
end_zone
end_file
  
```