



Welcome to the

Urban Challenge

Participants Conference



Agenda

1130 – 1145	Welcome	Dr. Tony Tether DARPA Director
1145 – 1200	Grand Challenge 2005	Mr. Ron Kurjanowicz DGC05 Program Manager
1200 – 1315	Program Plan	Dr. Norm Whitaker Urban Challenge Program Manager Ms. Kristen Fuller DARPA Contracts Officer
1315 – 1330	Break	
1330 – 1400	Rules	Dr. Norm Whitaker
1400 – 1430	Questions	



What is DARPA?

The Defense Advanced Research Projects Agency is the central R&D arm of the Department of Defense with the primary responsibility to conceive, explore, and demonstrate breakthrough system concepts and the most advanced technologies.





DARPA Grand Challenge

DGC I

Barstow to Primm

March 13, 2004



142 miles
10 hours
\$1M

DGC II

Desert Classic

October 8, 2005

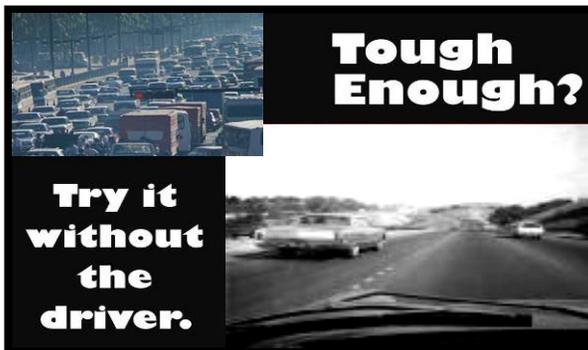


132 miles
10 hours
\$2M

DGC III

Urban Challenge

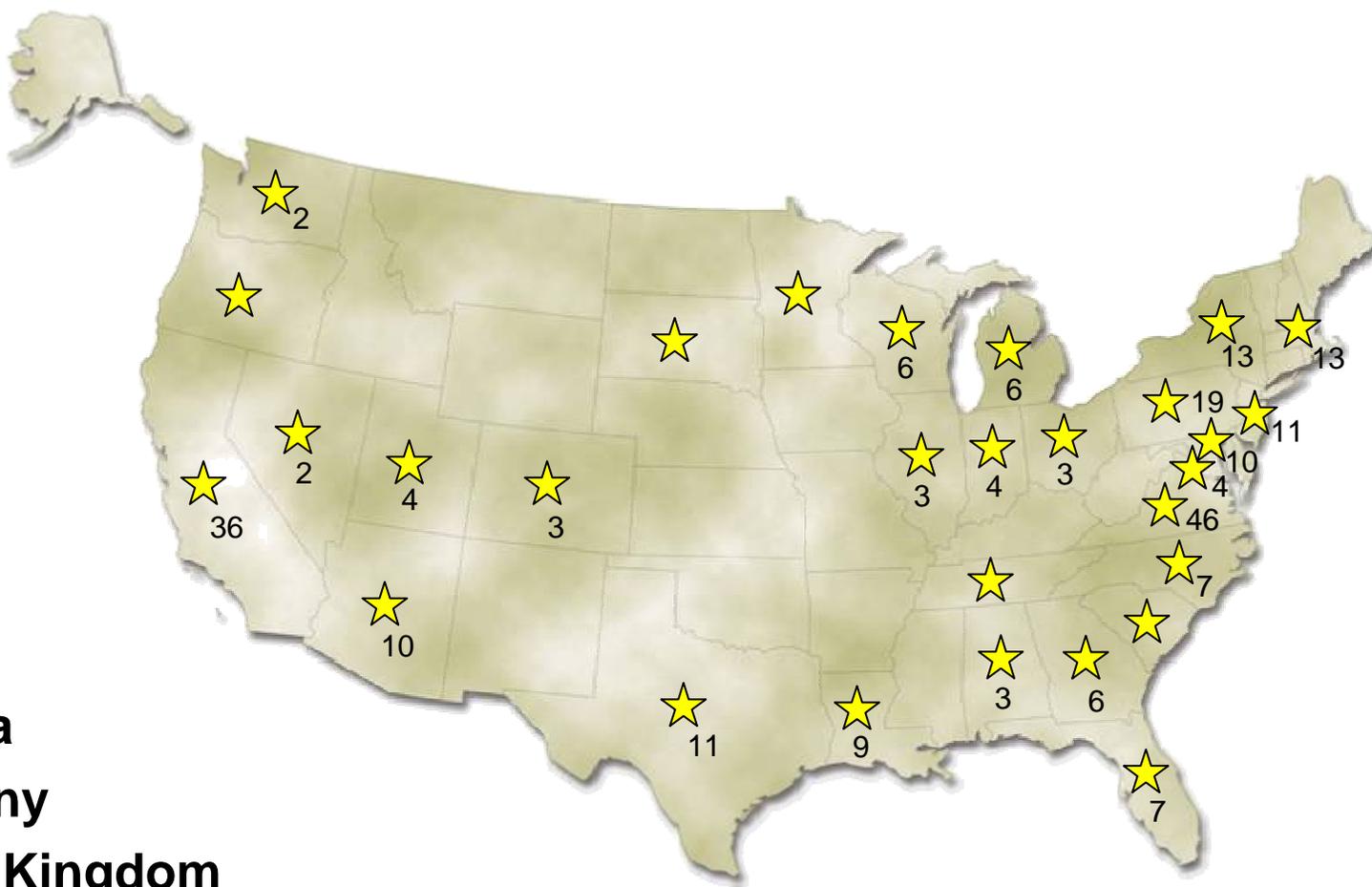
November 3, 2007



60 miles
6 hours
\$2.75M



On-Site Conference Participation



- ★ Canada
- ★ Germany
- ★ United Kingdom

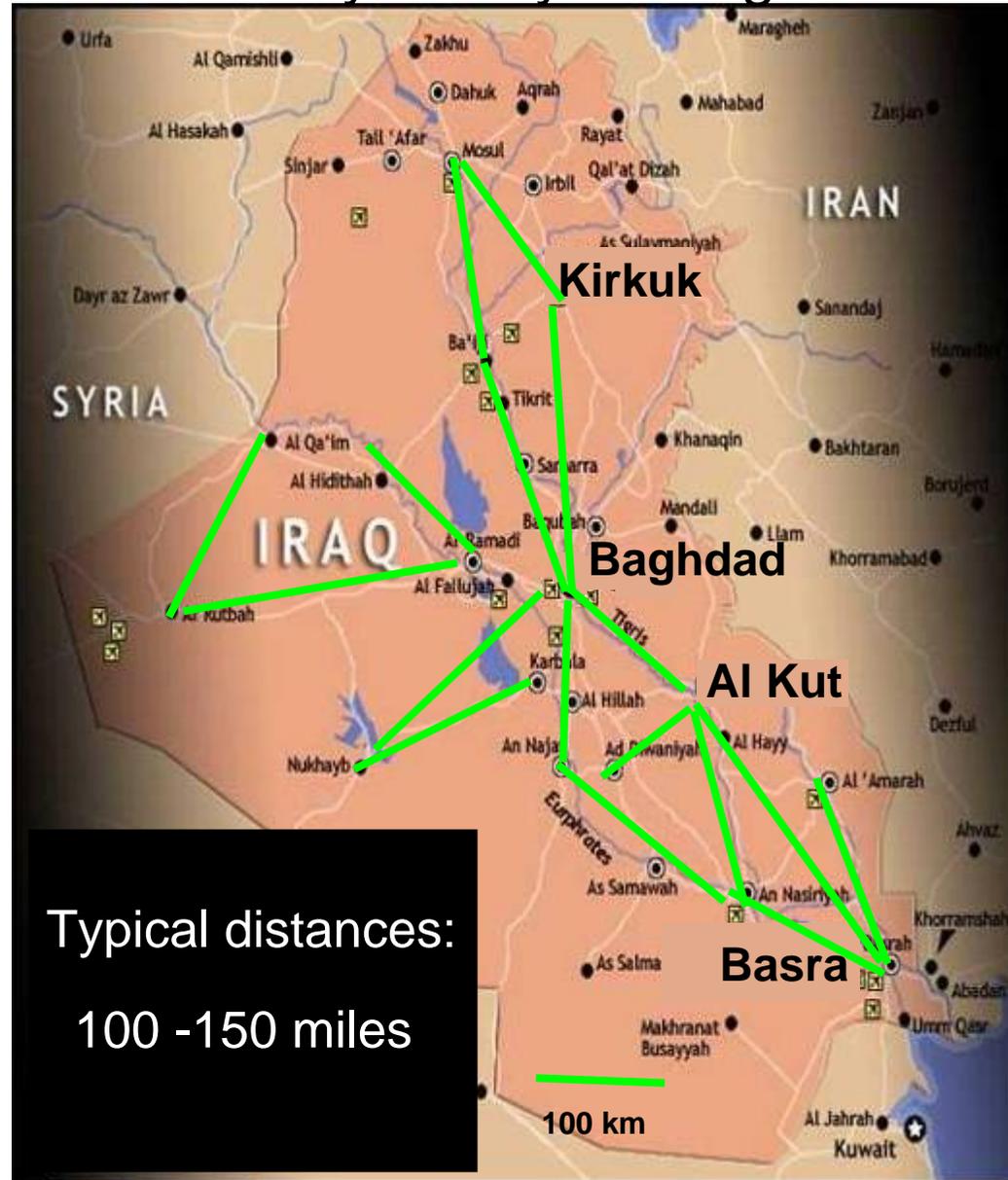
Representatives from 29 states

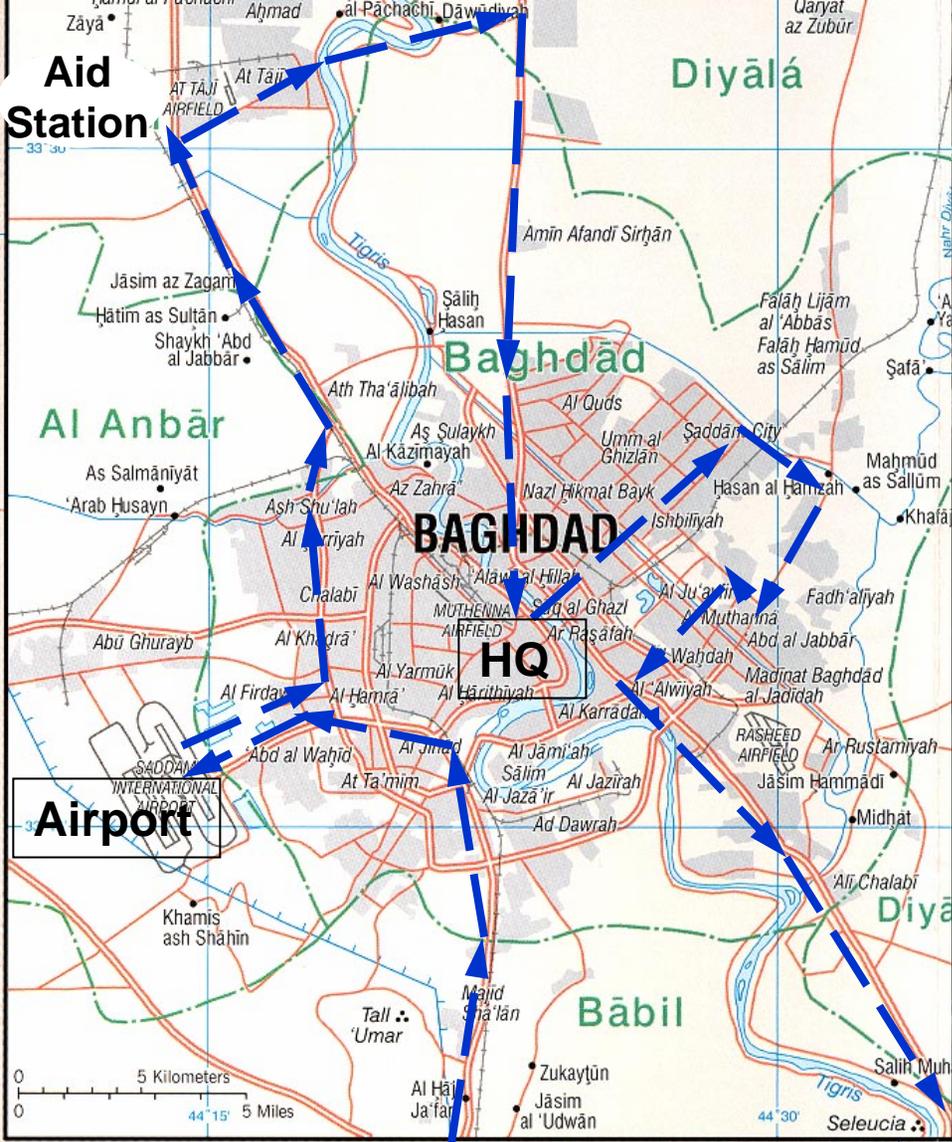


Grand Challenge 05

City to City Driving

- **Terrain**
 - Desert
 - Flat
 - Mountainous
- **Obstacles**
 - Bridges
 - Underpasses
 - Debris
 - Paved roadways
 - Poor roadways
 - Other Vehicles





60 Mile Supply Mission Through the City

11.08.11.55



Urban Challenge

City Driving

- Obey traffic laws
- Safe entry into traffic flow
- Safe passage through busy intersections
- Safe following or passage of moving vehicles
- Safe passage of a stopped vehicle
- Drive an alternate route when the primary route is blocked
- Safe U-turn





Prizes & Tracks A & B

Challenge: Complete 60 miles in traffic under 6 hours

- Prizes

- First Place: \$ 2,000,000
- Second: \$ 500,000
- Third: \$ 250,000

Track A: Submit proposal to Broad Agency Announcement. Best compliant proposals receive up to \$1 million technology development funds. Program ends at end of NQE. Successful performers invited to compete for Urban Challenge top three prizes.

Track B: Submit application, send video, get selected for DARPA site visit. Teams that succeed at the site visit receive \$50,000 to participate in National Qualification Event (NQE). Teams that succeed at NQE receive \$100,000 to participate in final event and compete for Urban Challenge top three prizes.



DARPA's Prize Authority

- **1999 - Today:**

The Secretary of Defense, acting through the Director of the Defense Advanced Research Projects Agency, may carry out a program to award cash prizes in recognition of outstanding achievements in basic, advanced, and applied research, technology development, and prototype development that have the potential for application to the performance of the military missions of the Department of Defense.

- **Expires September 30, 2007 (End of Fiscal Year 2007)**
- **New legislation sought to extend authority past FY 2007**



Prize Authority Legislation

House

Armed Services Committee

House Bill extends
DARPA's prize
authority to FY2010.
No other changes



House voted and
approved bill



Senate

Armed Services Committee

Bill extends prize authority
to FY2011, but removes
DARPA and adds other
DoD organizations



Bill not official yet.
Awaiting Senate vote;
expected by July 4



House – Senate
Conference



Senate's Proposed Revision to Existing Prize Authority Law

- **1999 - Today:**

The Secretary of Defense, acting through the Director of the Defense Advanced Research Projects Agency, may carry out a program to award cash prizes in recognition of outstanding achievements in basic, advanced, and applied research, technology development, and prototype development that have the potential for application to the performance of the military missions of the Department of Defense.

- **Senate Armed Services Committee Proposed Change:**

The Secretary of Defense, acting through the Director of Defense Research & Engineering and the Service Acquisition Executives of the military departments may carry out programs to award cash prizes.....



Impact on Urban Challenge if Proposed Revision Becomes Law

- Prizes

- First Place: \$ ~~2,000,000~~
- Second: \$ ~~500,000~~
- Third: \$ ~~250,000~~

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**Urban Challenge will be held, but DARPA will not have
authority to award cash prizes.**



Grand Challenge 2005



Site Visits



- Test Course**
- 8 meters wide
 - 200 meters long
 - 11 gates
 - Obstacles



The Grand Challenge

43 Semifinalists



43 teams from 15 states

1 high school team / 17 university teams

● 2004 Grand Challenge Team
● 2005 Grand Challenge New Entry



National Qualification Event

*California Speedway,
Ontario California
September 27 – October 5, 2005*





H1ghlander

September 19, 2005



7 days before National Qualification Event



National Qualification Event Track



Start Chute



Tunnel



Tank Trap



23 Grand Challenge 2005 Finalists



Axion Racing
Westlake
Village, CA



Desert Buckeyes
Columbus, OH



**The MITRE
Meteorites**
McLean, VA



**SciAutonics/
Auburn Engineering**
Thousand Oaks, CA



Team CajunBot
Lafayette, LA



Team ENSCO
Springfield, VA



MonsterMoto
Cedar Park, TX



Stanford Racing Team
Stanford, CA



Team Caltech
Pasadena, CA



**The Golem Group/
UCLA**
Santa Monica, CA



Mojávaton
Grand
Junction,
CO



Team TerraMax
Oshkosh, WI



CIMAR
Gainesville, FL



Gray Team
Metairie, LA



**Princeton
University**
Princeton, New
Jersey



**Virginia Tech
Team Rocky**
Blacksburg, VA



Team Cornell
Ithaca, NY



Insight Racing
Cary, NC



Red Team
Pittsburgh, PA



Team DAD
Digital Auto Drive
Morgan Hill, CA



**Intelligent Vehicle
Safety
Technologies I**
Littleton, CO



Red Team Too
Pittsburgh, PA



**Virginia Tech
Grand
Challenge
Team**
Blacksburg, VA



Start Line October 8, 2005 - 6:40 AM





Command Operations Center





The Course

Narrow Underpass



Long Tunnels



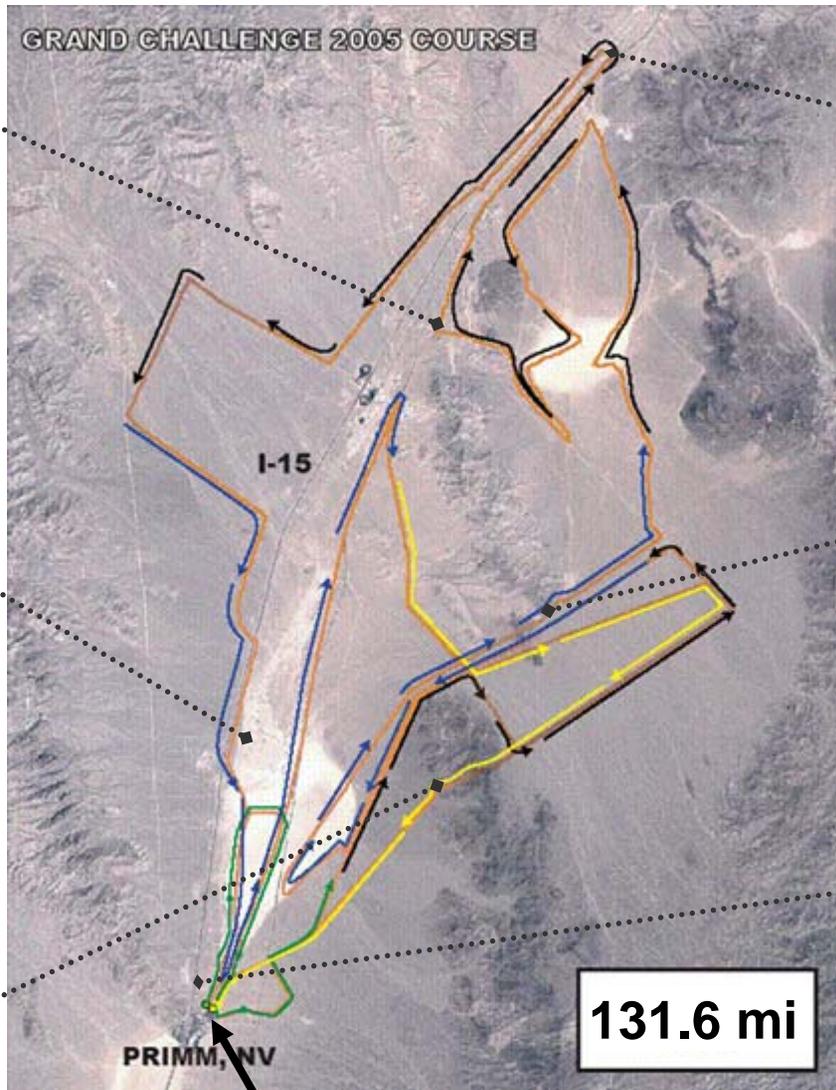
Lake Beds



Narrow Gates



Rough Roads



Start/Finish

Close Obstacles





Beer Bottle Pass – Mile 123





Grand Challenge Video



2005 Grand Challenge Results

STATUS BOARD

Final Results as of 10/9/2005



ID	TEAM	TIME	DISTANCE
3	Stanford Racing Team	6h 53m	131.70
19	Red Team	7h 4m	131.70
25	Red Team Too	7h 14m	131.70
30	Gray Team	7h 30m	131.70
21	Team TerraMax	12h 51m	131.70
28	Team ENSCO	DNF	81.20
23	Axion Racing	DNF	66.20
38	Virginia Tech Grand Challenge	DNF	43.50
9	Virginia Tech Team Rocky	DNF	39.40
10	Desert Buckeyes	DNF	29.00
4	Team DAD (Digital Auto Drive)	DNF	26.20
14	Insight Racing	DNF	25.60
1	Mojavaton	DNF	23.00
18	The Golem Group / UCLA	DNF	22.40
24	Team CajunBot	DNF	17.20
20	SciAutonics/Auburn Engineer	DNF	15.90
15	Intelligent Vehicle Safety Tecl	DNF	14.00
8	CIMAR	DNF	13.60
41	Princeton University	DNF	9.50
26	Team Cornell	DNF	8.90
2	Team Caltech	DNF	8.00
16	MonsterMoto	DNF	7.20
37	The MITRE Meteorites	DNF	0.73

2004 Distance



Stanley



Vehicle	Stanley
Team	Stanford Racing Team
Hometown	Palo Alto, California
Team Leader	Michael Montemerlo
Finishing time	6h 53m (19.2 mph)





Sandstorm



Vehicle	Sandstorm
Team	Red Team
Hometown	Pittsburgh, Pennsylvania
Team Leader	Red Whittaker
Finishing time	7h 04m (18.7 mph)





H1ghlander



Vehicle	H1ghlander
Team	Red Team Too
Hometown	Pittsburgh, Pennsylvania
Team Leader	Kevin Peterson
Finishing time	7h 14m (18.3 mph)





KAT-5



Vehicle	KAT-5
Team	Gray Team
Hometown	Metairie, Louisiana
Team Leader	Eric Gray
Finishing time	7h 30m (17.6 mph)





TerraMax



Vehicle	TerraMax
Team	Team TerraMax
Hometown	Oshkosh, Wisconsin
Team Leader	Jim Fravert
Finishing time	12h 51m (10.3 mph)





Living on the Edge





Program Plan



Program Objective

Safe autonomous driving in traffic

- **Safe**
No collisions
- **Capable**
Turns, stops, intersection, passing, merging, parking, following
- **Robust**
Blocked roads, erratic drivers, sparse waypoints, GPS outage





Program Scope

YES

- **Passing moving vehicles**
- **Merging into traffic**
- **Dirt roads, potholed roads**

NO

- **Speeds greater than 30 mph**
- **Highway driving**
- **Traffic signals or yield signs**
- **Difficult terrain**



Rules and the PIP

- Rules will change
 - Send suggestions to grandchallenge@darpa.mil
 - June 2, 2006 deadline
- PIP amendments will be posted to FedBizOpps
 - PIP and Rules consistency
 - Objectives will not change



We are not making new rules today

Follow:

- BAA/PIP and Rules
- www.darpa.mil/grandchallenge
- baa06-36@darpa.mil



Program Technical Team

- Sean O'Brien
- Jon Hahn
- Harry Berman



Program Plan

- • Overview
- Track A
- Track B



How to Participate

- 1. Form a Team**
- 2. Select Track A or Track B**
- 3. Submit an Application or Proposal**
- 4. Develop a Vehicle**
- 5. Qualify**
- 6. Compete**



1. Form a Team

- **Team Leader**

21 year-old U.S. citizen and resident

- **Team members**

Individuals can be on only one team

No nationality restrictions

- **Sponsors**

No restrictions

(see rules regarding Government assets and organizations).



Documentation Requirement

- U.S. Citizenship:**
- U.S. passport
 - Current drivers license and birth certificate

- U.S. Residency :**
- 2 required**
- Payroll stub issued by employer in the last 2 months
 - Utility bill not more than 2 months old issued to team leader (gas, electric, sewer, water, cable phone but not cell)
 - Receipt for personal property taxes or real estate taxes paid within the last year to a U.S. state, commonwealth, or locality
 - Current automobile or life insurance bill (cards or policies not accepted)
 - Voter Registration Card from U.S. state or commonwealth
 - Deed, mortgage, monthly mortgage statement, or residential rental/lease agreement

PIP and Rules will be changed



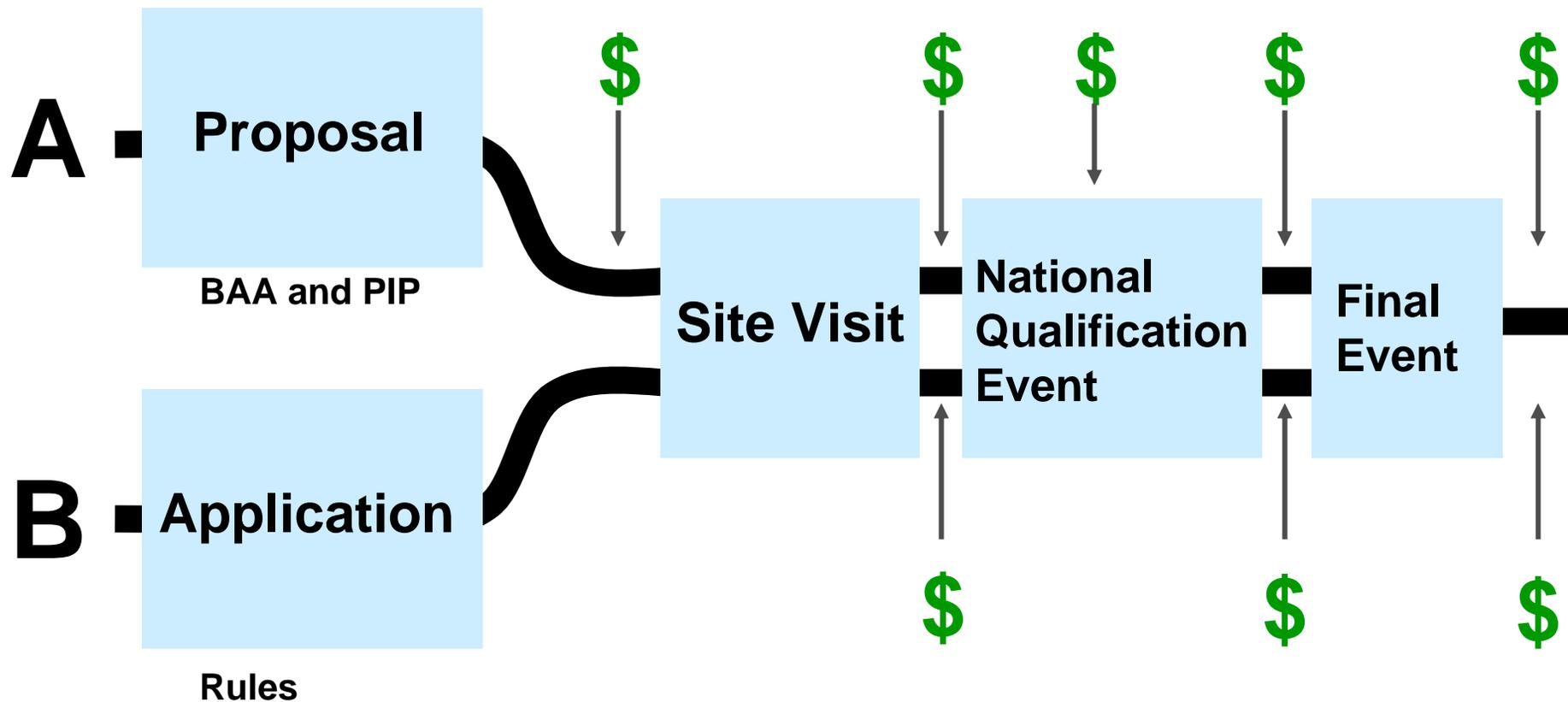
Team Example

Team Widget from Widget Industries
Mary Engineer and other employees

Team Leader: Mary Engineer
Team Members: Other employees
Team Sponsor: Widget Industries



2. Select Track A or B





Comparing Tracks

Track A

- Submit proposals
- Up to \$1M available through payable milestones
- Government Purpose Rights to technology

Track B

- Submit application including video
- \$50K for Semi-finalists \$100K for Finalists
- Government claims no rights to technology

Identical Technical Criteria



3. Submit Application or Proposal

Track A

- **Proposal** in required format
- June 23, 2006 deadline
- Optional video

Track B

- **Application:** 4 parts
- October 5, 2006 Deadline
- Mandatory video



Government Participation

- **Below the Federal level**

Unrestricted: state universities on either track

- **At the Federal level**

Track B participation only
(if allowed by charter)



Funding Restriction

- **None**

Track A teams are not limited to contract dollars

- **Use of other Government program assets**

Disclose in part 1 of the application



4. Develop a Vehicle

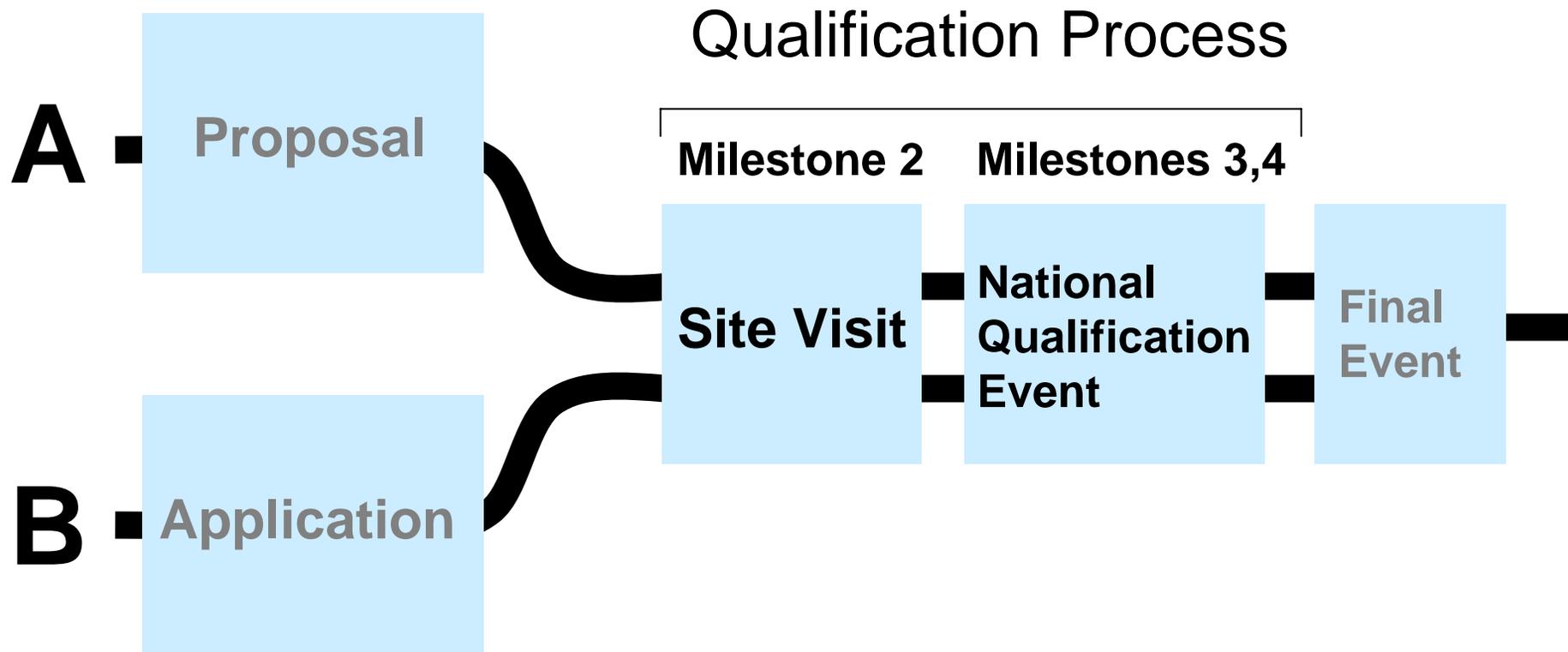
Vehicle Requirements

- **Weight:** 2000 to 30,000 lbs
- **Wheelbase:** Min. 72 inches Max. U-turn 30 foot-wide road
- **Production vehicle or documented safety record**
- **Manual E-stop required.**
- **Wireless communication prohibited while autonomous (see rules).**
- **Warning light and audible alarm. Brake lights and directionals.**
- **Team E-stop for Site Visit. DARPA E-stop for NQE.**

PIP will change: Same requirements on Tracks A and B



5. Qualify





Site Visit

- DARPA Staff
 - June 11 – July 20, 2007
- Location of your choice
 - In the United States
- 4 hours max
- Submit RNDP in advance
- Provide one traffic vehicle and one control vehicle
- Follow the DARPA guidelines



**NQE Selection Announcement
August 10, 2007**



National Qualification Event (NQE)

- **October 21-31, 2007**
- **Location to be announced**
- **Teams must arrive prepared**
- **Test integration of Government E-stop**
- **Advanced Navigation Test (Milestone 3)**
 - **No moving traffic**
- **Advanced Traffic Test (Milestone 4)**
 - **Repeated testing in moving traffic**
 - **Preparation for the Final Event**



Goal – no collisions



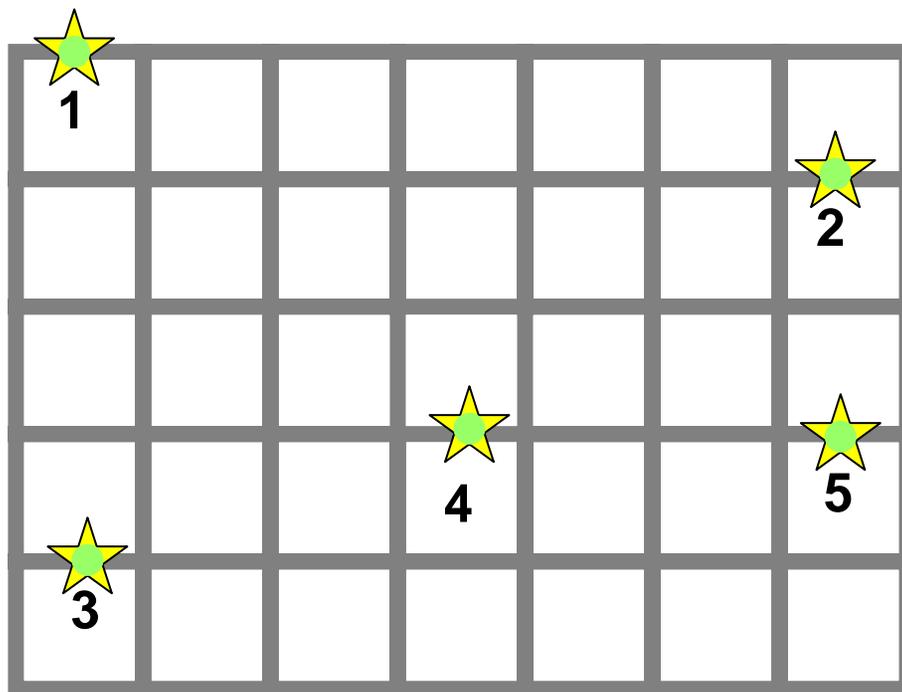
Qualification

Track B Semi-finalist limit: 20 Teams

**Only fully competent vehicles will
be allowed in the Final Event.**



6. Compete at the Final Event

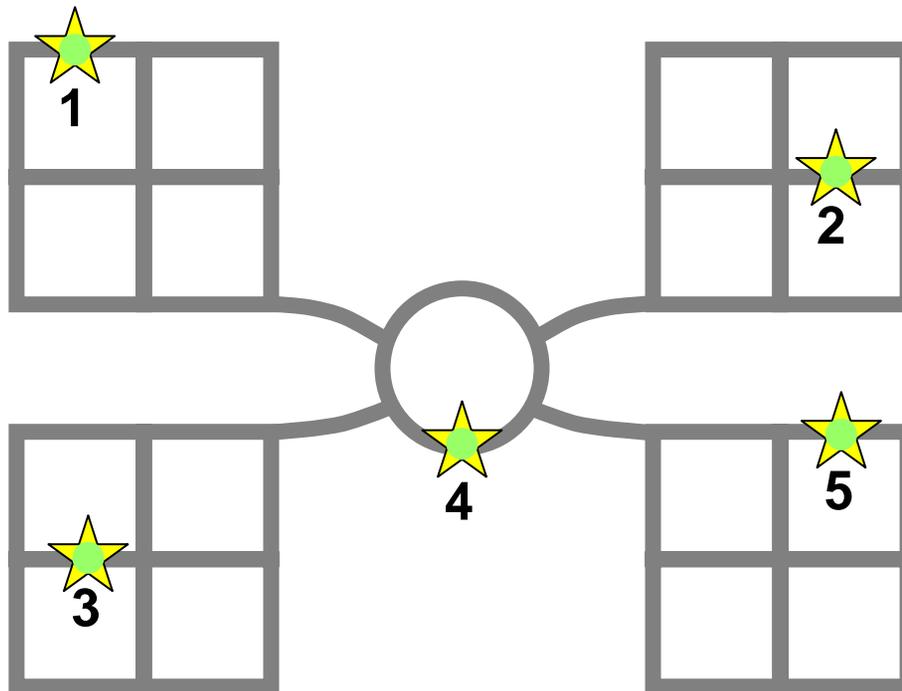


Urban Route Network

 Checkpoints

**All vehicles on the course together,
completing equivalent missions by
visiting checkpoints**

Creating Equivalent Missions



$$1 \text{ 4 } 3 \text{ 4 } 2 \text{ 4 } 5 \cong 5 \text{ 4 } 2 \text{ 4 } 1 \text{ 4 } 3$$

Many equivalent routes are possible



The Final Event

- Route network distributed at least 24 hours in advance
- Teams perform multiple missions



Pit crew performance counts



Mission Start

UFE only

final mission waypoint

team takes control of vehicle

robot 12

start chutes

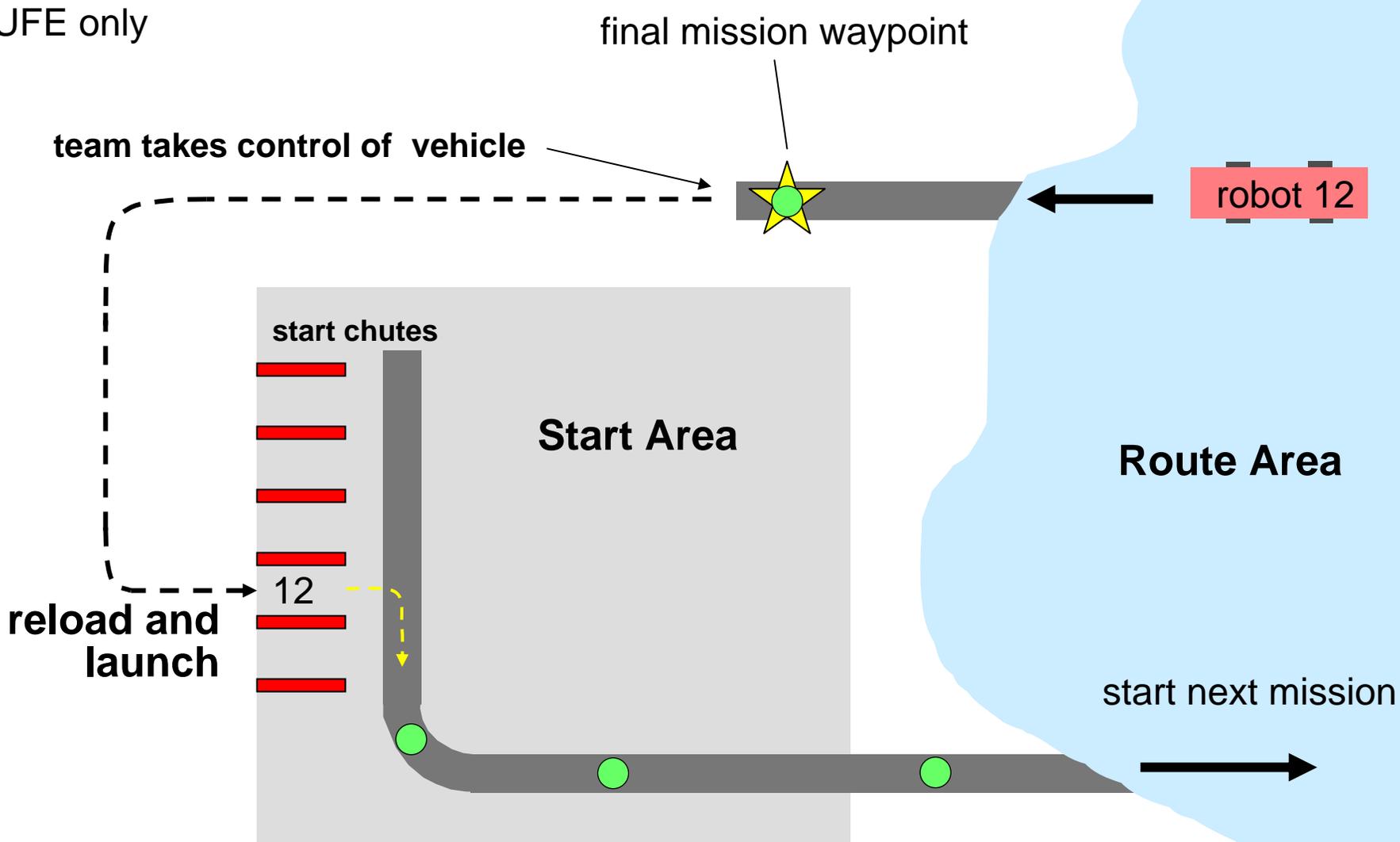
Start Area

Route Area

reload and launch

12

start next mission





Program Plan

- Overview
- • Track A
- Track B



Must Know Info

CMO

-
- Proposals must be received on or before **June 23, 2006 at 5:00 p.m. EDT**
 - Revisions, if any, will be posted to FEDBIZOPPS
 - Send all communications to BAA06-36@darpa.mil
 - FAQs: www.darpa.mil/grandchallenge
 - Proposal instructions are found in the Proposer Information Pamphlet (PIP)



More Must Know Info *CMO*

- Only Fixed Price FAR Contracts or Other Transaction for Prototype Agreements will be awarded
- Proposals must be entered into DARPA TFIMS before the proposal due date
 - TFIMS Instructions at www.darpa.mil/grandchallenge
 - Must apply for a password for the system, so don't wait until the last minute



PIP Highlights

CMO

-
- **Rights in Data**
 - Government Purpose Rights (GPR) to milestone reports and other documentation submitted at milestone meetings and technical interchange meetings
 - GPR to all elements of intellectual property for this program created in whole or in part using Government funding
 - Unlimited Rights to vehicle technical paper
 - **Intellectual Property (IP) Claims**
 - Proposers are required to submit a listing (proposal Attachment E) of any pre-existing noncommercial components of IP to which a claim is asserted



PIP Highlights

CMO

- Foreign Access to Technology
 - Teams must notify DARPA if the Arms Export Control Act, Export Administration Act, or International Traffic In Arms Regulations (ITAR) apply
- Organizational Conflict of Interest
 - Proposal must include a completed copy of affirmation as proposal Attachment C
- Waiver and Release of Indemnity and Liability
 - Must sign and notarize waiver and release of indemnity and liability (proposal Attachment D)



More on Contract Type *CMO*

- Proposals should not address profit as a separate element
 - Stimulating research and development, not acquiring goods or services. Funds for performance of technical effort
- A model Other Transaction Agreement is included in the PIP
 - Proposals for OTs must include proposal Attachment B
 - Not required when proposing a FAR contract



Contract Types

CMO

-
- **Contract** - the principal purpose of the instrument is **acquisition by purchase, lease, or barter of property or services for the direct benefit** or use of the Federal Government or whenever DARPA determines in a specific instance that the use of a type of procurement contract is appropriate
 - **Other Transaction for Prototype** - a legally binding instrument other than a procurement contract, grant, cooperative agreement, or other transaction for research/TIA **used for a prototype project** proposed to be acquired or developed by the Department of Defense (DoD)

Must meet one of the following requirements:

- Non-traditional Defense Contractor
- Provide one-third cost share
- SPE determines exceptional circumstances exist



OTs and Cost Sharing *CMO*

- Current costs only, not sunk costs
 - Sunk costs are those that were invested prior to the award of the OT
 - The value of the sunk costs is realized in a positive proposal evaluation
- The best forms of cost sharing are cash and IR&D because they are readily quantifiable



Proposal Evaluation

CMO

- Evaluation Criteria and Weighting
 - Listed in descending order of importance
 - Technical Approach
 - Management and Funding Plan
 - Strength of Team
- Scoring
 - Proposal ratings will range from 1 through 4, where 4 is the highest rating and 1 the lowest



Other Information

CMO

- Teaming and Eligibility
 - Only one proposal per prime. May participate as subcontractor on more than one team
 - Teams selected under Track A may not enter any other vehicles for either track
 - Government organizations may not respond to the BAA
- Only a duly authorized Contracting Officer may obligate the Government
- Proposals are treated by DARPA as Competitive Information/Source Selection Sensitive
 - Proposals may be handled by support contractor personnel subject to Non-Disclosure Agreements



Program Plan

- Overview
- Track A
- • Track B



Track B Application

part 1: **Team Information**

- Team leader and alternate required
- Pictures and other information for the website
- Vehicle technical information
- Use of Government contract assets information



Track B Application

part 2a: **Proof of Citizenship (photocopy)**

- Passport or
- Birth certificate and driver's license
- Due October 5, 2006

part 2b: **Waiver and Release of Indemnity and Liability**

- Signed and notarized
- Due October 5, 2006



Track B Application

part 3: **Site Visit Information** (due March 2, 2007)

- Description and directions to site visit location
- Route Network Definition File for the site

part 4: **Video Demonstration** (due April 13, 2007)

- 5 minutes maximum
- CD with video in .wmv format
- Content guidelines will be released by DARPA



Emergency Stop System

- Teams provide E-stop for site visit.
- DARPA will issue an E-stop system to all semi-finalists
 - Equipment remains Government property
 - Integrate according to instructions prior to NQE
- E-stop modes
 - RUN – autonomous operation
 - PAUSE – controlled halt
 - DISABLE – shut down engine





Technical Paper

- Publication quality
- Available for public release
 - Do not submit proprietary information
- 25% of site visit score
- Will be published after completion of Urban Challenge
- Track A: Due at Milestone 2
- Track B: Due April 13, 2007

DARPA Grand Challenge

Technical Paper for TerraMax

Submitted by Oshkosh Truck Co.
and
The Ohio State University

1. System Description

a. Mobility.

1. Describe the means of ground contact. Include a diagram showing the size and geometry of any wheels, tracks, legs, and/or other suspension components.

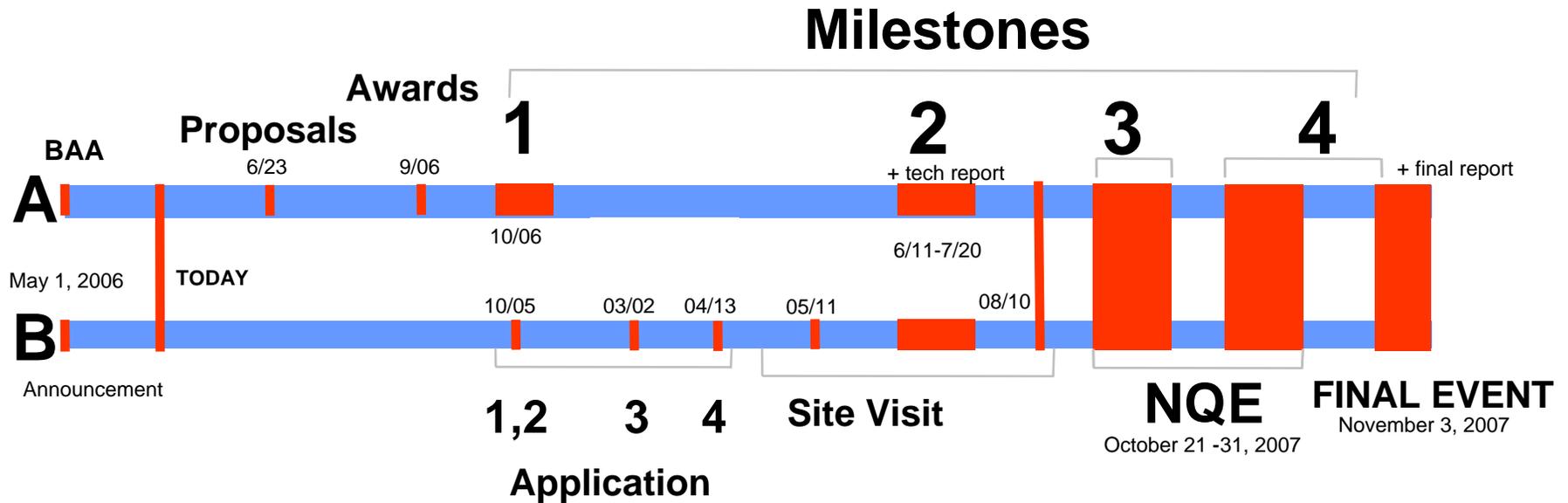
The vehicle platform is an Oshkosh Trucks MTRV ModelMK23. A brochure with technical specifications can be found at http://www.oshkoshtruck.com/pdf/Oshkosh_MTRV_brochure.pdf, which we also attach here. The minimum turning radius is 42.7 feet. However, if necessary, in "robot" mode (explained below) the vehicle will be able to turn a tighter corner in multiple back-forth motions. The vehicle can traverse a 60% grade and a 30% side slope. The vehicle cab and exhaust stack have been shortened to the dimensions given in section 3.f.2 to accommodate known requirements of the course.

A photograph of the TerraMax vehicle, a large green military-style truck with multiple large wheels, parked on a paved surface.

Figure 1. TerraMax arriving at the OSU Campus.



Summary Schedule



- March 2, 2007** **Site Visit RNDF due**
- April 13, 2007** **Video + Tech Paper due**
- May 11, 2007** **Site Visit Announcement**
- August 10, 2007** **Semi-finalist Announcements**



Rules

- • **Route Definition**
- **Technical Criteria**
- **Event Operations**



Route Definition

RNDF

Route Network Definition File

**At least 24 hours
in advance of start**

MDF₁

Mission Data File

**at least 5 minutes
before start**

MDF₂

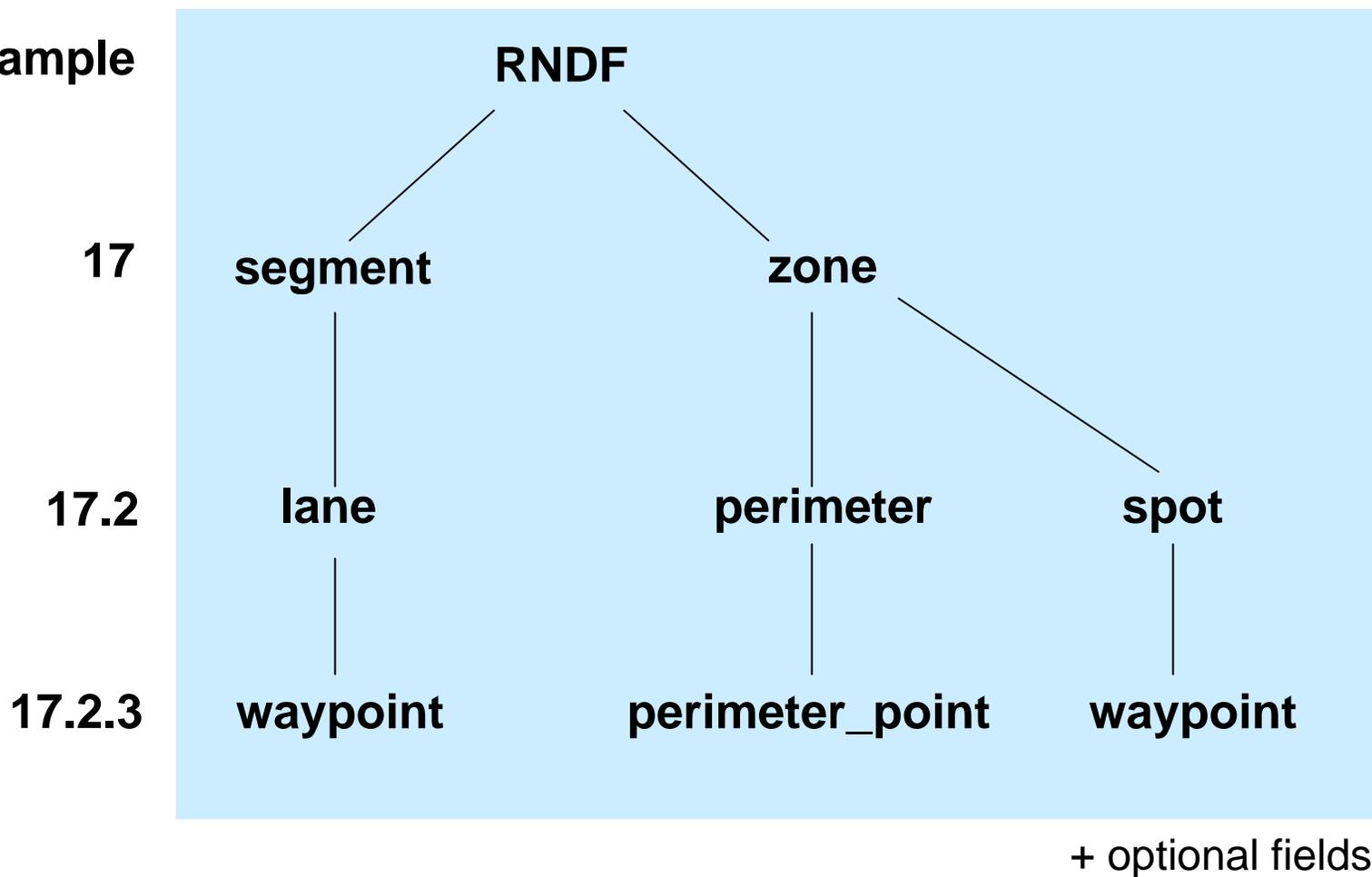
**at least 5 minutes
before second mission**

+ optional additional missions



RNDF - Route Network Definition File

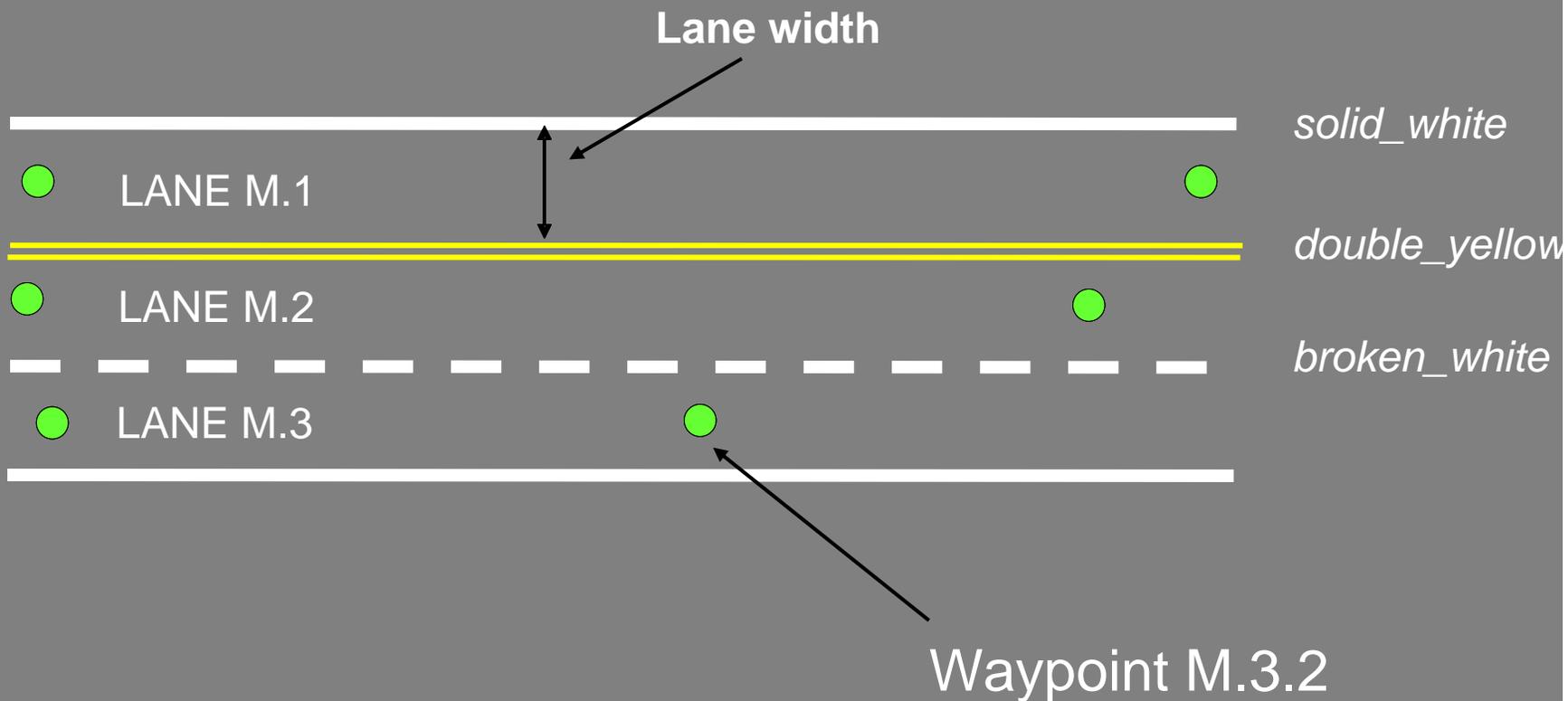
Example



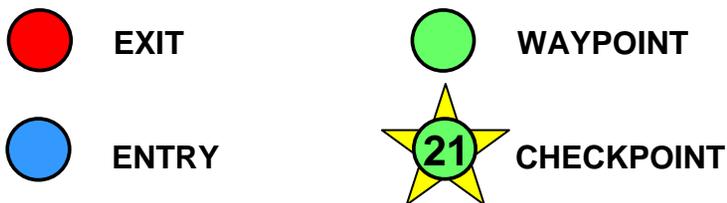
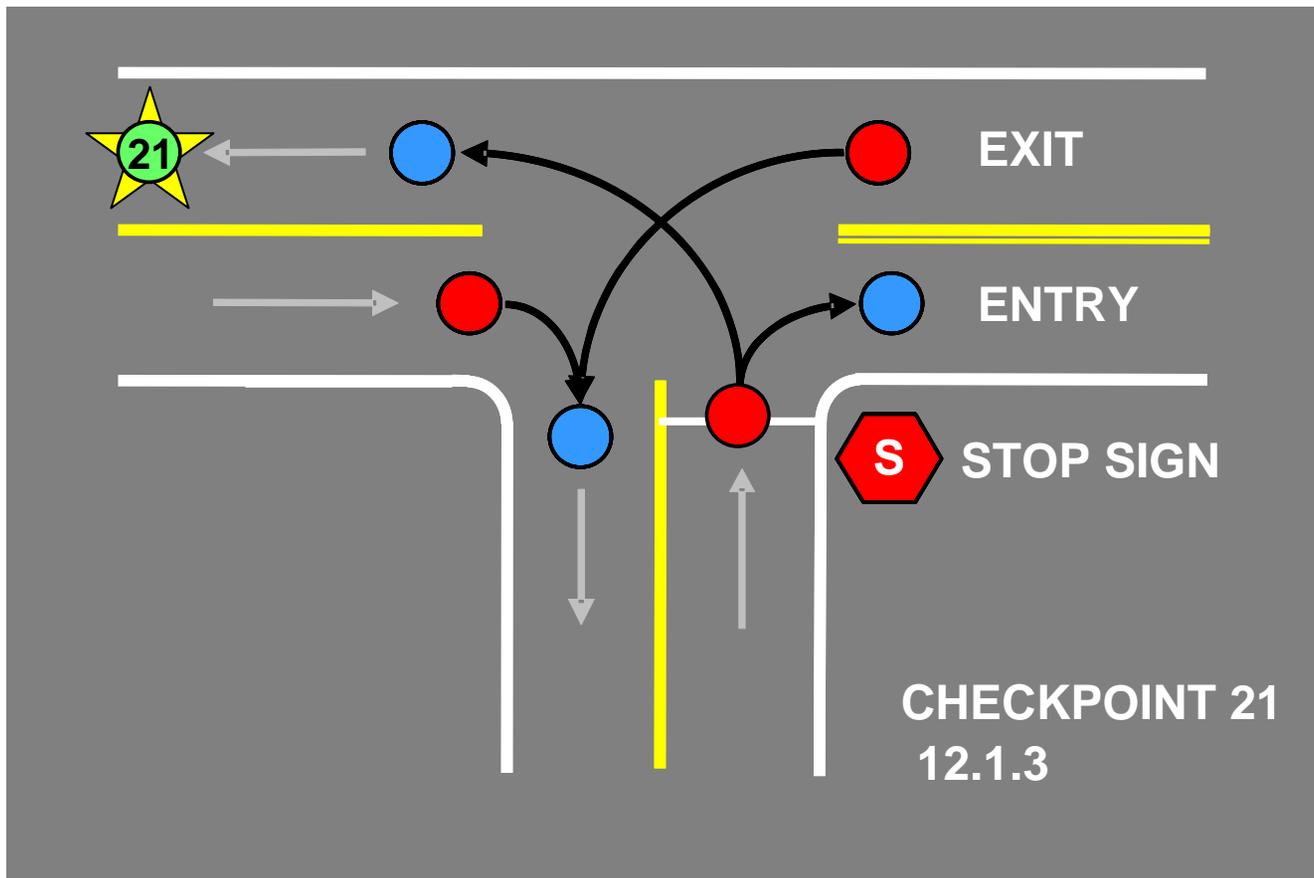


Segments and Lanes

SEGMENT M

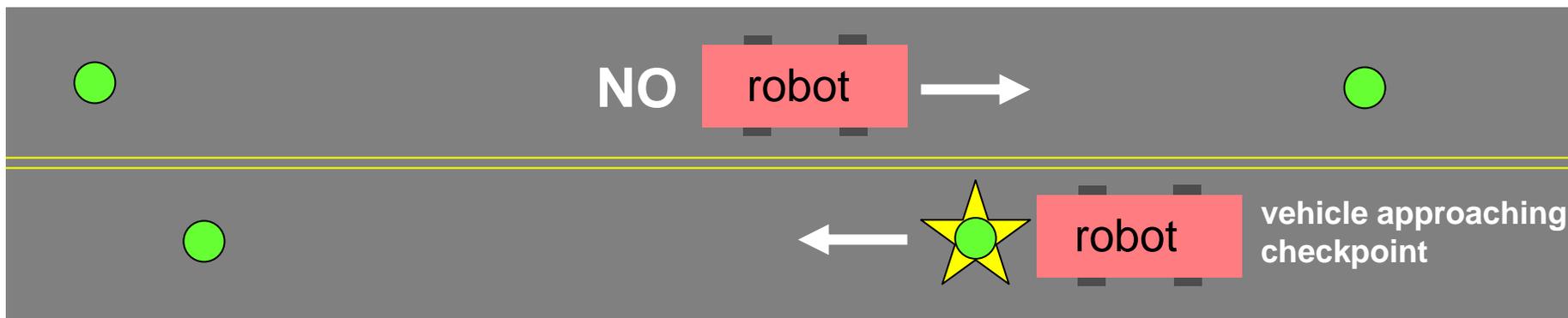


Exits and Checkpoints

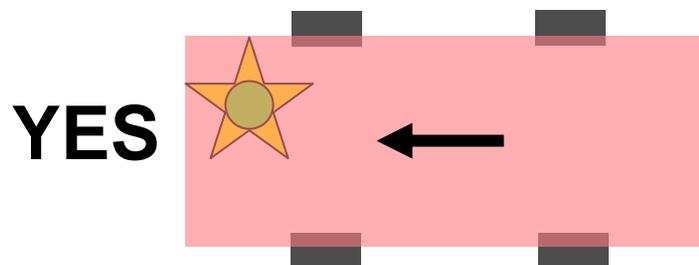




How to visit a checkpoint



Front bumper must completely pass over checkpoint in the proper lane



Road Markings



lane width

double_yellow
in RNDF

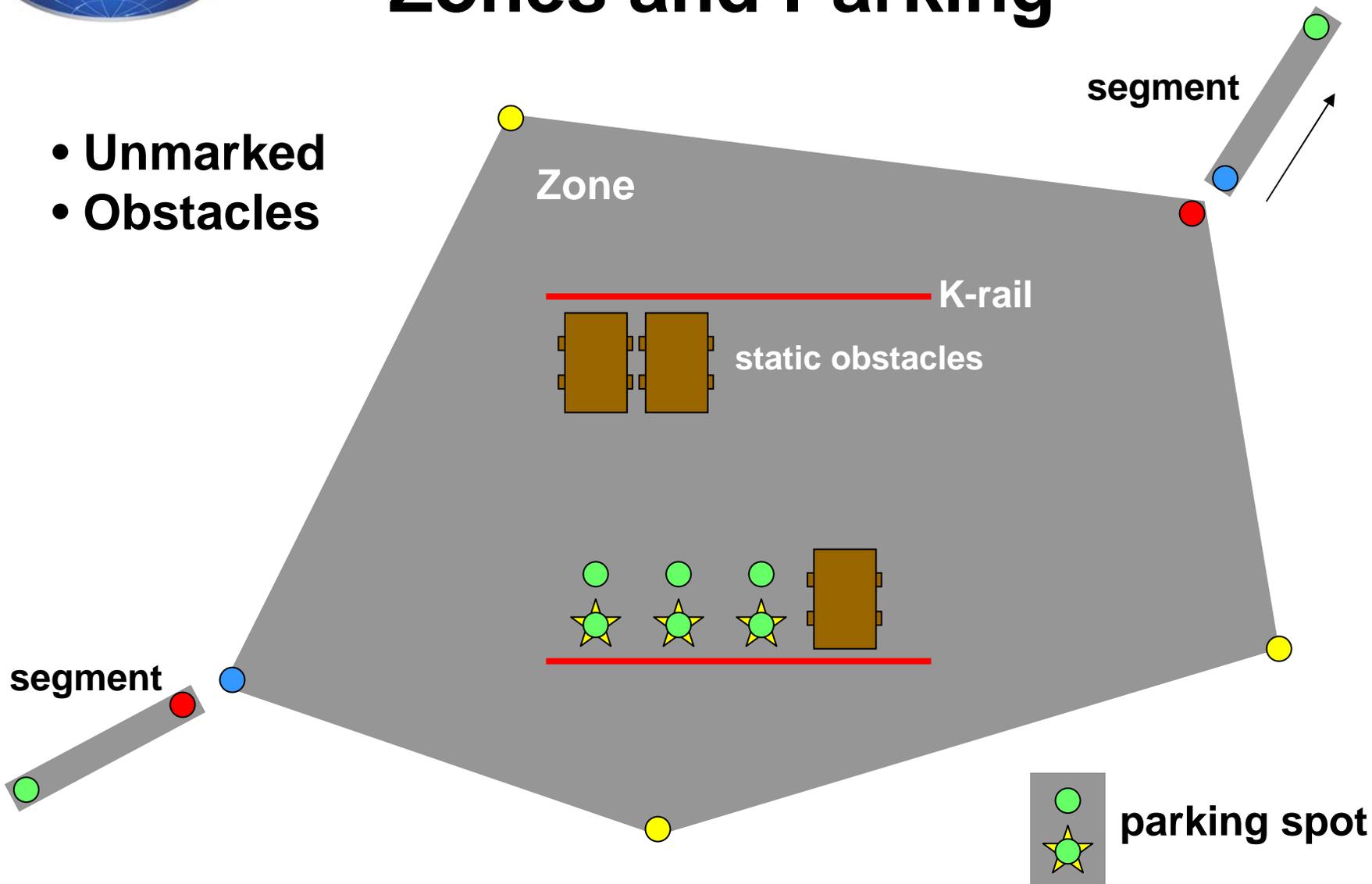
white
not in RNDF

Curb

Stop Line

Zones and Parking

- Unmarked
- Obstacles





MDF - Mission Data File

MDF

checkpoints

7
23
1
2
1
2
5

- Random start
- Follow in order
- May repeat

speed limits

- Speeds in miles per hour
- May change from mission to mission
- Per segment

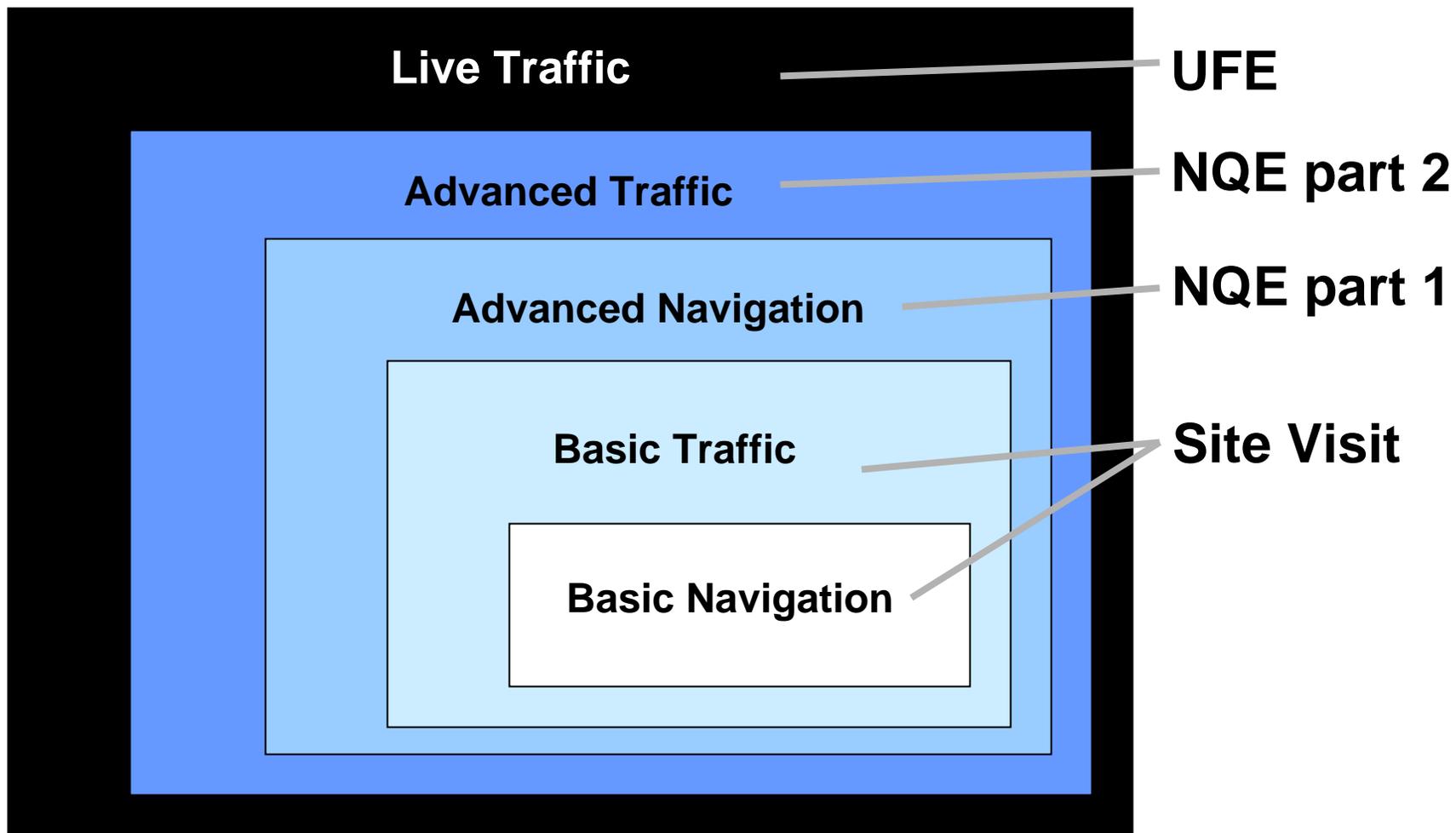


Rules

- Route Definition
- • Technical Criteria
- Event Operations



Required Behaviors



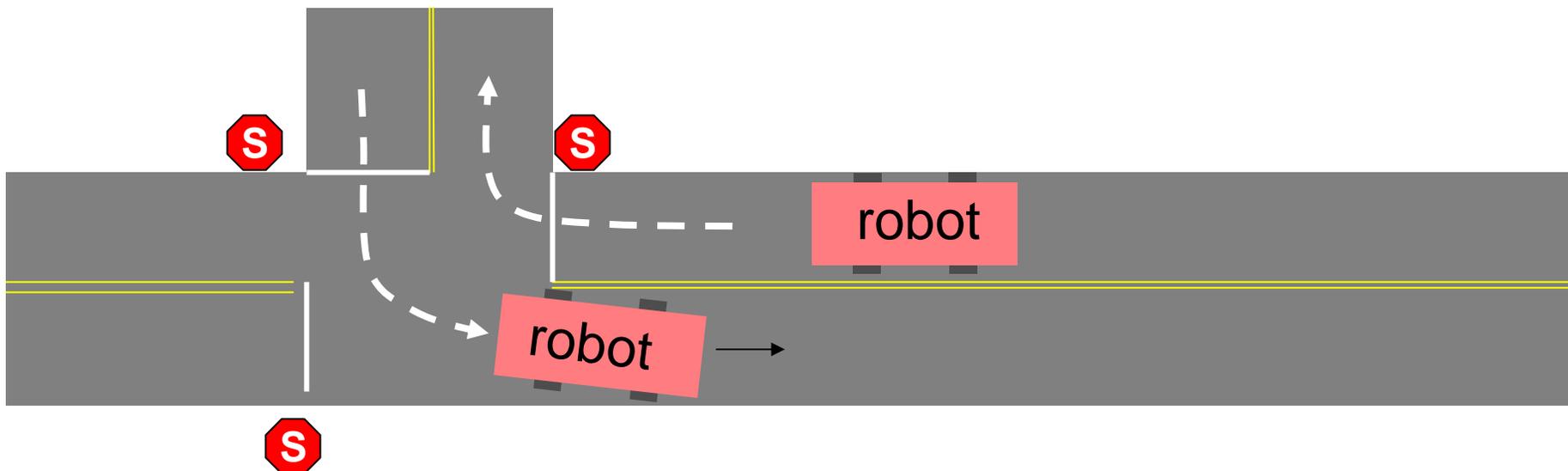


Technical Criteria Examples



Basic Navigation

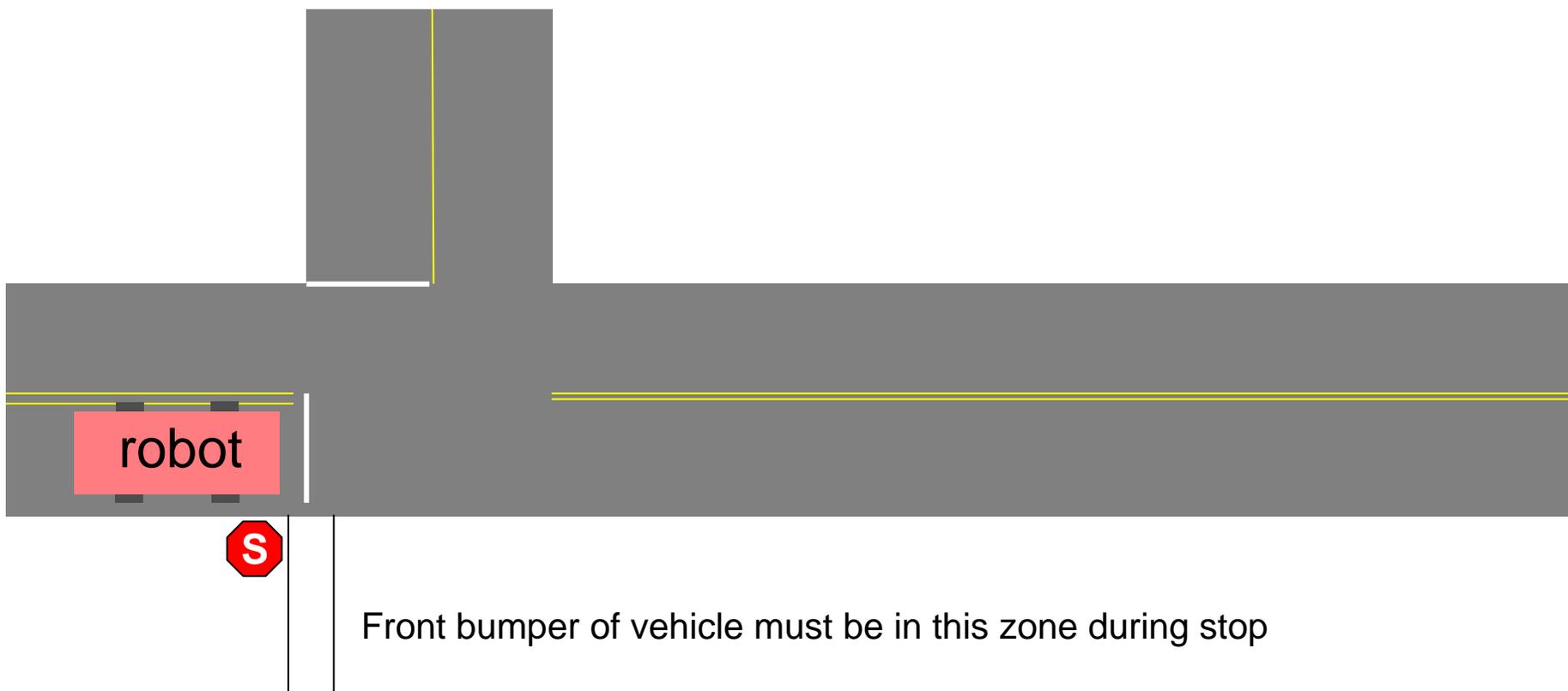
Vehicle stays entirely within travel lane around corners.





Basic Navigation

Vehicle stops within 1 meter of stop line.

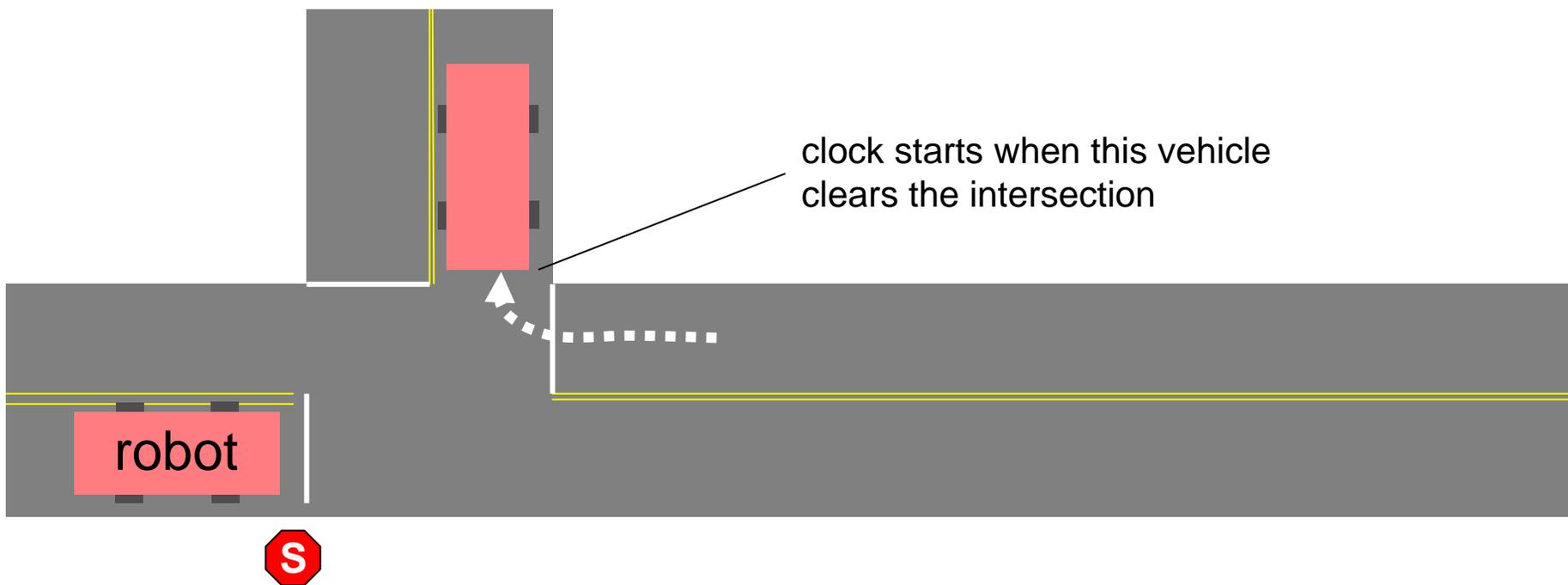


Front bumper of vehicle must be in this zone during stop



Basic Navigation

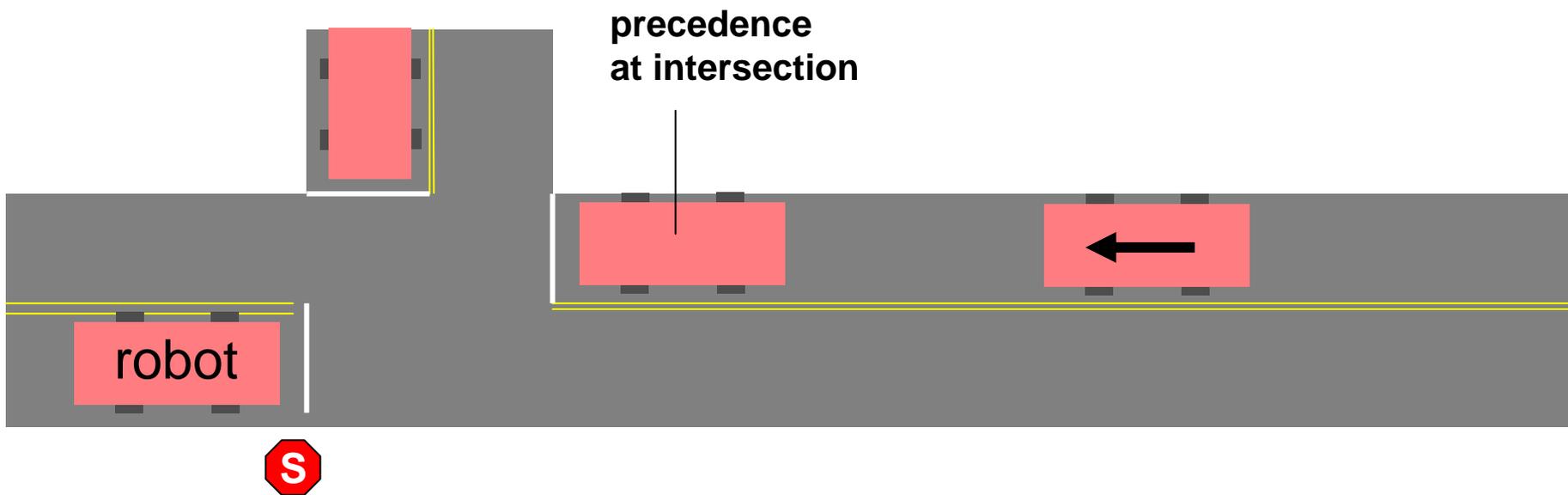
Vehicle exhibits less than 10 seconds of delay when intersection is clear.





Basic Traffic

Vehicle exhibits correct precedence order at intersection.

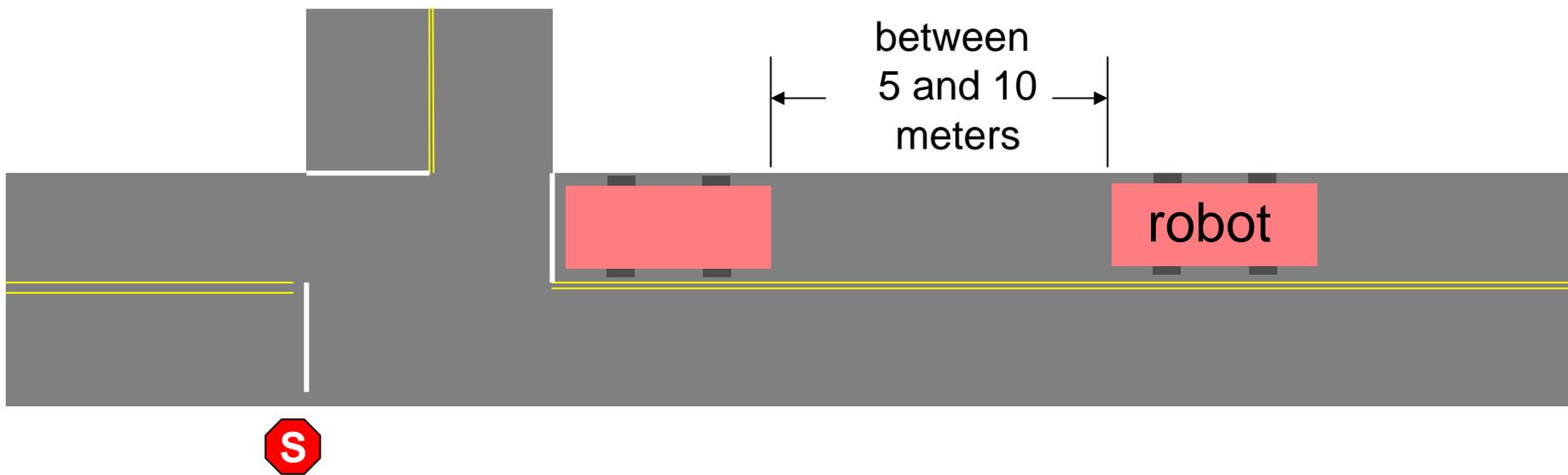


First to reach stop line is the first to leave.



Basic Traffic

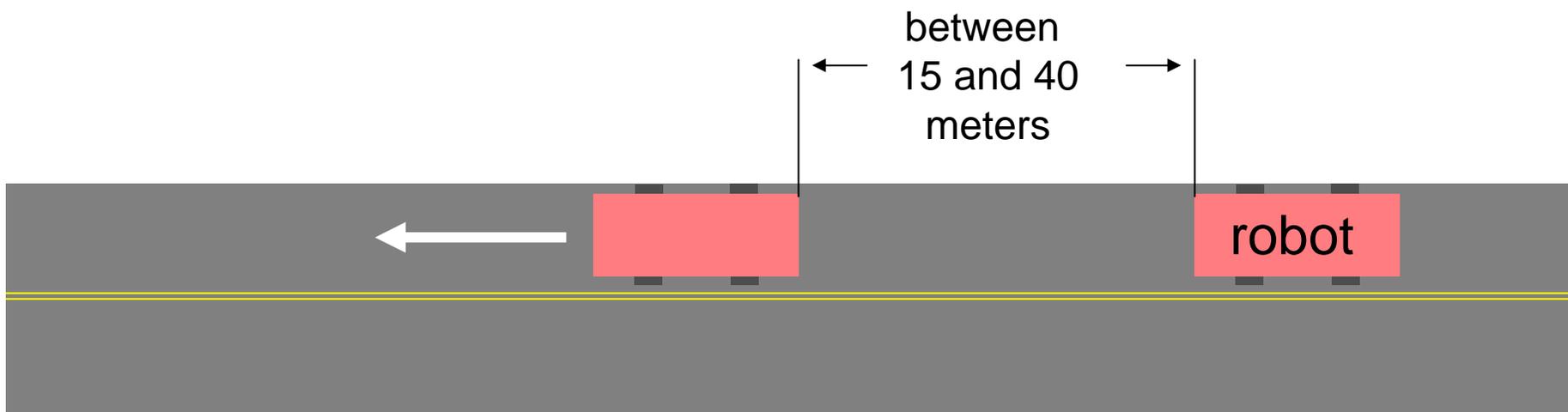
Vehicle stops between 5 and 10 meters behind stopped lead vehicle.





Basic Traffic

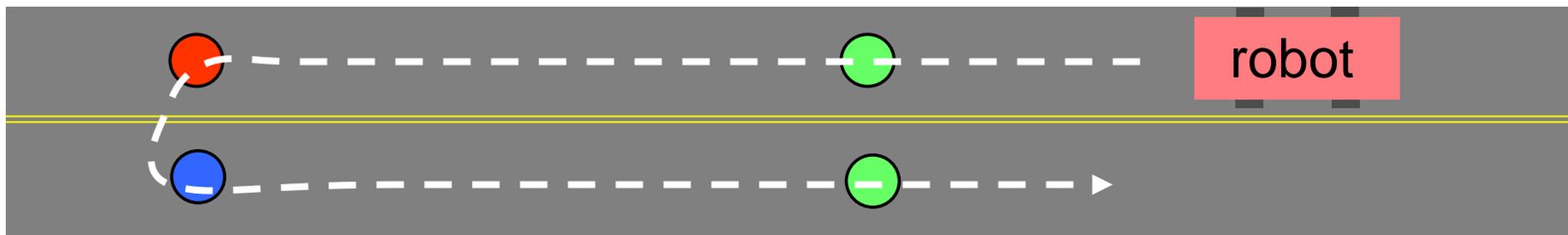
Vehicle maintains 15 meter safety buffer at 15 mph.





Advanced Navigation

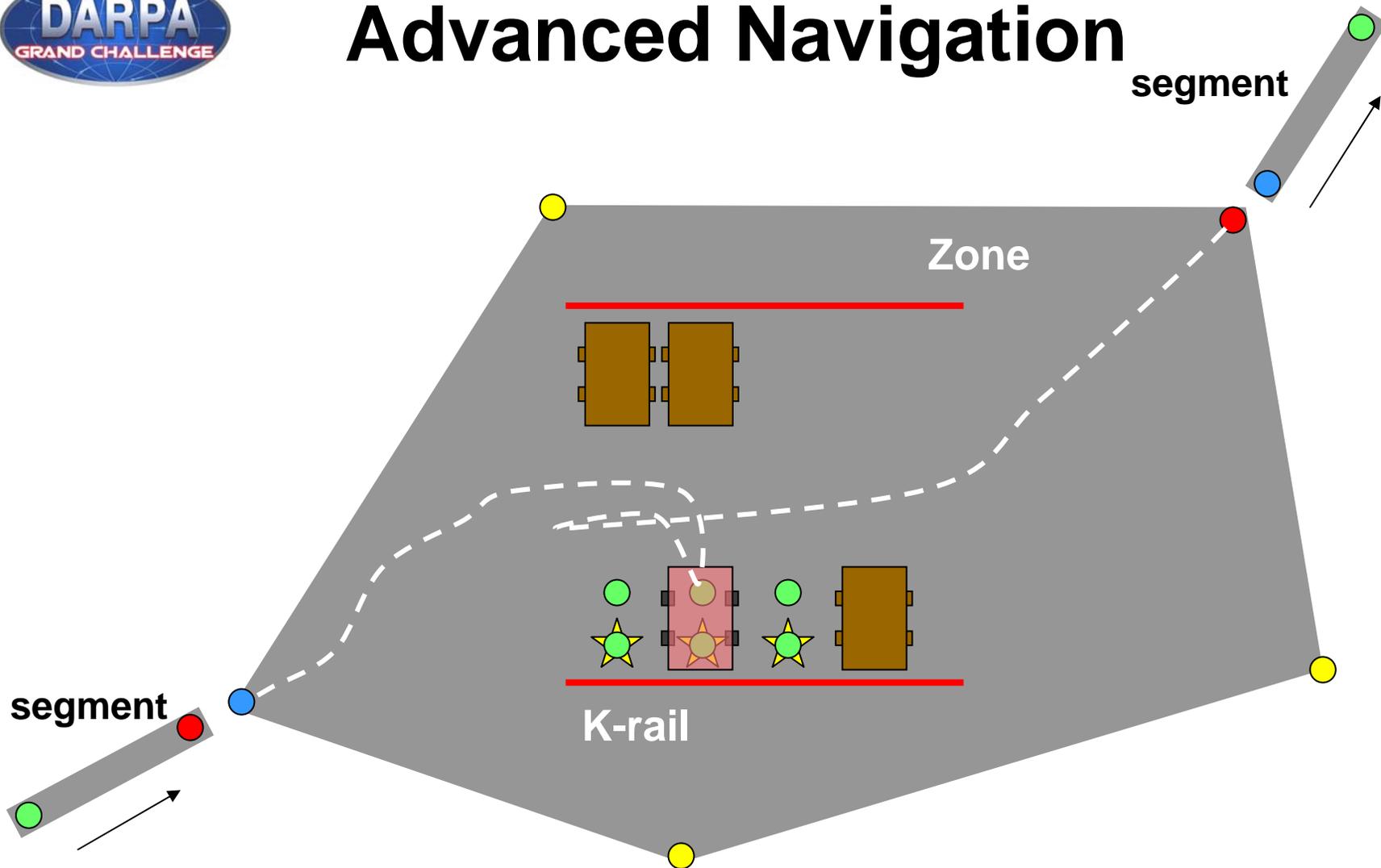
A U-turn may be effected through one or more three-point turns.



-  Waypoint
-  Entry waypoint
-  Exit waypoint



Advanced Navigation



Vehicle exhibits correct parking lot behavior with less than 10 seconds excess delay.



What is Excess Delay?

To avoid jamming up roads and parking lots, vehicles need to move when the way is clear.

Excess delay is timed during “stop and stare”

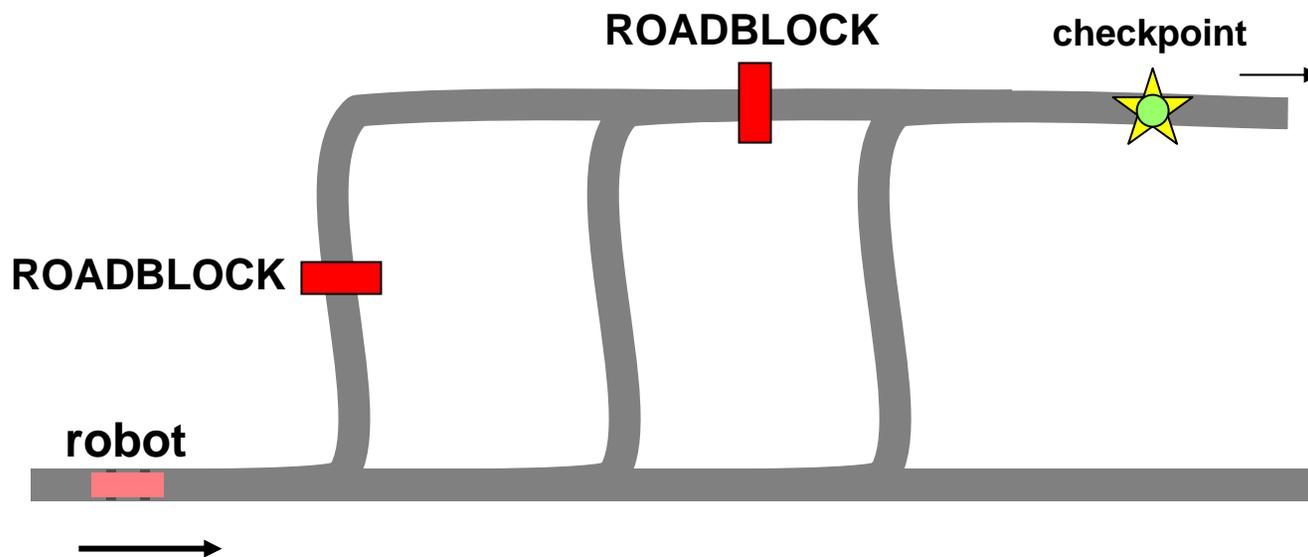
Taxicab Algorithm





Advanced Navigation

Vehicle re-plans when primary route is blocked.





Advanced Navigation

Vehicle navigates roads with sparse waypoints.

Intersection not called out in RNDF

Sparse waypoints on curved road

One-way road





Advanced Navigation

Road-following situations:

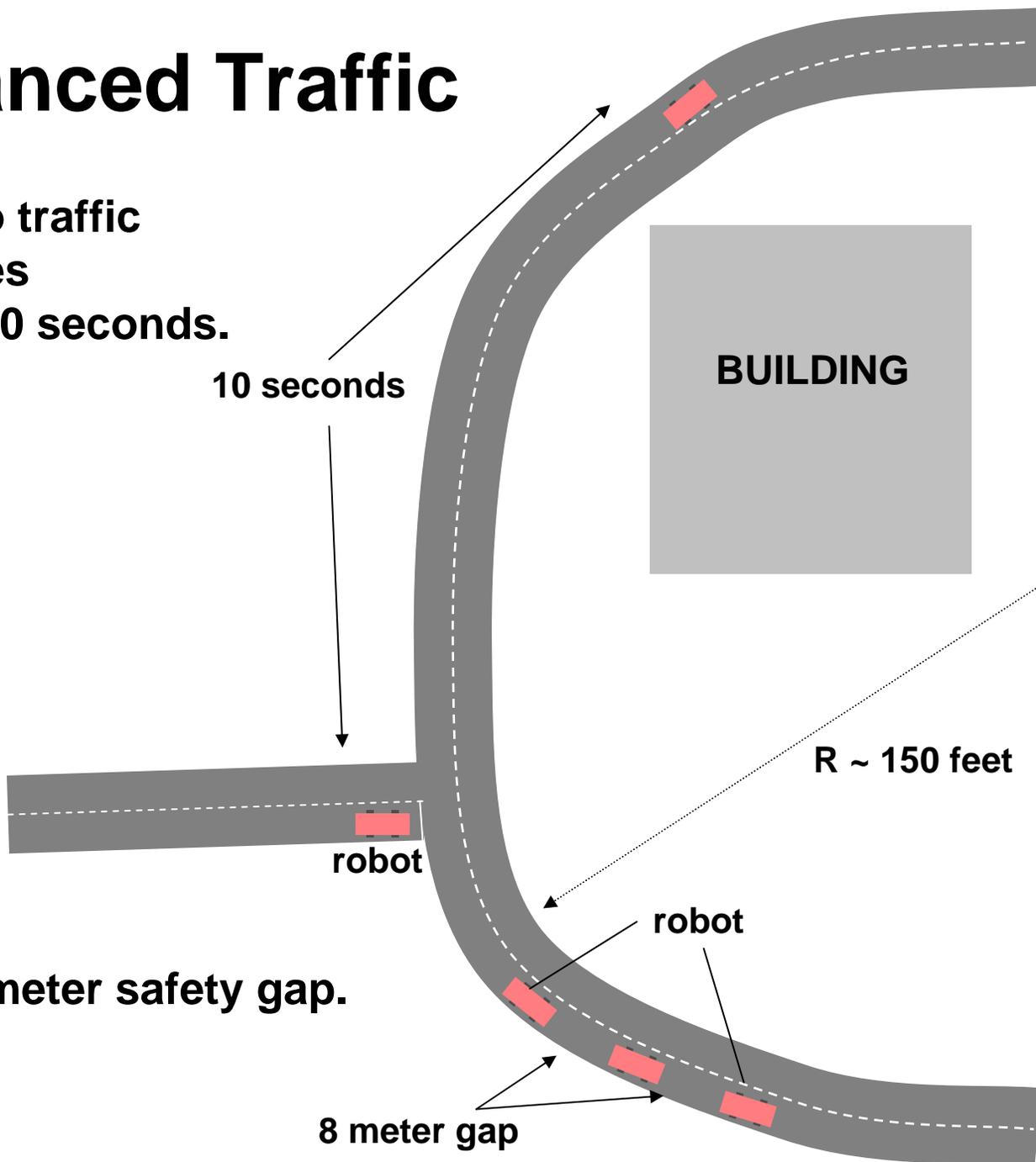
- **Curbs, berms, vegetation**
- **Street lines may be missing**
- **Winding roads**
- **Sparse waypoints -
may not be in center of road**





Advanced Traffic

- Vehicle should pull into traffic when oncoming vehicles leave a gap of at least 10 seconds.

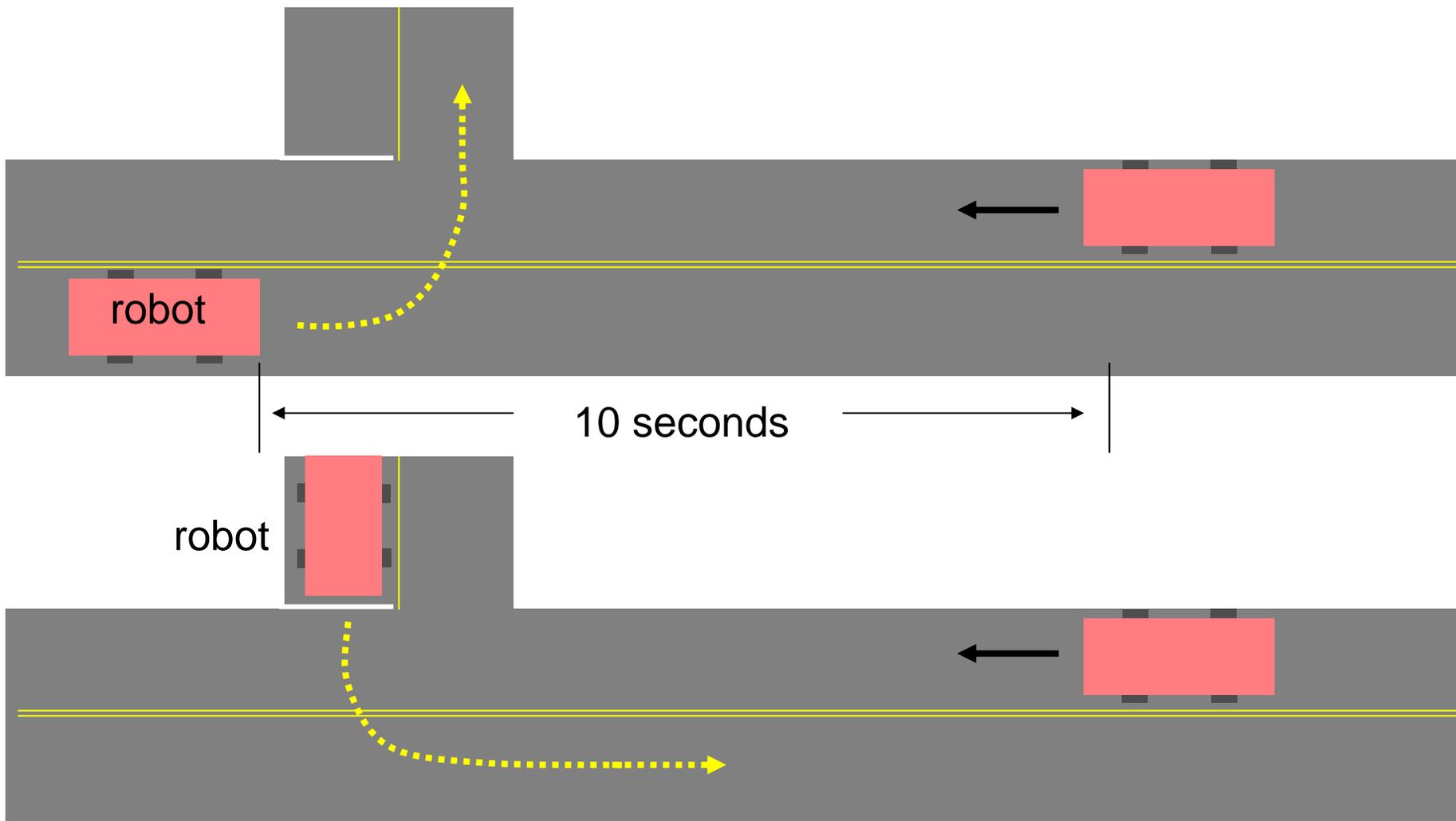


- Vehicle maintains 8 meter safety gap.



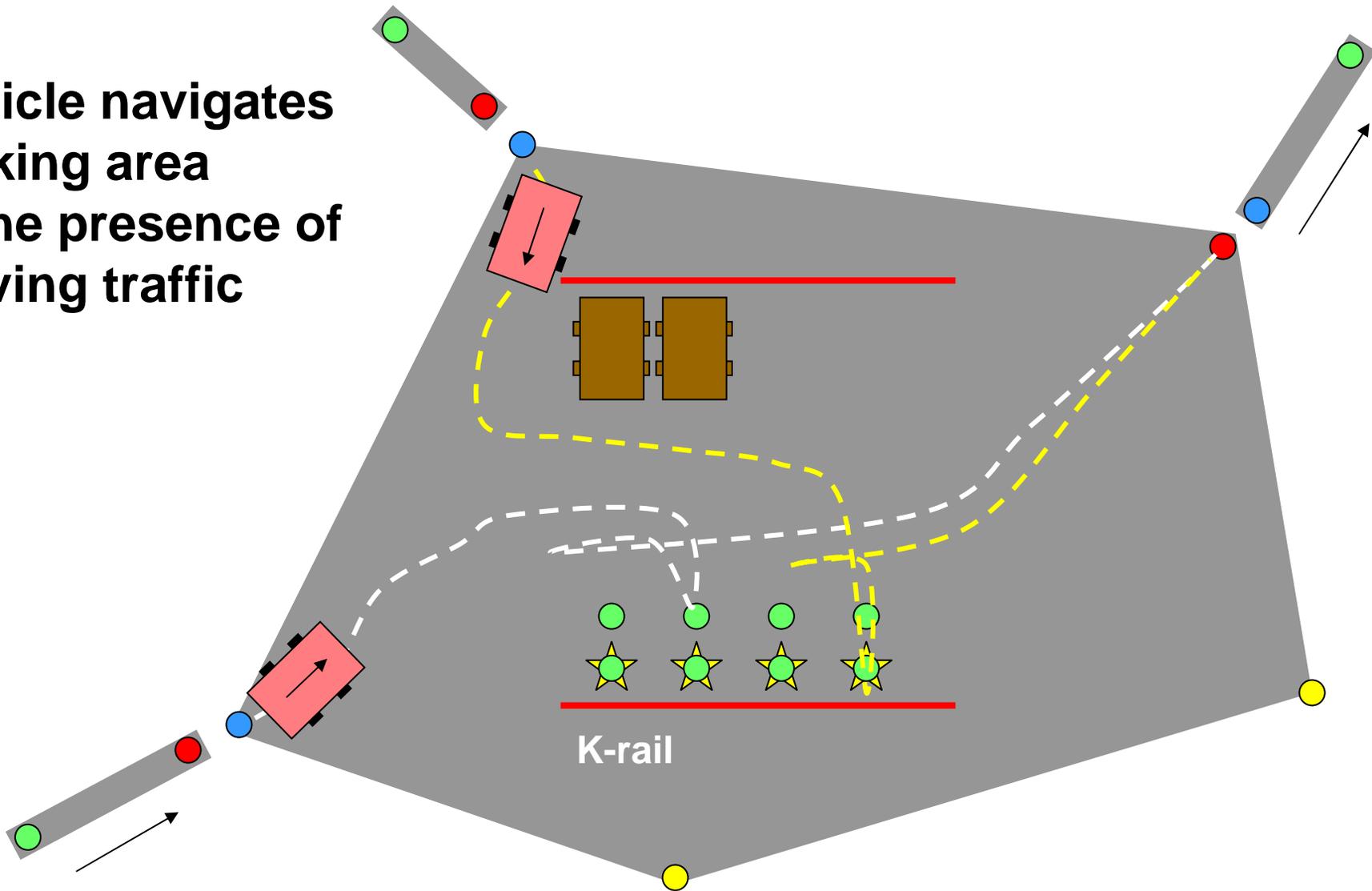
Advanced Traffic

Vehicle makes a left turn across moving traffic and proceeds with less than 10 seconds excess delay.



Advanced Traffic

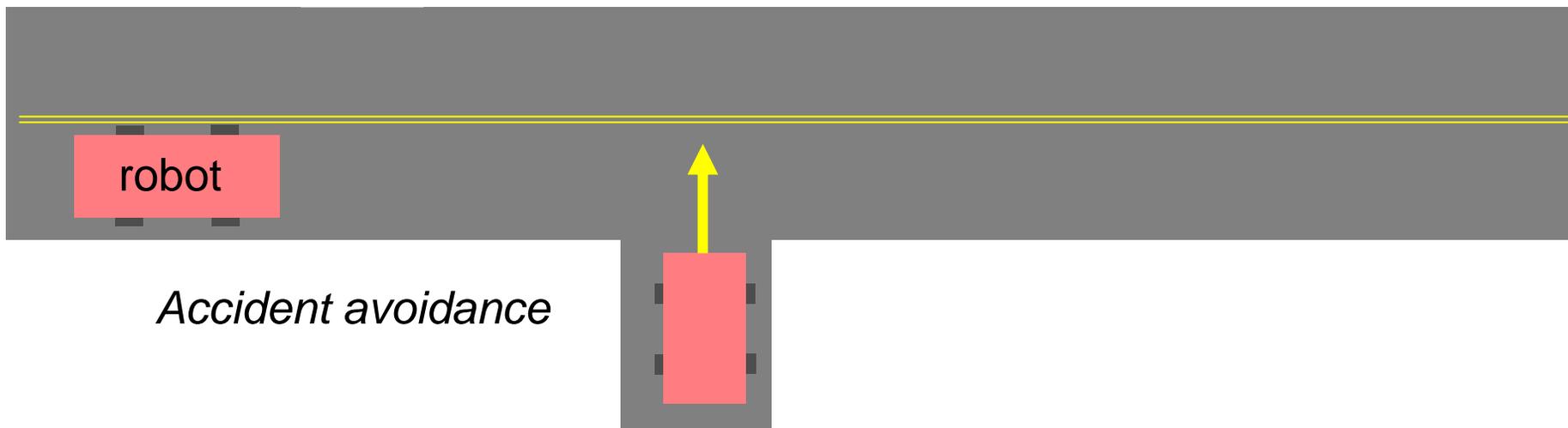
Vehicle navigates parking area in the presence of moving traffic





Advanced Traffic

Vehicle exhibits safe behavior at all times to avoid collisions and near collisions.





Rules

- **Route Definition**
- **Technical Criteria**
- • **Event Operations**



Rules

1. Penalties

- DARPA will have official observers on the course
- Causing a collision is grounds for disqualification
- Dangerous driving is grounds for disqualification
- Time penalties will be used for traffic infractions
- Rules of the Road with penalty table will be released



Rules

2. Collisions

- **All-vehicles E-stopped and course cleared.**
- **Responsibility assessed by DARPA**
- **Vehicles causing collisions may be disqualified**
- **Victim vehicles may be allowed minor repair and re-start**
- **Chief Judge's decisions are final**

DARPA will not use E-stop to prevent course collisions

Rules

3. Time Corrections

- E-stop pauses
- Start chute offset
- Penalties
- Chief Judge corrections

NOT

- Time between missions





Rules

4. Pre-running

- **Pre-running is forbidden.**
- **Gaining advantage by using information that is not generally available is forbidden.**
- **DARPA will release advance information about the course.**
- **Course area may be closed before the event.**

Emphasis is on the comparison of technical approaches using the same starting information



Rules

5. Other rules documents

- **Master Schedule**
- **RNDF and MDF**
- **Video Guidelines**
- **Technical Paper Guidelines**
- **Site Visit Procedures**
- **E-stop Guidelines**
- **Rules of the Road**
- **National Qualification Event Procedures**
- **Final Event Procedures**
- **NQE Route Network Definition File**
- **UFE Route Network Definition File**

Please send feedback to the DGC mailbox



Priorities

- 1. No collisions**
- 2. Complete the mission**
- 3. Minimize penalties**