Implementing GIS in DARPA's Grand Challenge Race

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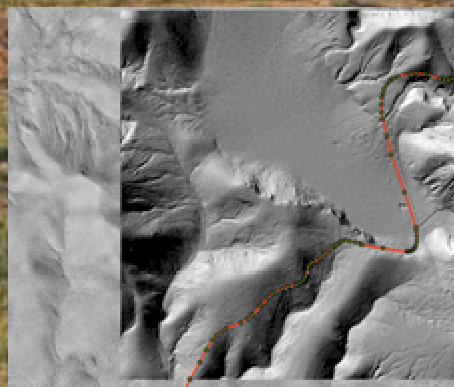


Abstract

- This paper presents **GIS** use in **autonomous vehicles navigation**. It will cover three main subjects. First, an introduction to **DARPA's Grand Challenge Race**, the first autonomous vehicle race to be conducted ever; second, the **applications of GIS** in autonomous vehicles in the **defense market**; and third, the different concerns that were addressed for **one of the vehicles in the race**. Specifically covered will be aspects of **GIS integration**, autonomous path following, **mapping input requirements**, and approaches to **terrain and mobility analysis**. Unique problems related to vehicle physical characteristics and performance would also be addressed.

Who is DARPA?

- DARPA is the central research and development organization for the U.S. Department of Defense.
- DARPA manages and directs basic and applied research and development projects for the Department of Defense
- DARPA pursues research and technology where the risk and payoff are both very high and where success may provide dramatic advances for traditional military roles and missions.

Information courtesy of DARPA

What is the Grand Challenge Race?

- DARPA announced that it would award a cash prize of $1 Million to the team that builds an autonomous robotic ground vehicle that will successfully win a race from Los Angeles to Las Vegas. The race will include on-road and off-road navigation and must be completed in under ten hours. The date of the race was set for March 13, 2004.

Logo courtesy of DARPA

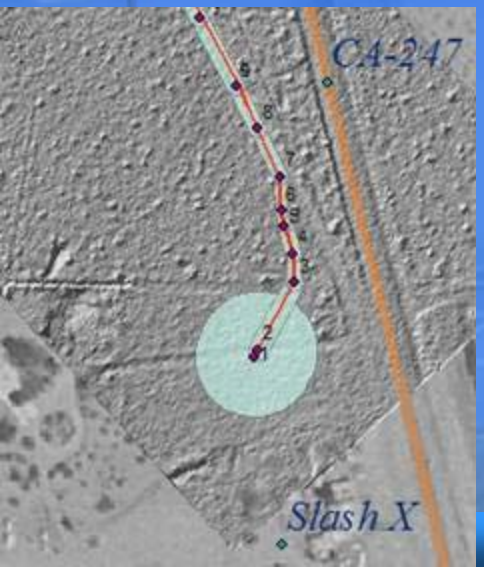
Autonomous Vehicles in Defense

- **Main Roles**
  - Supply
  - Surveillance
  - Reconnaissance
  - Targeting
  - Countermine
- **FCS (Future Combat Systems)**
  - It shall be the goal of the armed forces… that by 2015, one-third of the operational ground combat vehicles of the armed forces shall are unmanned

National defense authorization act for fiscal year 2001 (S. 2549, Sec. 217)

DGCR's General Rules

- Vehicle should be completely autonomous
- Vehicle is given the exact route two hours prior to the race, via Route Data Definition File (RDDF)
- Vehicle must stay within the course boundaries and within defined upper limit velocity as defined in the RDDF

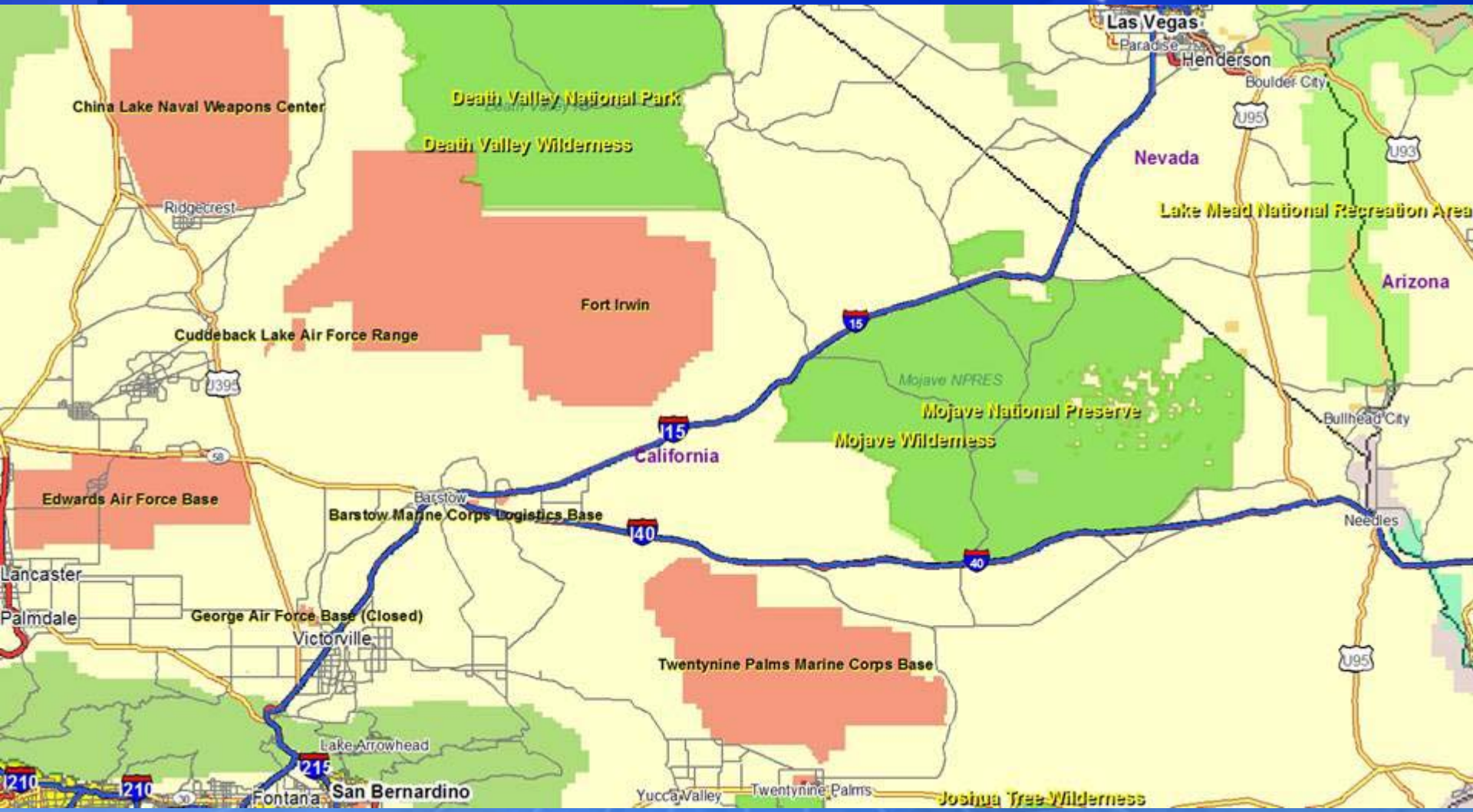


WP Number	WP Latitude	WP Longitude	Lateral Boundary	Speed Limit	Phase Line		
	[DD]	[DD]	[Feet]	[MPH]	[Hr]	[Min]	[Sec]
1	34.7607233	-117.0107599	90	10	#####	#####	#####
2	34.7607515	-117.0107413	15	10	#####	#####	#####
3	34.761033	-117.01056	12	10	#####	#####	#####
4	34.7611515	-117.0105663	12	10	#####	#####	#####
5	34.7612679	-117.0106085	10	10	#####	#####	#####
6	34.7613292	-117.0106236	10	15	#####	#####	#####
7	34.7614692	-117.0106302	11	15	#####	#####	#####
8	34.7616695	-117.0107448	13	25	#####	#####	#####
9	34.7618438	-117.0108514	13	25	#####	#####	#####

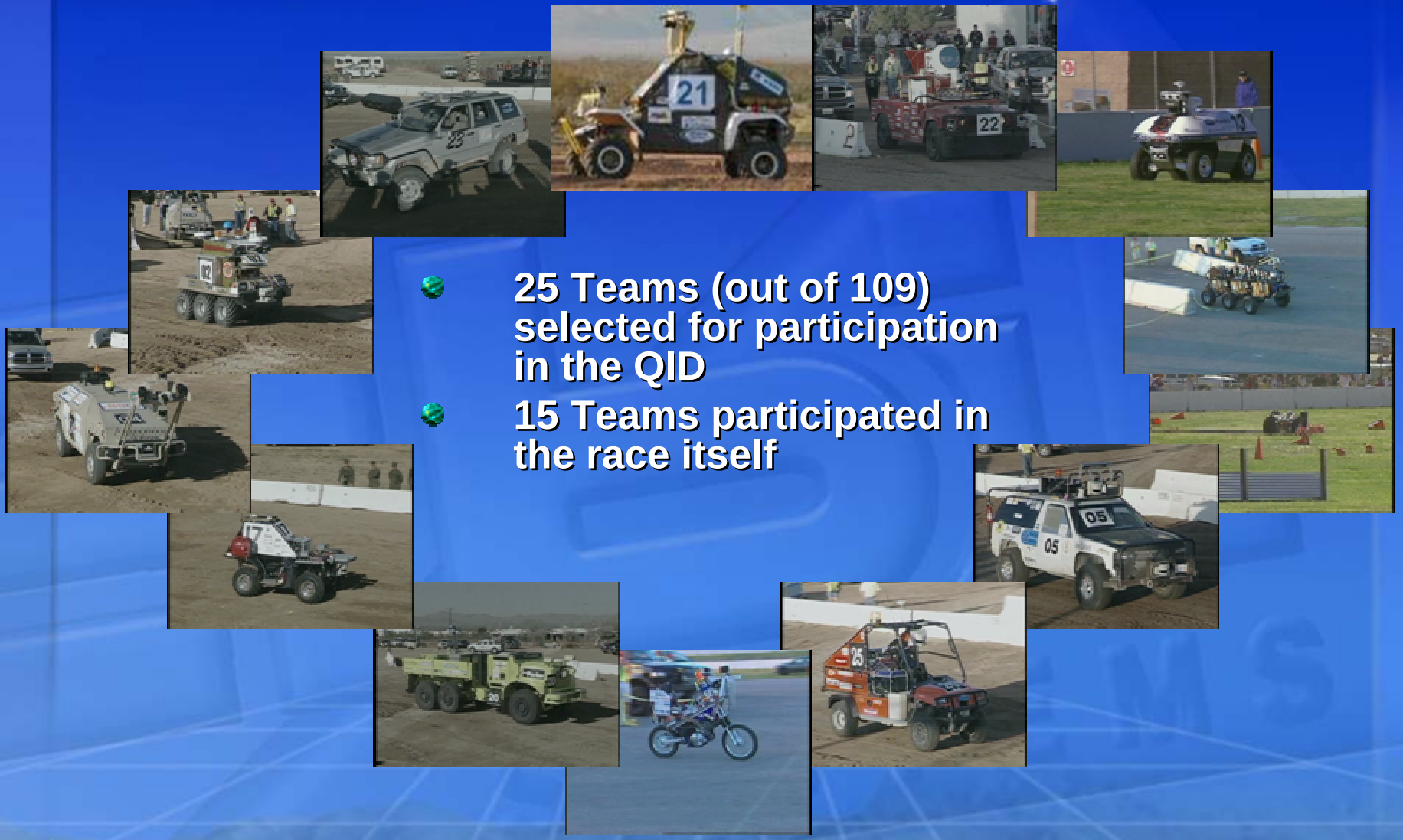
The Race Course

Photos courtesy of DARPA

Race Area


Las Vegas
Paradise
Henderson
Boulder City
China Lake Naval Weapons Center
Death Valley National Park
Death Valley Wilderness
Nevada
U95
U93
Lake Mead National Recreation Area
Ridgecrest
Fort Irwin
Arizona
Cuddeback Lake Air Force Range
15
Mojave NPRES
Mojave National Preserve
Mojave Wilderness
Bullhead City
U395
58
15
California
Edwards Air Force Base
Barstow
Barstow Marine Corps Logistics Base
40
Needles
Lancaster
Palmdale
George Air Force Base (Closed)
Victorville
Twentynine Palms Marine Corps Base
U95
Lake Arrowhead
210
215
210
Fontana
San Bernardino
Yucca Valley
Twentynine Palms
Joshua Tree Wilderness

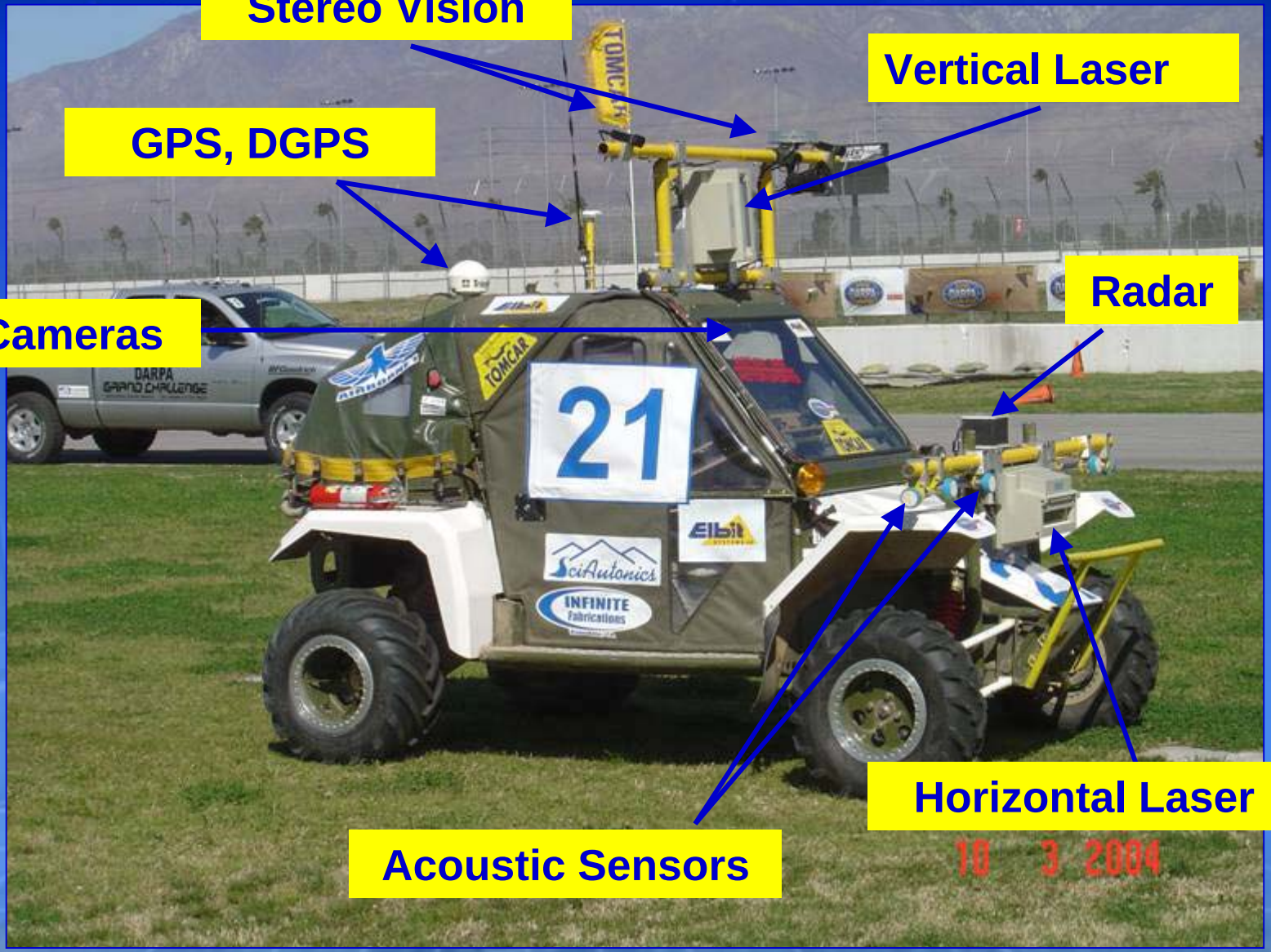
The Teams



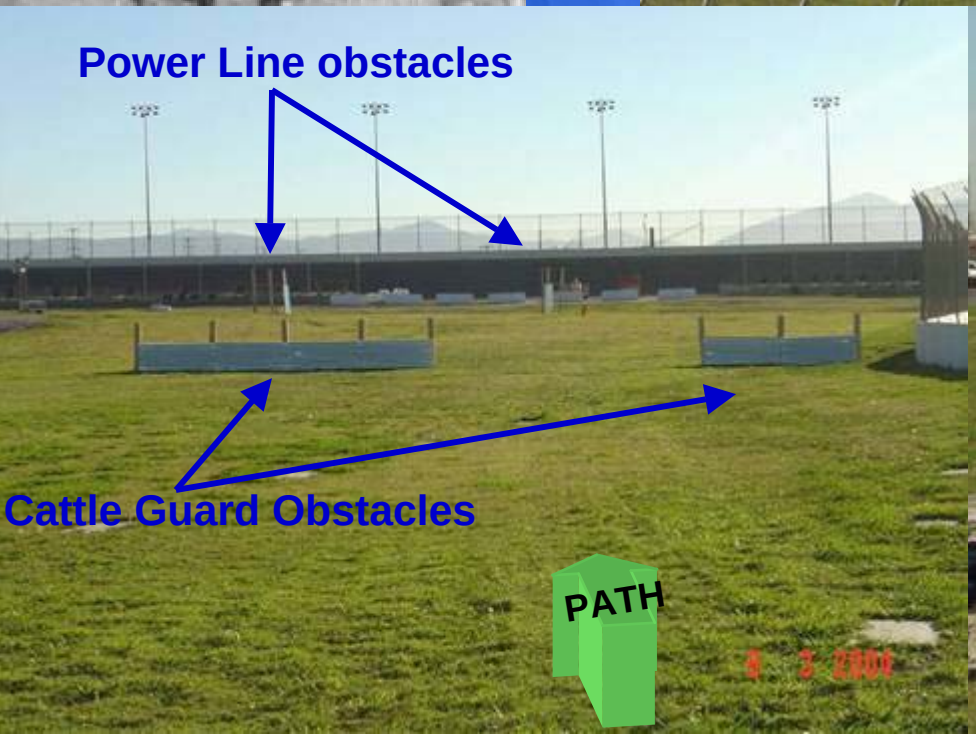
- 25 Teams (out of 109) selected for participation in the QID
- 15 Teams participated in the race itself

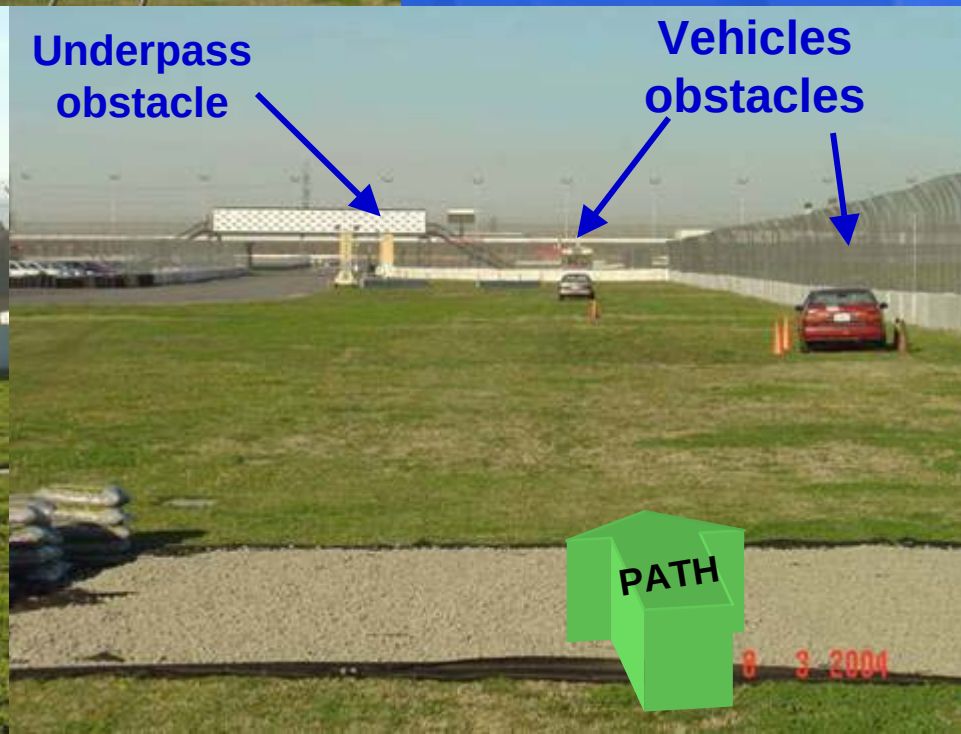
Photos courtesy of DARPA

Typical vehicle configuration



Qualification Inspection and Demonstration (QID)





GIS System

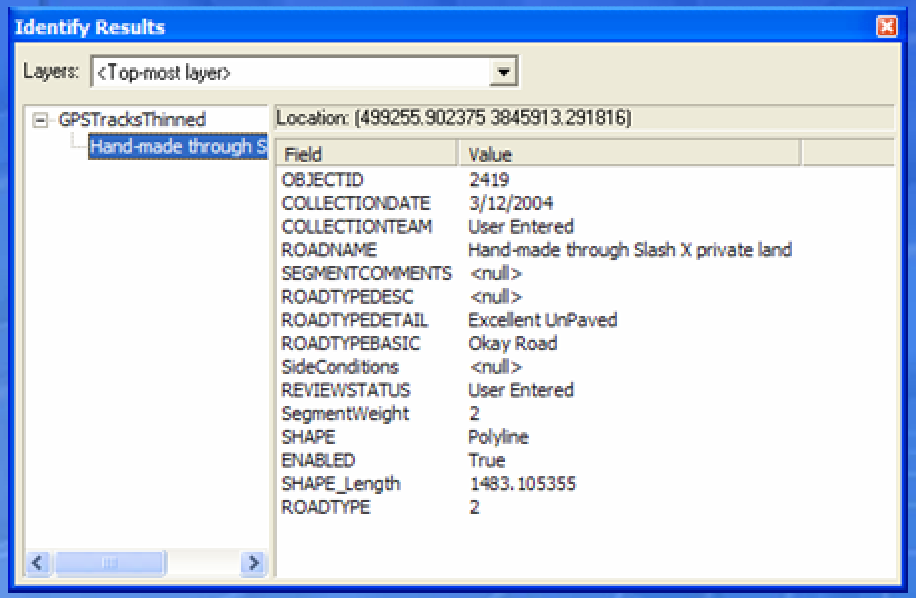
- **Composed of the following ESRI products**
  - ArcMap – ArcInfo
    - Geometric Network analysis
    - Advanced Editing
  - Spatial & 3D analyst extensions
    - Slope, Aspect and interpolate to raster Calculation of Shortest path
  - ArcSDE
    - Storage of Raster data
  - ArcPAD
    - Acquiring DGPS tracks on the field
  - ArcObjects – additional programming
    - RDDF file acquisition
    - Route separation to sub-stations
    - Automatic conflict calculation within route
    - Conflicts editor user interface
    - Route unification, smoothing
    - Write file to UGV usage interface

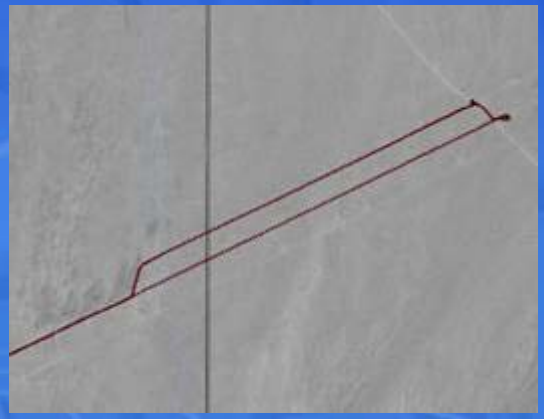
Mapping Products

- **Topographic Maps**
  - Scales : 1:250K, 1:100K and 1:24K
  - Accuracy [CE90%] : 12m, 80m and 201m
- **Digital Elevation Model**
  - National Elevation Dataset (NED)
    - 30m pixel posting
    - ~8m Vertical accuracy
  - LIDAR based data (terrain & surface)
    - 1.3m pixel spacing
    - Accuracy: Horizontal: 0.5m [CE90%] ; Vertical: 20cm
- **Digital Ortho Quarter Quads (DOQQ's)**
  - 1m/pixel resolution
  - Horizontal Accuracy [CE90%] : 10m

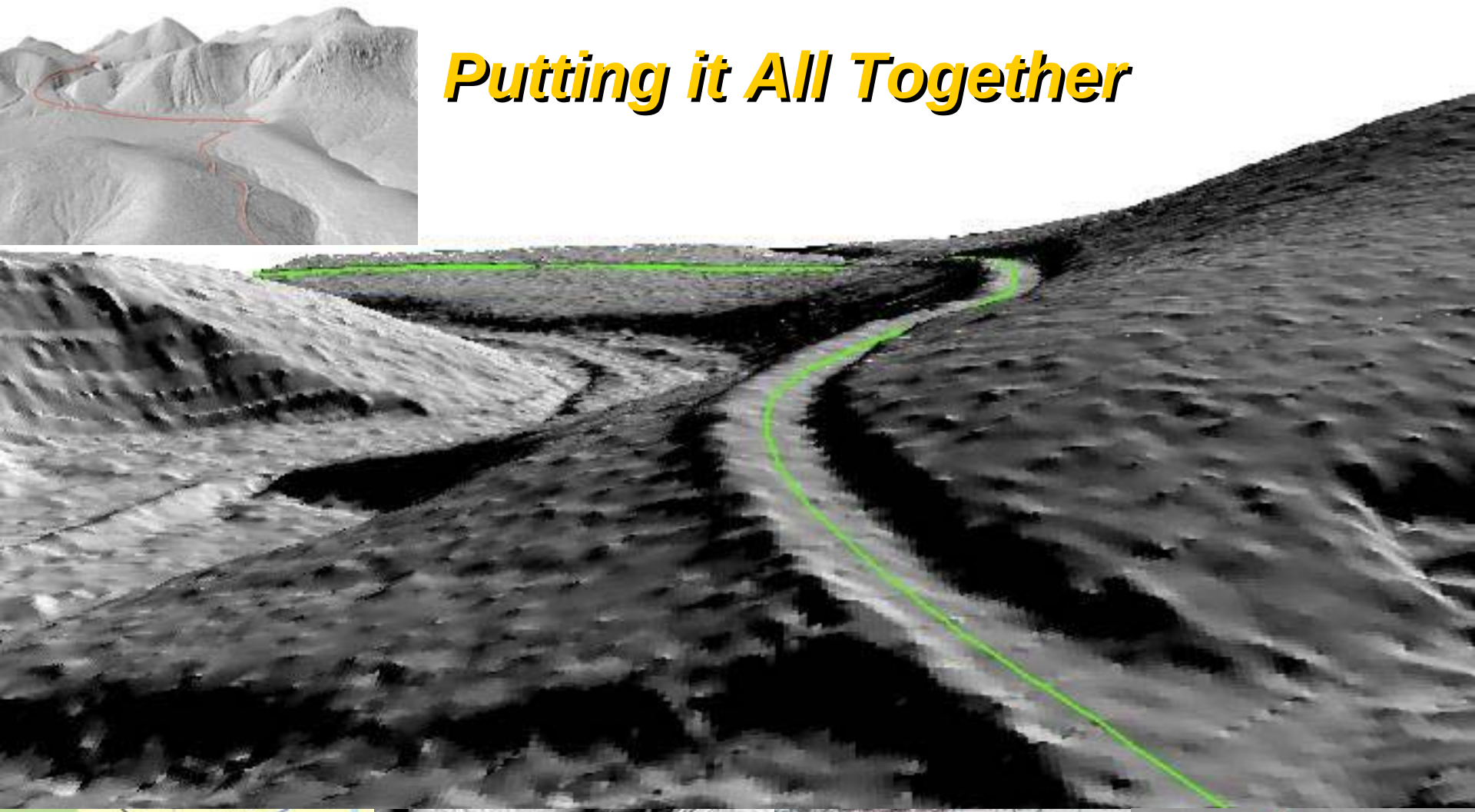
Mapping Products (Cont.)

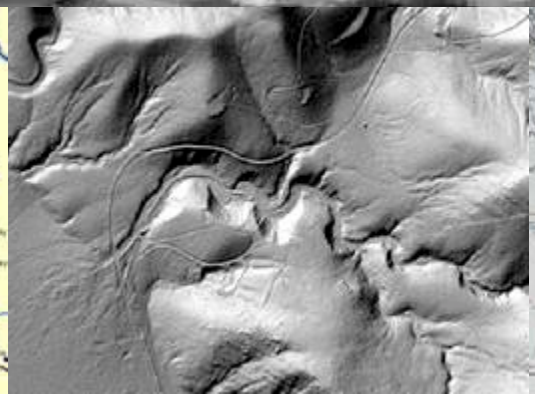
- **DGPS Tracks**
  - Collected directly into ArcPAD
  - Preprocessed by Trimble® for higher accuracy
  - Semi-automatic tracks smooth and correction
  - Detailed information for each track recorded

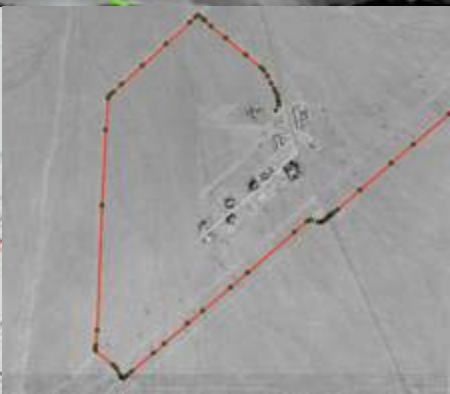




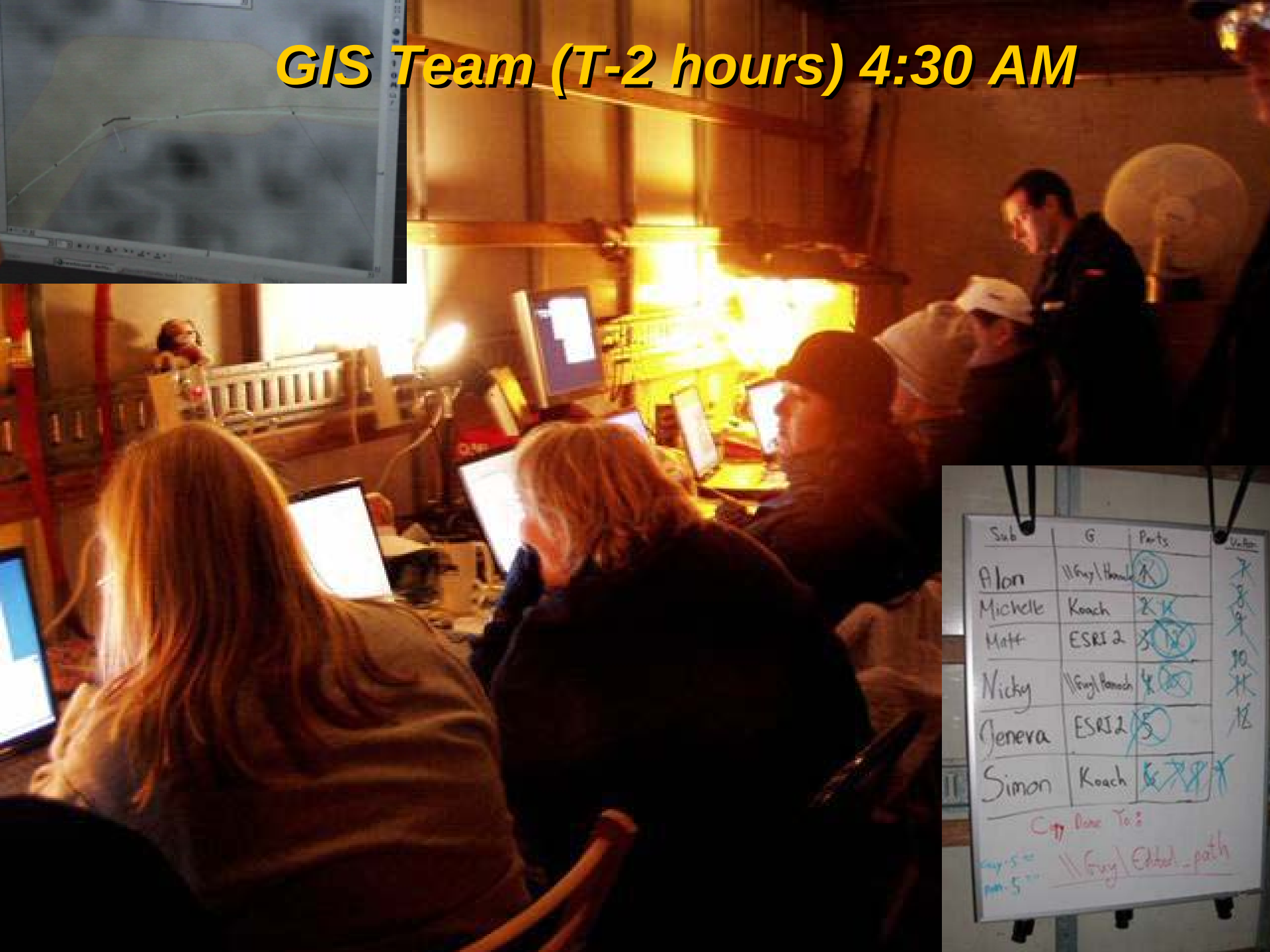
Putting it All Together







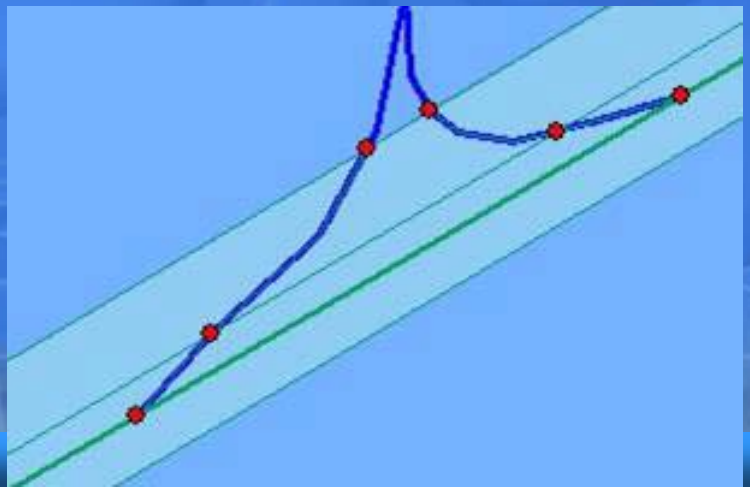
GIS Team (T-2 hours) 4:30 AM



Approaches to terrain and Mobility analysis

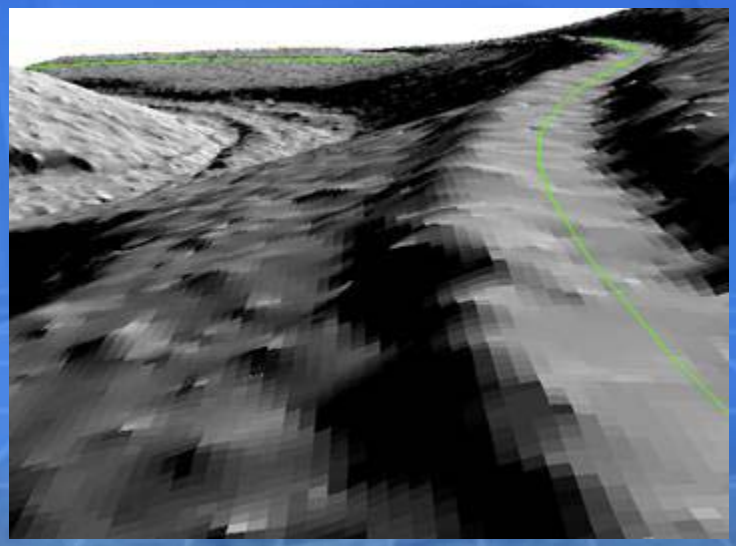
- **Raster Based**
  - General
    - Based on pixel cost weight and distance
  - Pros
    - Whole area approach
    - Not confined to specific tracks
  - Cons
    - Slow on large dataset
    - Per Pixel approach

- **vector based**
  - General
    - Based on geometric network approach
  - Pros
    - Fast
    - Weighted
  - Cons
    - Defined trails/roads only



Unique Characteristics for UGV

- **Good mobility map is required**
- **Unique problems**
  - Direction specific
  - Vehicle limitations
  - Physical path (turning radius)
- **High resolution required (sub-meter level)**



Acknowledgments

- **DARPA media gallery**
  - http://www.darpa.mil
- **USGS – U.S. Geological Survey**
  - DRG, DEM, NED and DOQQ courtesy of the U.S. Geological Survey
  - http://www.usgs.gov
- **ESRI dedicated volunteers…**

End Notes

- The Defense Advanced Research Projects Agency (DARPA) of the U.S. Department of Defense announced that it will hold a second Grand Challenge for Autonomous Robotic Ground Vehicles on October 8, 2005.
- As with the inaugural event held in March 2004, autonomous vehicles will attempt to navigate a challenging course of varying terrain.
- The team that completes the Grand Challenge 2005 route within a specified time will receive a cash prize of $2 million.

Information courtesy of DARPA

References

- DARPA web site
  - http://www.darpa.mil

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