DARPA URBAN CHALLENGE 2007

Car Technologies – Stanford and CMU

Stanford Racing

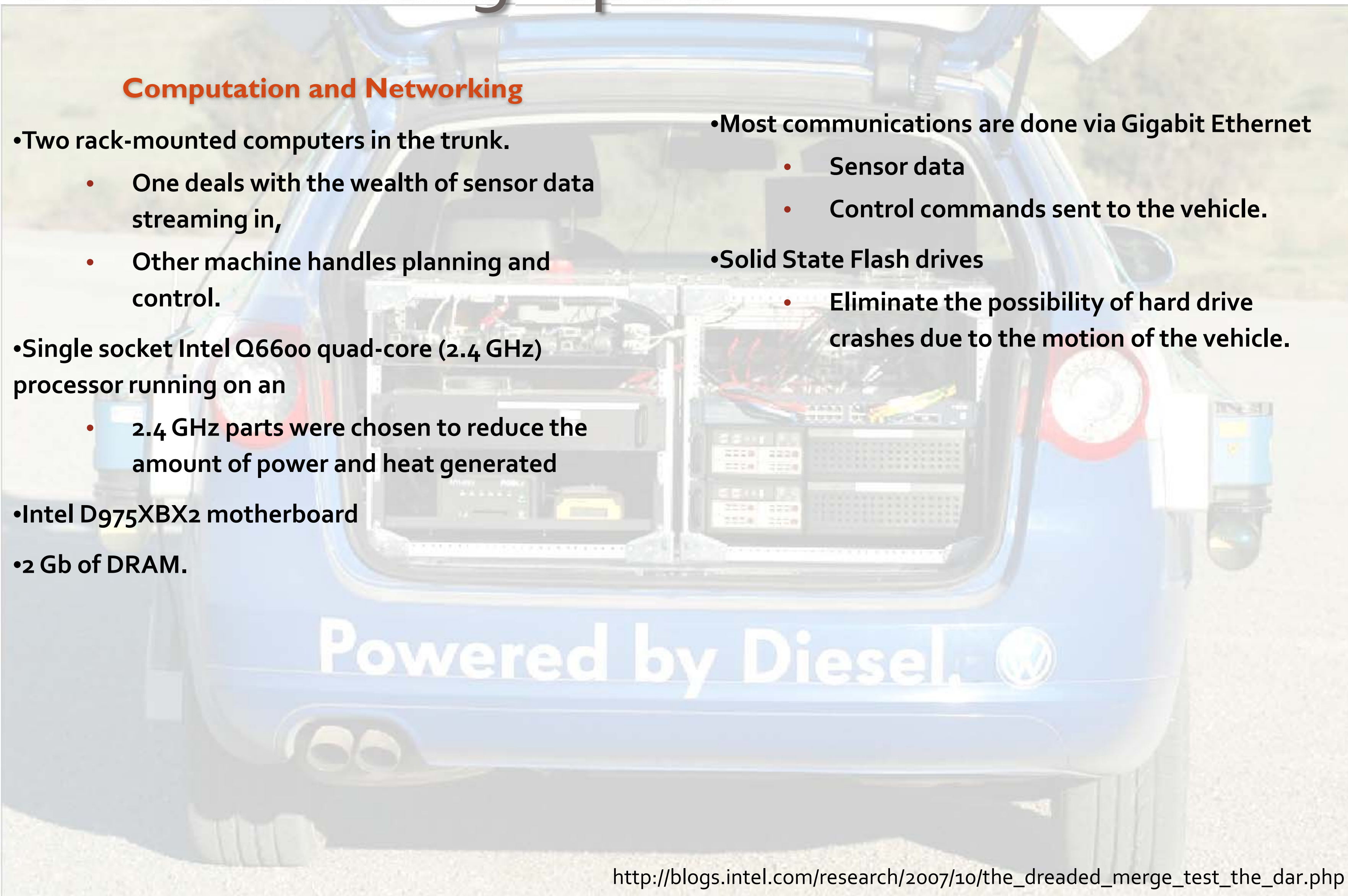
- Stanford Racing's entry was dubbed "Junior" in honor of Leland Stanford Jr.

- Team led by Sebastian Thrun and Mike Montemerlo (from SAIL)

- VW Passat

- Primary focus on software – but a lot more hardware then before.

Stanford Racing - specs



Computation and Networking

- Two rack-mounted computers in the trunk.
  - One deals with the wealth of sensor data streaming in,
  - Other machine handles planning and control.
- Single socket Intel Q6600 quad-core (2.4 GHz) processor running on an
  - 2.4 GHz parts were chosen to reduce the amount of power and heat generated
- Intel D975XBX2 motherboard
- 2 Gb of DRAM.
- Most communications are done via Gigabit Ethernet
  - Sensor data
  - Control commands sent to the vehicle.
- Solid State Flash drives
  - Eliminate the possibility of hard drive crashes due to the motion of the vehicle.

http://blogs.intel.com/research/2007/10/the_dreaded_merge_test_the_dar.php

Stanford Racing - specs

Position

•Position and orientation are estimated by an Applanix POS LV 420 system that

- provides realtime integration of
    - multiple dual-frequency GPS receivers,
    - a high-performance inertial measurement unit,
    - Wheel odometry
    - Omnistar's satellite-based Virtual Base Station service.
- Real-time accuracy is ~50cm and 1/50th of a degree.

"The POS LV system generates precise, robust positioning and orientation information for mobile data acquisition systems. The system combines all the advantages of GPS with those of inertial technology, to provide continuous and accurate data. By utilizing the POS LV system, data capture can be undertaken quickly and efficiently."

–Applanix Product Description

http://cs.stanford.edu/group/roadrunner/pdfs/final_factsheet_junior.pdf

Stanford Racing - specs

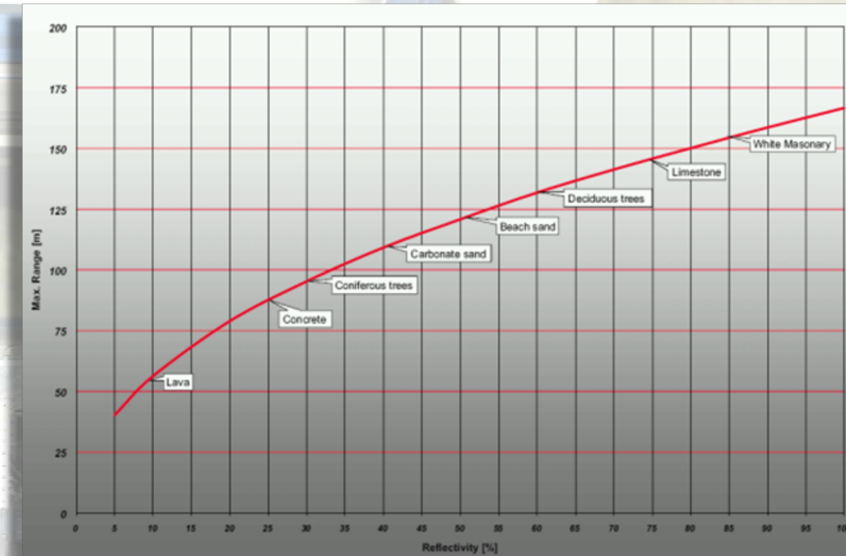
Localization

•Junior's position and the path on the road are both optimized in real-time

- Two side-facing SICK Lidars
- Forward-facing RIEGL LMS-Q120 Lidar,

• Finds lane markings from brightness differences in the ground and improve

•position estimation to within 5cm.



RIEGL LMS-Q120

•Maximum range 150 m @ 80% target

•Ranging accuracy 25 mm

•Data rate up to 10,000 measures / sec

•Scanning rate up to 100 scans / sec

•Scanning range 80˚

•Perfectly linear scan

•Integrated TCP/IP Ethernet interface

http://www.riegl.com/industrial_scanners_/lms_q120_/datasheet_lmsq120.pdf

Stanford Racing - specs

Perception

- Velodyne HD Lidar
  - looks in every direction 10 times a second, combining 64 individual lasers into millions of 3D points at up to 65m range.
  - 64 lasers
  - 360 degree field of view (azimuth)
  - 0.09 degree angular resolution (azimuth)
  - 26.5 degree field of view (elevation) +2.5 degrees up to -24 down with 64 equally spaced angular subdivisions
  - 5 cm resolution (distance)
  - 10 Hz field of view update
  - 2,621,440 points per second
  - Clip1
  - Clip2
  - Clip3

- Five BOSCH radar sensors
  - point straight and to each side to track up to 32 obstacles simultaneously over a range of 200m.
- Two IBEO ALASCA XT Lidars in the front and two SICK LD-LRS Lidars in the rear
  - handle ranges up to 100m.
- These sensors allow for continuous, high-accuracy coverage of the environment.

http://cs.stanford.edu/group/roadrunner/pdfs/final_factsheet_junior.pdf

CMU: Tartan Racing

- Won the DARPA Urban Challenge.
- Led once again by Red Wittacker
- Named for Charles F. 'Boss' Kettering, legendary inventor, automotive innovator, and co-founder of DELCO

CMU: Tartan Racing -specs

Computation and Networking

- 10 Intel Core2Duo blades
- 2.16 GHz
- Compact PCI chassis
- 2-GB NetApp data-storage appliance
- Gigabit Ethernet communications layer
- 8-kW Aura Systems Auragen belt-driven, underhood generator.
- More than 250,000 lines of code
- Evaluates more than 1000 candidate trajectories per second

Chris Urmson, Director of Technology for Tartan Racing, shows the computers and electronics that are embedded in the Tartan Racing vehicle. The rear cargo area also includes a safety system that allows the vehicle to be stopped via a radio signal, if needed.

http://www.sae.org/automag/electronics/06-2007/1-115-6-47.pdf

CMU: Tartan Racing -specs

Position

• Also used the Applanix System that Stanford used.

Localization

• CMU used technology both from MobilEye and Continental Automotive Systems.

•Both of these companies provide similar products.

•Was not obvious which products were used from each.

•Lane Departure from Mobil Eye.

•CMU stat sheet references "2 steered Continental ISF 172," for "Long Range Lidar"

- No evidence from CAS for that

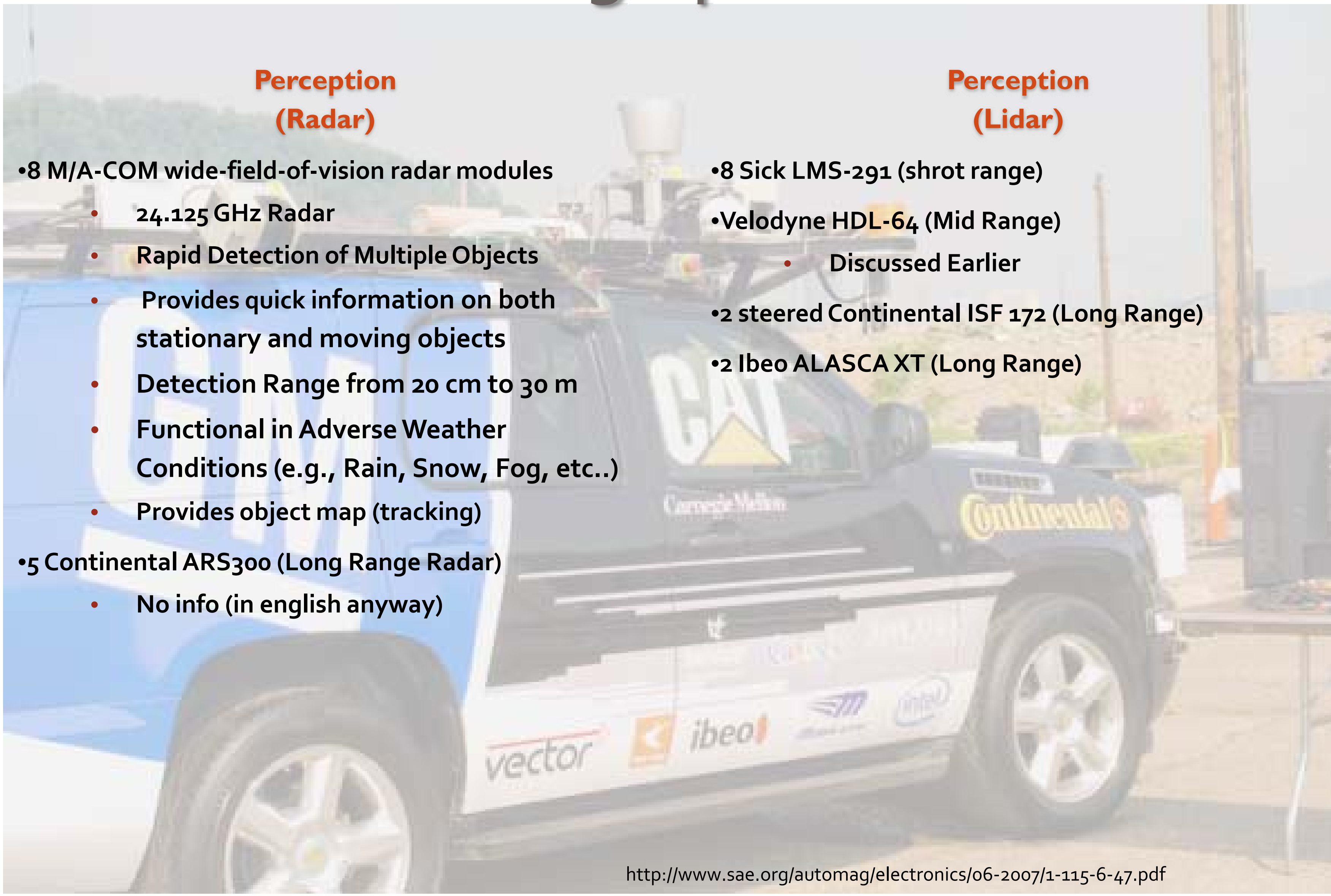
•CAS press release:
"...vehicle equipped with environmental sensors and Sealant tires from Continental..."

•Has many components related to

- Driver Assistance (like lane departure)
- Vehicle Sensores (like Electronic Stability Control)

http://www.sae.org/automag/electronics/06-2007/1-115-6-47.pdf

CMU: Tartan Racing -specs



Perception (Radar)

- 8 M/A-COM wide-field-of-vision radar modules
  - 24.125 GHz Radar
  - Rapid Detection of Multiple Objects
  - Provides quick information on both stationary and moving objects
  - Detection Range from 20 cm to 30 m
  - Functional in Adverse Weather Conditions (e.g., Rain, Snow, Fog, etc..)
  - Provides object map (tracking)
- 5 Continental ARS300 (Long Range Radar)
  - No info (in english anyway)

Perception (Lidar)

- 8 Sick LMS-291 (shrot range)
- Velodyne HDL-64 (Mid Range)
  - Discussed Earlier
- 2 steered Continental ISF 172 (Long Range)
- 2 Ibeo ALASCA XT (Long Range)

http://www.sae.org/automag/electronics/06-2007/1-115-6-47.pdf