From the Roads to the Skies

Stanford University
EE15N - The Art and Science of Engineering Design
Dr. Celia Oakley
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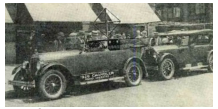
Design

Make the design process
more effective and efficient

Autonomous Cars

Houdina Automobile
(Radio-Control)



UK Citroen
(Embedded Electronic Cables)

DARPA
Autonomous
Land Vehicle (ALV)

Ernst Dickmanns
and Mercedes Benz
VaMP and VITA-2

DARPA Grand Challenge
Stanford Racing Team
Stanley

Google X, Chauffeur, Waymo

1920s - 1970s | 1980s | 1990s | 2000s | 2010s | 2020s

???

Stanford Cart
(Video Processing)

RCA Labs
(Line-Following Car)

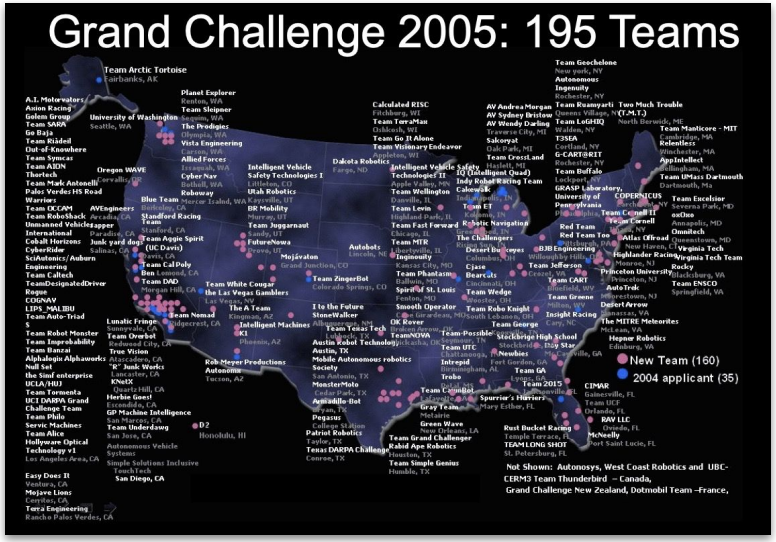
CMU Navlab 1

University of Parma
ARGO Autonomous Vehicle

DARPA Urban Challenge
CMU Tartan Racing
Boss

Stanford Racing Team

- Why DARPA offered the Grand Challenges
  - To simulate innovation through prizes
- First DARPA Grand Challenge, $1M Prize
  - March 13, 2004
  - 150 mile route
  - CMU - Sandstorm, 7.32 miles (NO WINNER)
- Second DARPA Grand Challenge, $2M Prize
  - October 8, 2005
  - 132 mile route
  - Stanford Racing Team - Stanley, 132 miles
  - 6:54 hours

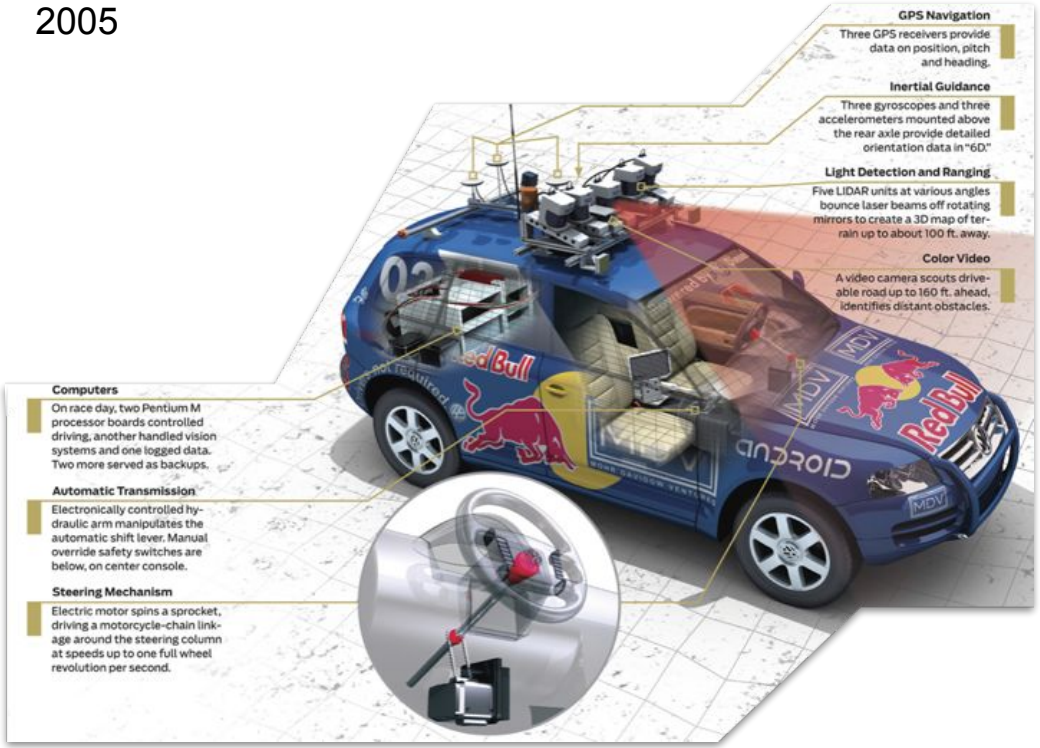


Why Stanford was Successful

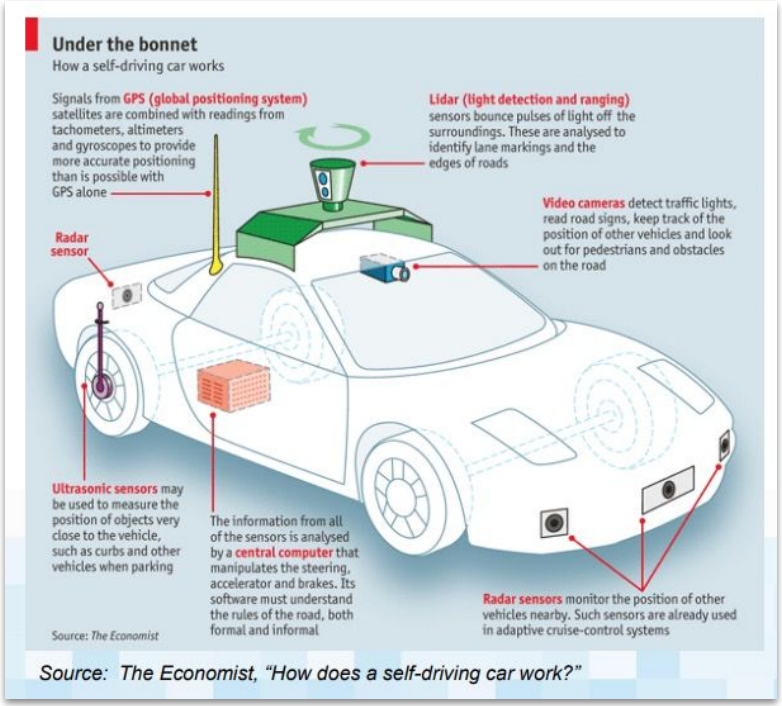
- Leveraged not entering the 2004 Challenge
- Didn’t recreate the wheel (pun)
- Focused on innovation and integration
- Smart software and sensor selection
- Lean, mean non-dysfunctional team
- Not afraid to test
- Tested against the 2004 course

Stanley

2005



2015



Source: The Economist, "How does a self-driving car work?"

Testing

- DARPA rule details
- Starting and take-over scenarios
- Test Plan - 150 pages
- Extensive field testing
  - Stanford Parking Structure
    - Simple obstacles
  - Ranch in Barstow, CA
    - Near 2004 Race Course
    - First autonomous mile
    - DARPA Site Visit
  - VW Test Center in Arizona
    - Collision avoidance
    - Endurance testing
  - National Qualifying Event (NQE)
    - Variety of Conditions

The Race

- 4:30 AM Teams receive course data
- 6:30 AM Race starts
- 6:35 AM Stanley starts (seeded 2nd)
- ~12:00 PM Stanley passes H1lander
- ~ 1:30 PM Stanley wins!

- All that testing paid off

“Flying Cars”

Jetsons
Created in 1962, Set in 2062

“Mark my words: a combination airplane and motorcar is coming. You may smile, but it will come.” - Henry Ford, 1940

Gwinn Aircar

Wagner Aerocar

ConvAirCar

Moller Skycar

Tactical Robotics Cormorant (AirMule)

Maverick

Hoversurf

Lilium Jet

Kitty Hawk Cora

Toyota Cartivator

Boeing + Aurora

???

1920s - 1970s | 1980s | 1990s | 2000s | 2010s | 2020s

Taylor Aerocar

AVE Mizar

Waterman Arrowbile

Bryan Autoplane

ICON A5

Terrifugia Transition

Opener BlackFly

AeroMobile

Volocopter

Zee.Aero Zee

Airbus A^3 Vahana

EHang 184

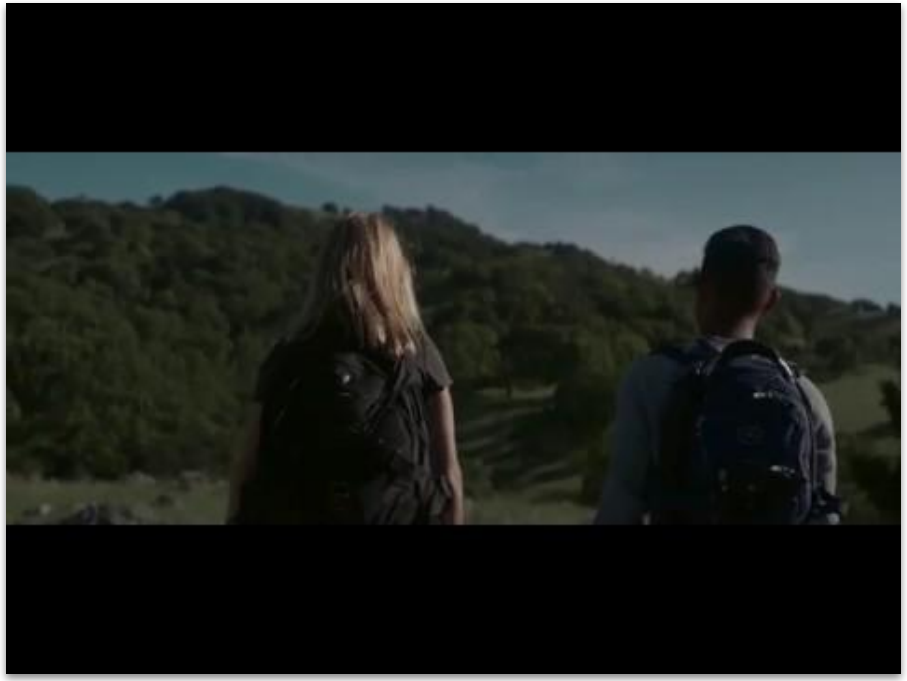
SureFly

Engine(s) (gasoline)

Motors (electric)

Opener, Inc.

- BlackFly, the world's first:
  - Ultralight all-electric fixed-wing
  - Vertical take-off and landing (VTOL)
  - Personal Aerial Vehicle (PAV)
- Founded in Canada in 2011
- Now located in Palo Alto
- Public Launch on July 12, 2018



Milestones

Milestone A

- Must be achieved within 24 months
  - Build 3 fully-operational prototype vehicles
  - Demonstrate 2-minute hover with a 200 lbs payload for each vehicle
  - Demonstrate a VTOL 10-mile flight by remote control with a 200 lbs payload

Milestone B

- Must be achieved within 48 months
  - Build 20 fully-operational vehicles
  - Demonstrate 30-mile autonomous flight with a 200 lbs payload for each vehicle
  - Accumulate a 10,000 miles over a minimum flown distance of 30 miles with a 200 lbs payload
  - Operate major incident-free for 1,000 miles flown

BlackFly

Safety is our highest priority

- Three flight controllers
- Triple-modular redundant sensors
- Redundant motors, elevons, and batteries
- Isolated, distributed batteries
- Autonomous takeoff and landings
- Software flight-envelope protection
- Geofence-capable
- Real-time alerts
- Intuitive joystick
- Return-to-Home
- Auto-Land
- Ballistic parachute
- Comprehensive training

Dash

- Short for Dashboard
- CRAVE
  - Clarity
  - Record
  - Accountability
  - Visibility
  - Ease
- Manage by exception
- Subscribe - email notifications

Checklists

before

after

- Critical to our business
- Can feel tedious and therefore prone to error
- Leverage the computer
  - Make the computer do the grunt work
  - Provide a fun, easy-to-use interface
  - Use a consistent format
  - Collect required information
  - Perform calculations automatically
  - Give the user credit
  - Hold the user responsible
  - Manage by exception

Configuration Management

- Keep track of key components
- Assign Tracking Numbers
  - Serial Numbers and/or Lot Numbers
- Hang information off Tracking Numbers
  - e.g., Flights, Flags, Service Records
- Know part history
- Know where parts are installed
- Know which parts comprise an aircraft
- When issues arise, don’t chase tail

Flight Testing

- Testing drives development
- Well-defined processes and roles
- Leverage Dash
- Most flights are autonomous
- Mother Nature is our teacher
- Debug-to-solution time is short
- 1,800+ flights
- 22,000+ miles with full payload

Conclusion

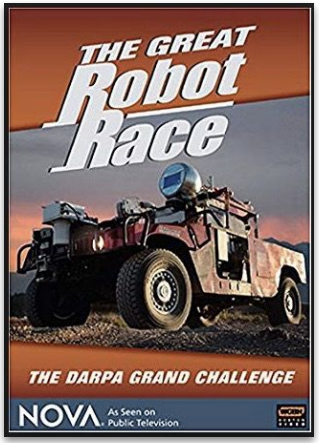
Takeaways

- Follow your passions
- Think beyond intricate design details
- Develop tools to operate efficiently and effectively
- Test, test, test

Further Information

- DARPA Grand Challenge
  - NOVA's The Great Robot Race
- Opener, Inc.
  - https://opener.aero

Thank you!



OPENER