# DARPA Ground Robotics

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# Ground Robotics Goals

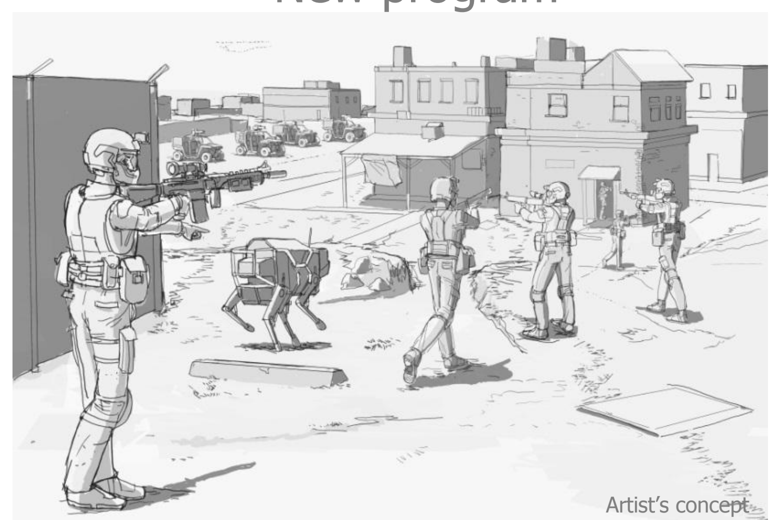
- Improved autonomy, mobility, speed, cost, and energy efficiency
- Untethered operation using battery pack for mixed-mission operation
- Onboard perception to support autonomy
- Carrying the load to aid the warfighter
- Rapid commercial growth

*DARPA Robotics Challenge Finals: June 5-6, 2015 in Pomona, CA*

Current programs


DRC: *Task-level autonomy to operate in hazardous, degraded conditions*

New program




Squad X: *New capabilities and unit-level experimentation*

# DARPA Robotics Challenge (DRC)

# Why a Disaster Response Challenge?


Fukushima Daiichi, March 2011

- "… close study of the disaster's first 24 hours, before the cascade of failures carried reactor 1 beyond any hope of salvation, reveals clear inflection points where minor differences would have prevented events from spiraling out of control."

  *IEEE Spectrum,* Nov 2011 p. 36

- We are vulnerable to natural and man-made disasters
- Humanitarian assistance/ Disaster response (HADR) is 1 of the 10 primary missions of the US DoD
  - *Sustaining U.S. Global Leadership: Priorities for 21st Century Defense*, Letter from the White House, January 2012
- HADR is a universally understood and appreciated mission
- Enables participation of "best and brightest" performers from anywhere in the world

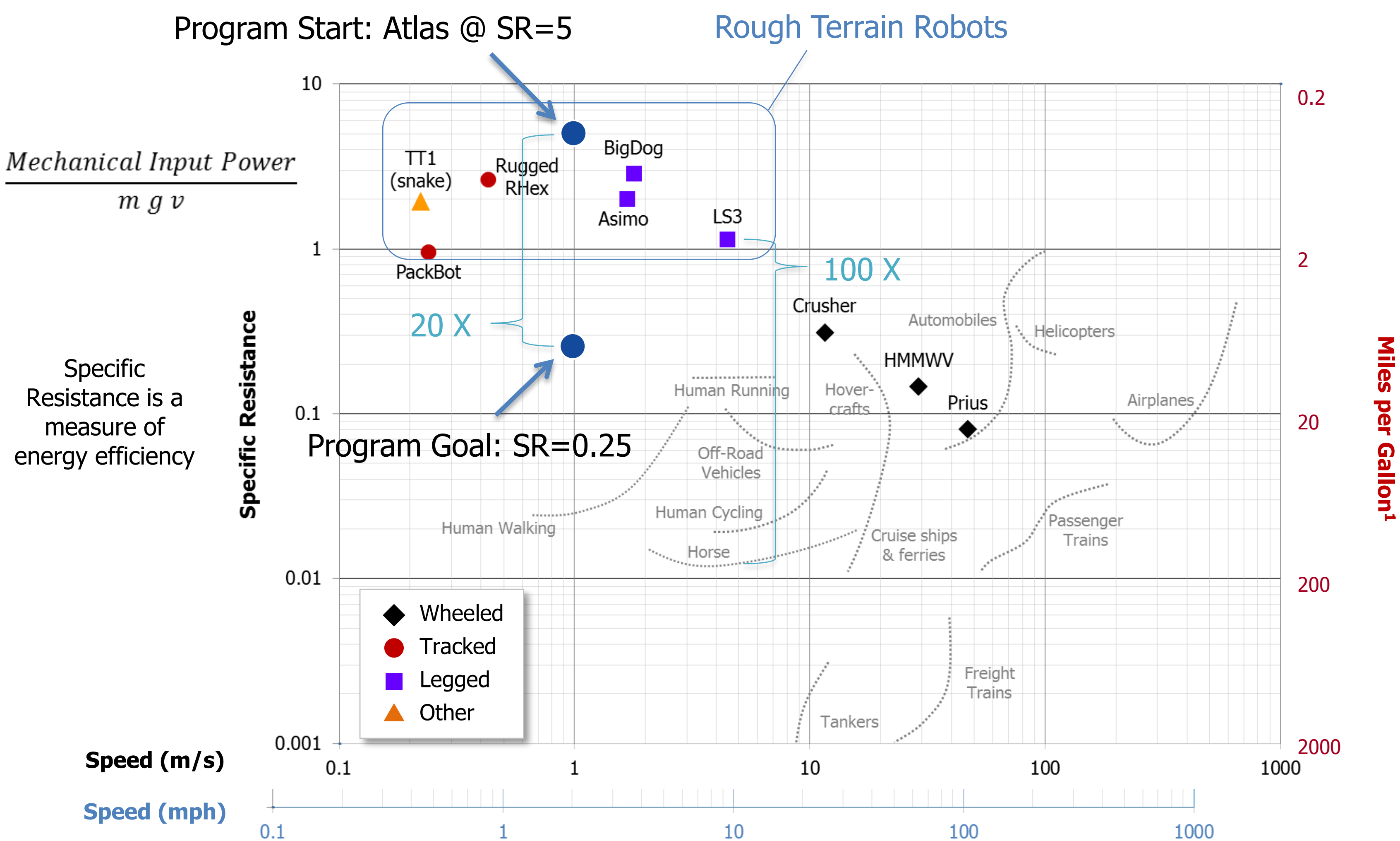
# Anticipated Robotic Challenge Trials Tasks

Capability Exercised

| Sample Tasks | Autonomy - Perception | Autonomy – Decision-making | Mounted Mobility | Dismounted Mobility | Dexterity | Strength | Endurance |
|---|---|---|---|---|---|---|---|
| 1. Drive utility vehicle (e.g. Gator, Ranger) | X | X | X | | X | | |
| 2. Travel dismounted 20 m through various terrains | X | | | X | | | X |
| 3. Remove debris blocking entryway | X | | | X | X | X | X |
| 4. Open door, enter building | X | | | X | X | | X |
| 5. Climb industrial ladder/stairs/walkway | X | | | X | | | X |
| 6. Break through wall | X | X | | | X | X | X |
| 7. Locate and close valve | X | X | | X | X | X | X |
| 8. Connect fire hose | X | | | X | X | X | X |

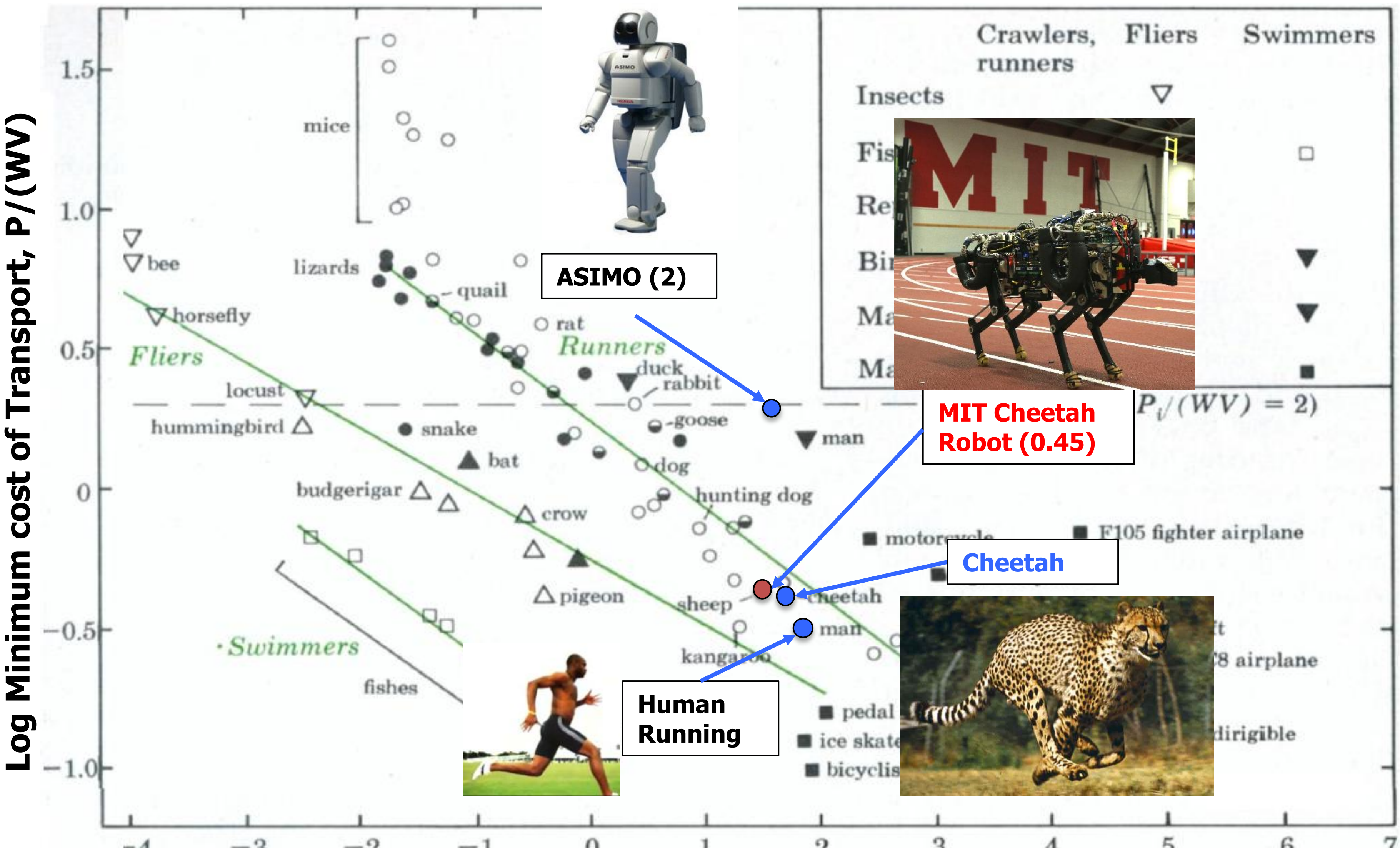
# Task Example: Terrain

# Energy Efficiency of Vehicles + Robots




[1]Miles per Gallon for a Toyota Camry (1045 kg) running on gasoline, using an energy conversion efficiency of 25%

# Total Cost of Transport ($P_{total}$/WV)



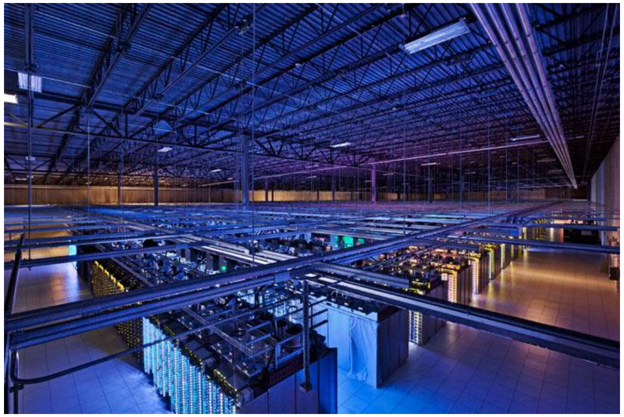

Adopted from Tucker 1975

# Legged Squad Support System (LS3)

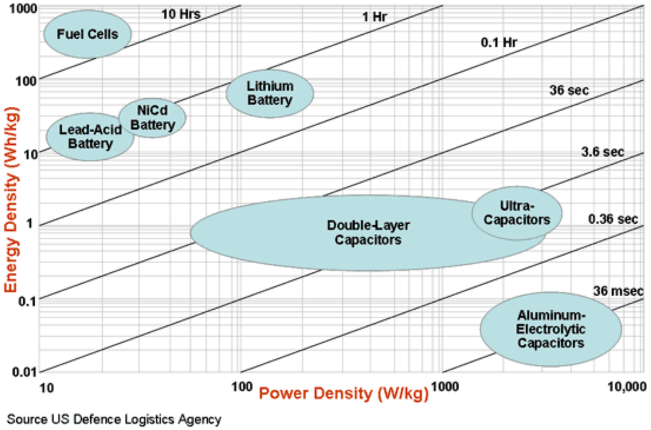
# "Spot"

# Cloud Robotics + Robotics Beyond the Cloud

- World's data storage now measured in zettabytes (10^21 bytes)
  - By comparison – number of synapses in human brain: ~ 10^14
  - About 10 billion images have been uploaded
- World's computing capacity approaching 1 zetta OPS
  - Google is one of world's largest consumers and manufacturers of computers
  - Highest performance video games now do 80% of their computing in the cloud
- High speed wireless connection to the Internet becoming ubiquitous
  - Example: Google Chromecast ($35)
- Batteries have low energy density (approx. 1/10 fossil fuels)
  - SWaP is at a premium in mobile devices
- Hard part of robotics is between the ears (of the robot)
  - Many problems get easier with lots of data + processing
    - Example: Use of maps for autonomous driving
    - Example: Visual object perception
- **<u>Big Idea : Put the robot brain on the cloud</u>**
  - Side benefit – all robots learn from each robot's experience
- We still needs to develop competency in:
  - Unstructured, austere environments
  - Intermittent communications
  - Better-than-human performance
  - Low SWaP
  - Limited a priori knowledge
  - Critical (human life) missions



A server room in Council Bluffs, Iowa.
*Photo: Google/Connie Zhou*

# Squad X Core Technologies (SXCT)

# Robots Leading Formations


- Currently requires an operator to maneuver the robot, which reduces the situational awareness of one (or more) squad members
- Situational awareness gained from sensors requires humans to detect and classify potential threats and is often not organic to squad
- Potential to provide standoff from threats while simultaneously providing offensive and defensive capabilities
- A young Marine asked, in reference to the LS3, “Can you get it to carry our IED-detection equipment?”

# Robots in Formation

- Robot is autonomously following an operator; it is not following in formation
  - Perception capabilities focused on following the operator
  - Operator must carry additional load to lead robot
- Robot is responsible for sensing the entire world and does not leverage sensing capabilities of, or information from, other members in the squad
- Potential to offload physical burden while simultaneously providing offensive and defensive capabilities
- A young Marine asked “Can you get the LS3 to follow us in formation?”

# Technology Development Goals

The Squad X Core Technologies program comprises four Technical Areas:

| | | |
|---|---|---|
| 1 | Precision Engagement | Enable the rifle squad to precisely engage threats out to 1,000 meters while maintaining compatibility with infantry weapon systems and human factors limitations |
| 2 | Non-Kinetic Engagement | Enable the rifle squad to disrupt enemy command and control, communications and use of unmanned assets to ranges greater than 300 meters while maneuvering at a squad-relevant operational pace |
| 3 | Squad Sensing | Enable the rifle squad to detect line of sight and non-line-of-sight threats out to 1,000 meters while maneuvering at a squad-relevant operational pace |
| 4 | Squad Autonomy | Enable the rifle squad to improve their individual and collective localization accuracy to less than 6 meters in GPS-denied environments through collaboration with unmanned systems maneuvering reliably in squad formations |

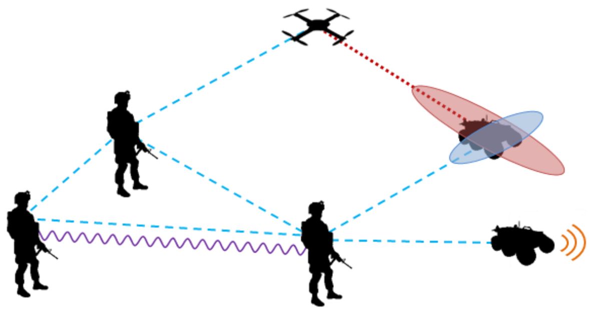
# TA4 – Squad Autonomy: Manned-Unmanned Teaming

**Adapt:** Multi-agent techniques for human and machine collaborative localization

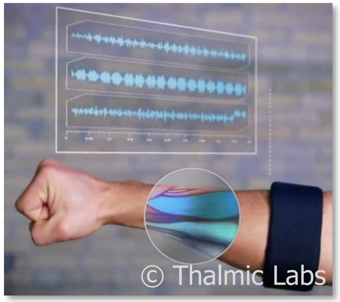
**Extend:** Current perception techniques for increased speed and robustness

**Develop:** Unmanned system behaviors (e.g., scouting and formation keeping)

**Multiple Techniques and Platforms**



**Squad-Relevant Behaviors**


**Payoffs:**
- Squad-level localization with heterogeneous agents in GPS-denied environments
- Manned/unmanned teaming at increased operational tempo with minimal interventions

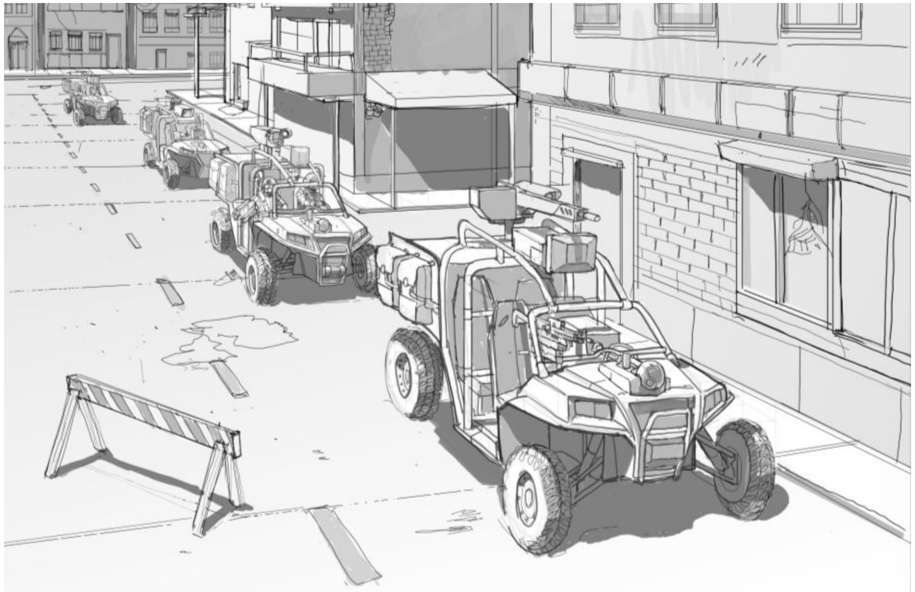
**Challenges:**
- Accuracy and drift, over both time and distance, with SWaP-C constraints
- Operational tempo in complex and dynamic environments

# Proposed Program: Mobile Infantry

Mobile Infantry would seek to explore the development of a system-based, mixed team of mounted/dismounted warfighters and semi-autonomous variants of current or planned small off-road platforms

Proposed Program Goals:

- Execute an expanded mission set from those currently employed
- Allow for a combined set of mounted and dismounted operations and for a larger area of operations over more aggressive timelines than standard infantry units
- Maintain dismounted warfighter scales for operational deployment
- Develop platform/sensor systems that are adaptations of existing/expected platforms



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