# The Need for Sound Decision Making in Systems Analysis

By

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# New York Times Article: "What you Really Need to Know"

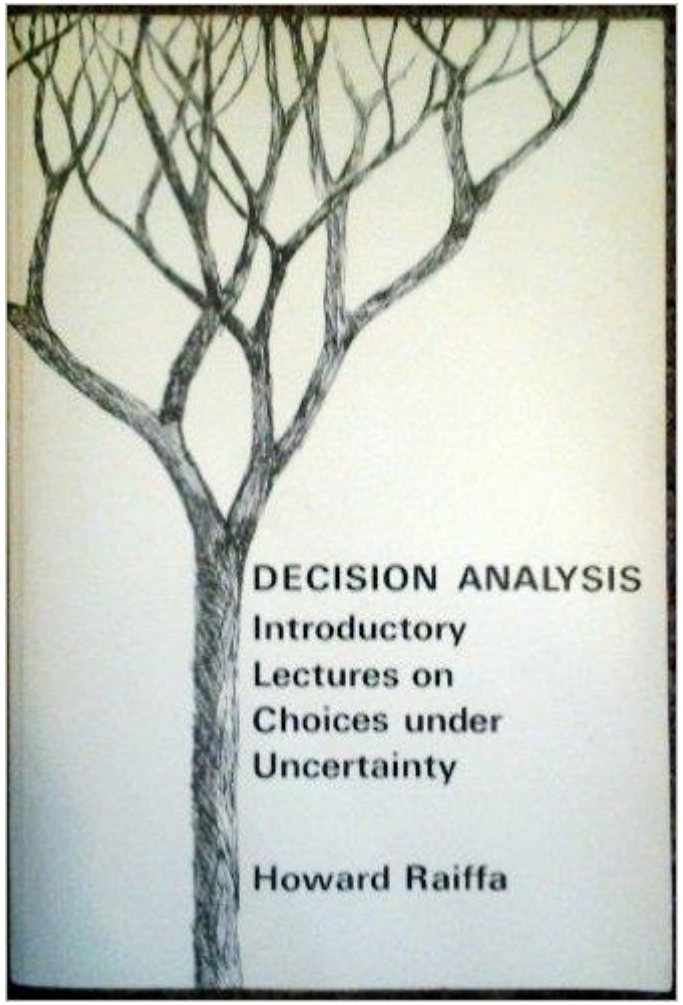
*"In an earlier era, when many people were involved in surveying land, it made sense to require that almost every student entering a top college know something of trigonometry.*

*Today, a basic grounding in probability, statistics, and decision analysis makes far more sense."*

*Larry Summers*

http://www.nytimes.com/2014/01/22/education/edlife/the-21st-century-education.html?_r=3&scp=1&sq=Larry%20Summers,%20education&st=cse

# New York Times Article by Larry Summers



"I got hooked"

*Larry Summers*

# 46 Years Later …..

Using Decision Trees in Space Decisions

# Asteroid Strategy

The President announced in April 2010 a human mission to an asteroid. The budget leverages NASA's human and robotic activities for the mission and also accelerates efforts to address potentially hazardous asteroids:

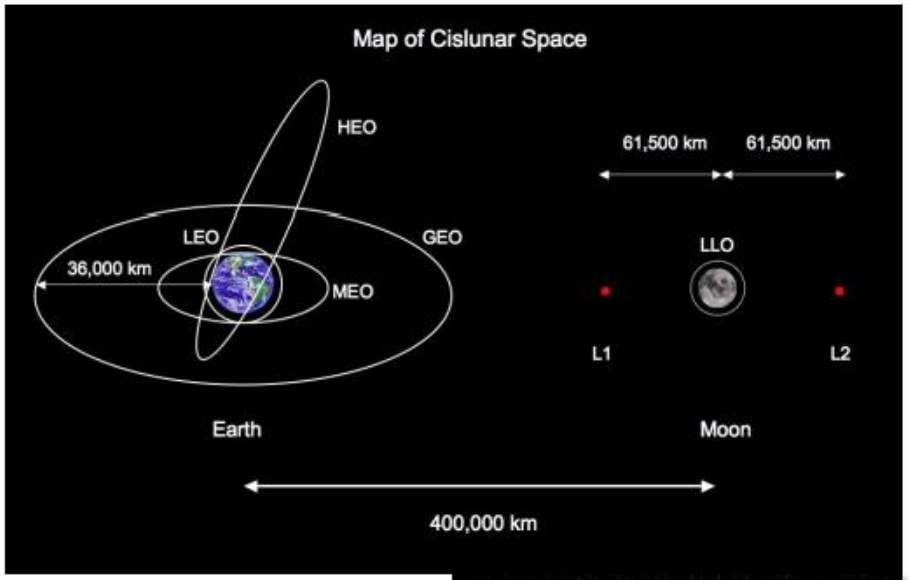
- To protect our planet
- To advance exploration capabilities and technologies for human space flight
- To learn how to best utilize space resources.

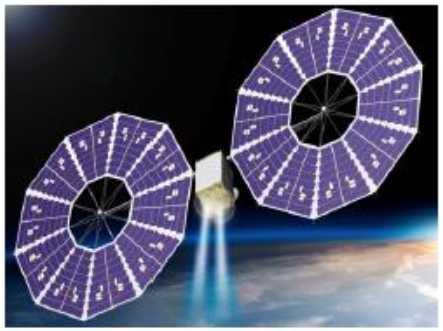
The FY14 budget aligns relevant portions of NASA's science, space technology, and human exploration capabilities to plan for the mission.

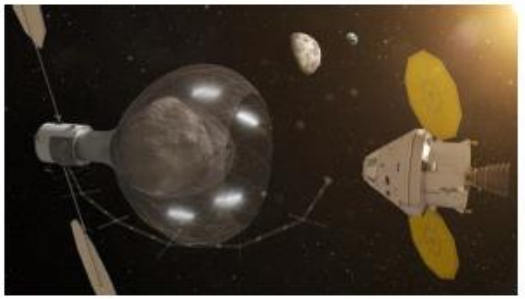
NASA will build on a rich history of engaging citizen scientists, researchers and individual innovators in this quest.

# Mission Concept

- Capture and redirect a 7-10 meter diameter, ~500 ton near-Earth asteroid (NEA) to a stable orbit in trans-lunar space
- Enable astronaut missions to the asteroid as early as 2021
- Parallel and forward-leaning development approach

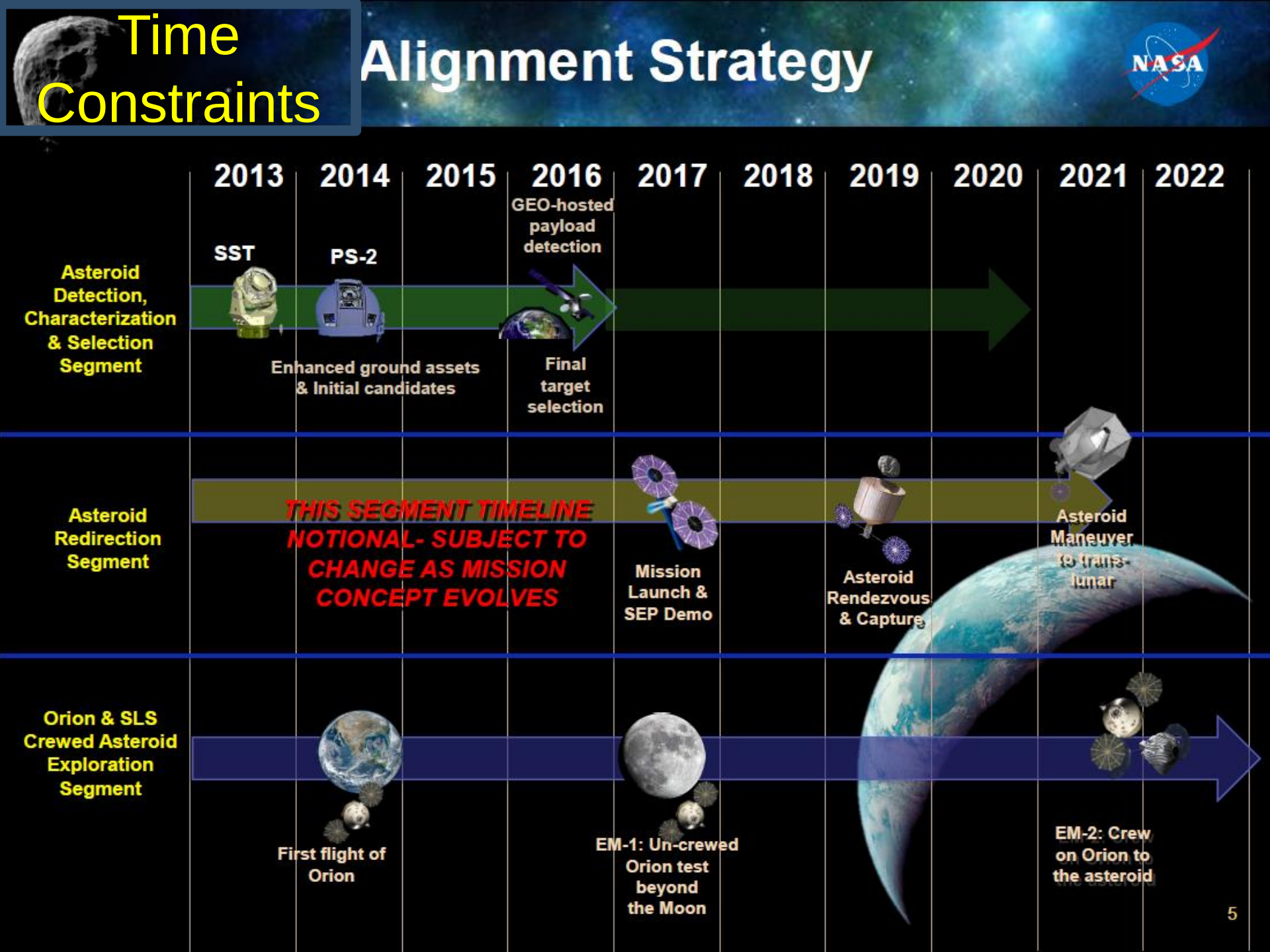




# Time Constraints

# Alignment Strategy



# NASA's Mission Objectives? Stakeholders?

Who are the stakeholders?

Advance Science
Public Perception
Work toward long term objectives

Safety of crew
Safety of planet

Public Perception
Money

Ability to deflect Asteroid for planetary protection

Possible private investors !

# Uncertainty?

Generic Decision Tree for 1 Alternative

February 2nd 2014

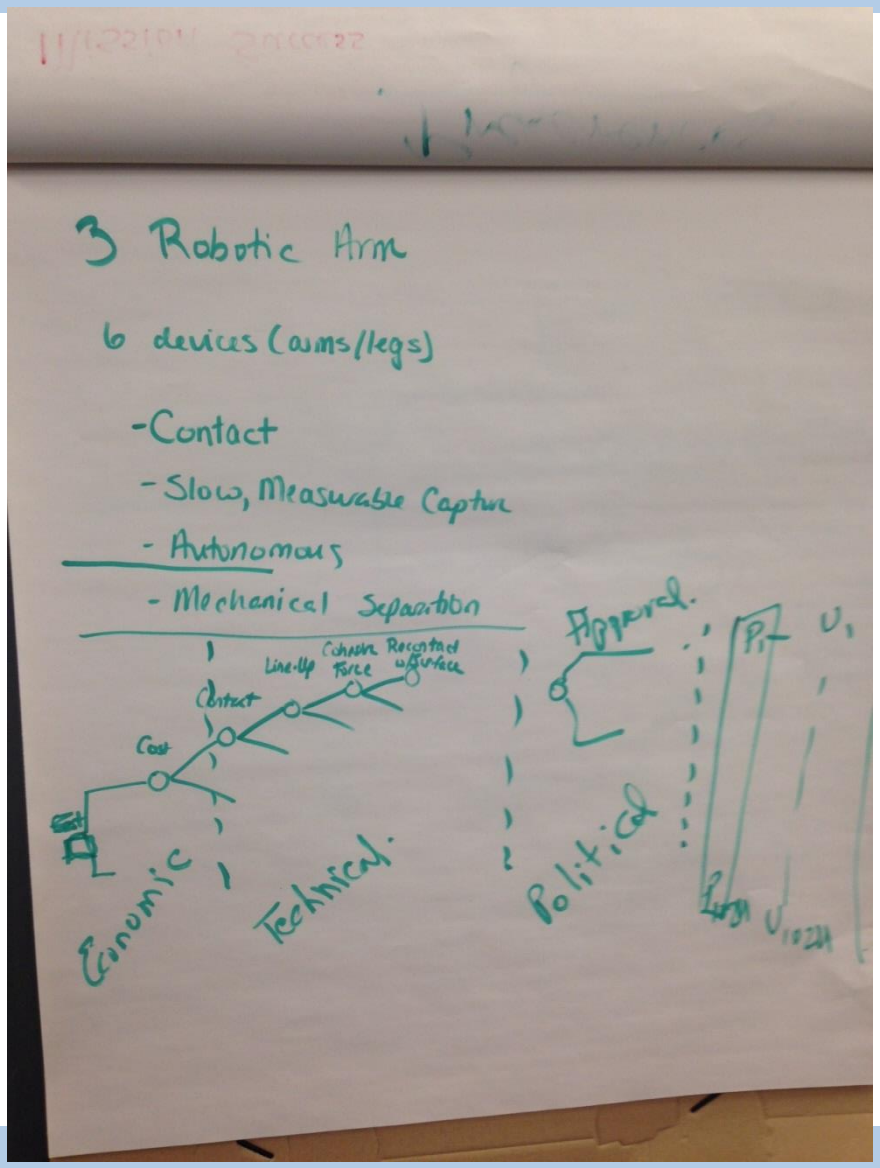
Probability of Capture

*With sensitivity analysis, we showed that improving probability of capture will add significant value to the space mission.*

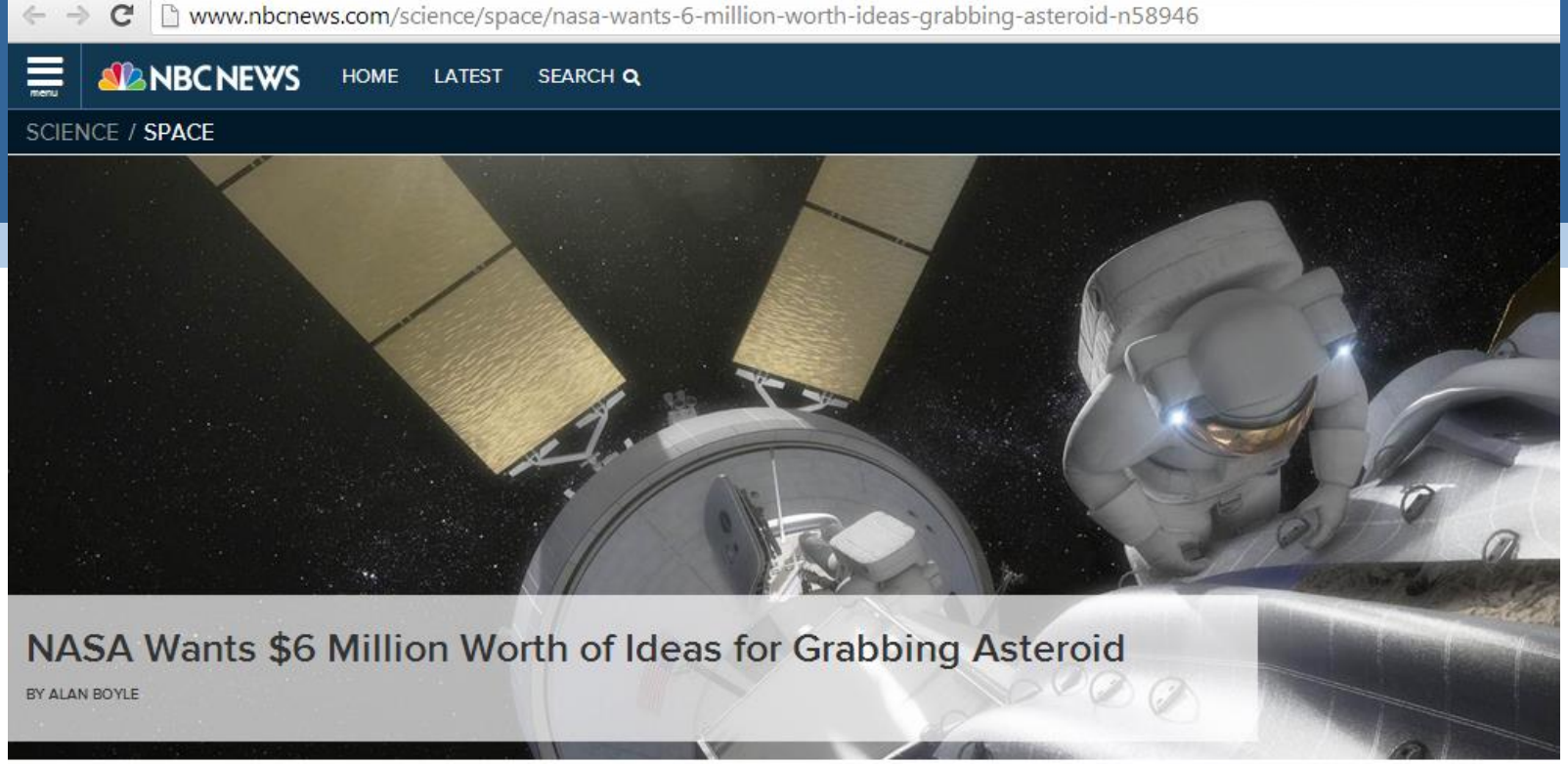
It will help with

*Positive Public Perception/Awareness
*Advance Science ( Return with rich Asteroid)
*Funding Approval (Money)
*Safety of Crew
*Allow more time for observing/ C/C
*Allow more time for deflection

*Worth more than $50 million radar.*



# Email from my student




March 21st 2014

NASA is putting out a formal call for projects that will help robots and astronauts grab an asteroid from deep space and bring it closer to Earth for study.

The Broad Agency Announcement, released Friday, envisions spending up to $6 million on as many as 25 proposals this year. The proposals should focus on technologies that can be used to identify potential targets, send robotic spacecraft to capture the selected asteroid and put it in a stable orbit beyond the moon, or help astronauts get to the space rock and bring back samples in the mid-2020s.

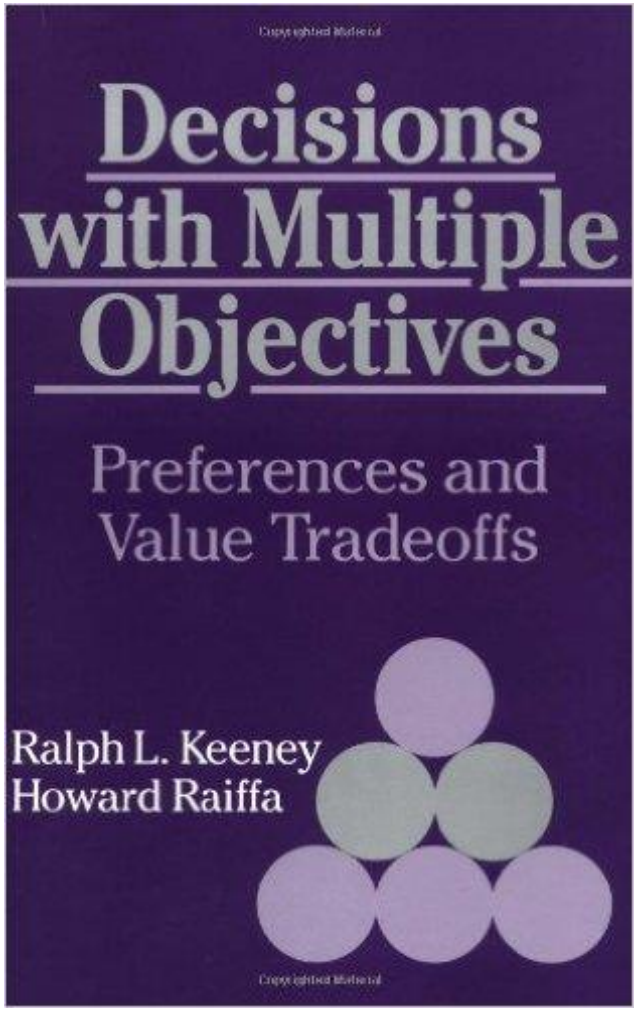
"We're reaching out to seek new and innovative ideas as we extend the frontier of space exploration," Bill Gerstenmaier, NASA's associate administrator for human exploration and operations, said in a news release. "To reach Mars, we'll rely on new technologies and advanced capabilities proven through the Asteroid Initiative. We're looking forward to exciting ideas from outside NASA as well to help realize that vision."

**Capitalizing on ideas**

The space agency is planning an Asteroid Initiative Opportunities Forum at NASA Headquarters in Washington on Wednesday to provide more information for potential participants. Next week's forum will be live-streamed online to folks who sign up.

http://www.nbcnews.com/science/space/nasa-wants-6-million-worth-ideas-grabbing-asteroid-n58946

# Decisions with Multiple Objectives



# 37 Years Later …..

Control of Unmanned Aerial Systems (UAS) using Multiattribute Utility Theory

# Real-Time UAS Decision Making

Control Dynamics for Agents

$$\dot{x}_i = g_i(x_i)u_i + h_i(x_i), x_i(0) = x_{io}, \forall t \in [0, \infty), \forall i \in \mathbf{N}.$$

Multiple Attributes

- Surveillance
- Collision avoidance
- Tracking

How do we derive real-time decision making algorithms for unmanned aerial systems (UAS) to meet these objectives?

Control-theoretic algorithms require an appropriate Lyapunov function with certain properties. ***Can be hard to find and hard to solve, even when found.***

Valicka, C., D. Stipanovic, and A.E. Abbas, "Multiattribute Utility Functions for Multiobjective Control," Proceedings of the 2013 American Control Conference, Washington, District of Columbia, June 17-19, 2013.
Valika C, Stipanovic D, and A.E.Abbas, 2015 "Control Strategies for Players in Pursuit-Evasion Games Based On Their Preferences," International Game Theory Review"(Forthcoming)

# Real-Time UAS Decision Making

Multiple Attributes

- Surveillance
- Collision avoidance
- Tracking

Inspired by the additive and multiplicative forms

$$C(v_1,...,v_n) = a\psi^{-1}[\prod_{i=1}^{n}\psi(l_i + (1-l_i)v_i)] + b$$

Most general form of a mutliattribute utility function satisfying additive ordinal preferences
Has a meaningful interpretation for its assessment

Abbas, A. E. 2009. Multiattribute Utility Copulas. *Operations Research,* 57 (6), 1367-1383..
Abbas, A. E. and Z. Sun. 2015. Multiattribute Utility functions satisfying Mutual Preferential Independence. *Operations Research,* 63(2), 378 – 393.

# Real-Time UAS Decision Making

## Control Dynamics for Agents

$$\dot{x}_i = g_i(x_i)u_i + h_i(x_i), x_i(0) = x_{io}, \forall t \in [0,\infty), \forall i \in \mathbf{N}.$$

## Multiple Attributes

- Surveillance
- Collision avoidance
- Tracking

$$C(v_1,...,v_n) = a\psi^{-1}[\prod_{i=1}^{n}\psi(l_i + (1-l_i)v_i)] + b$$

$$\max(v_1,\ldots,v_m) \le -\ln\left(\frac{C(e^{-v_1},\ldots,e^{-v_m})-1}{a(1-l_{Max})}+1\right)$$

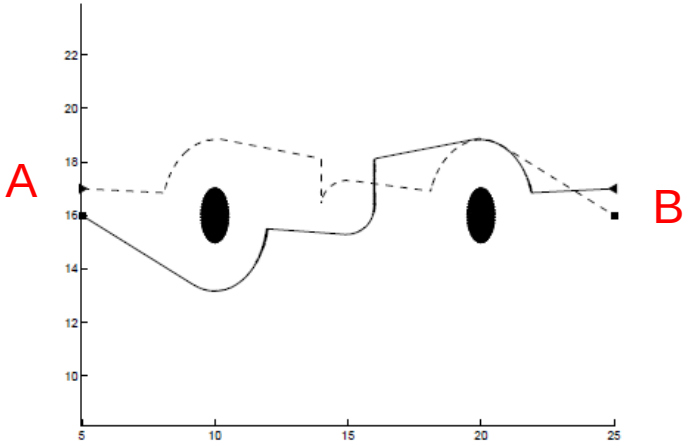
*Multiattribute Utility* functions with mutual preferential independence can be used in Lyapunov-like functions for control of agents pursuing multiple objectives.

The multiattribute utility function can be assessed in a meaningful way instead of having to search for the Lyapunov function.

Closed form expression for the control laws makes the problem feasible for real-time decisions.

# Tracking and Collision Avoidance

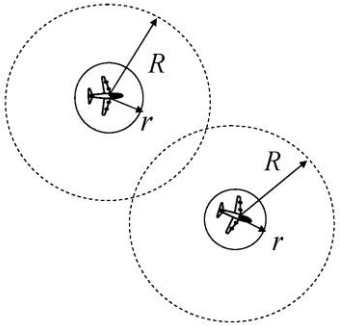
$$\dot{x}_i = g_i(x_i)u_i + h_i(x_i), x_i(0) = x_{io}, \forall t \in [0,\infty), \forall i \in \mathbf{N}.$$




## Tracking

$$v_{ij}^p(x_i^p, x_j^p) = \max\{0, \| x_i^p - x_j^p \|^2 - \hat{R}_{ij}^2\}^2.$$

## Collision Avoidance




## Surveillance

By this we mean that the vehicles' sensors have footprints whose union is much smaller than the area to be covered. Thus they have to move around to survey the most amount of space in the given domain.

# A Great Success Story for Decision Analysis

http://www.youtube.com/watch?v=JRCxZA6ay3M&lr=1&uid=75HjFw2U3ipbrDj3ara7bg

# The Raiffa-Howard Award

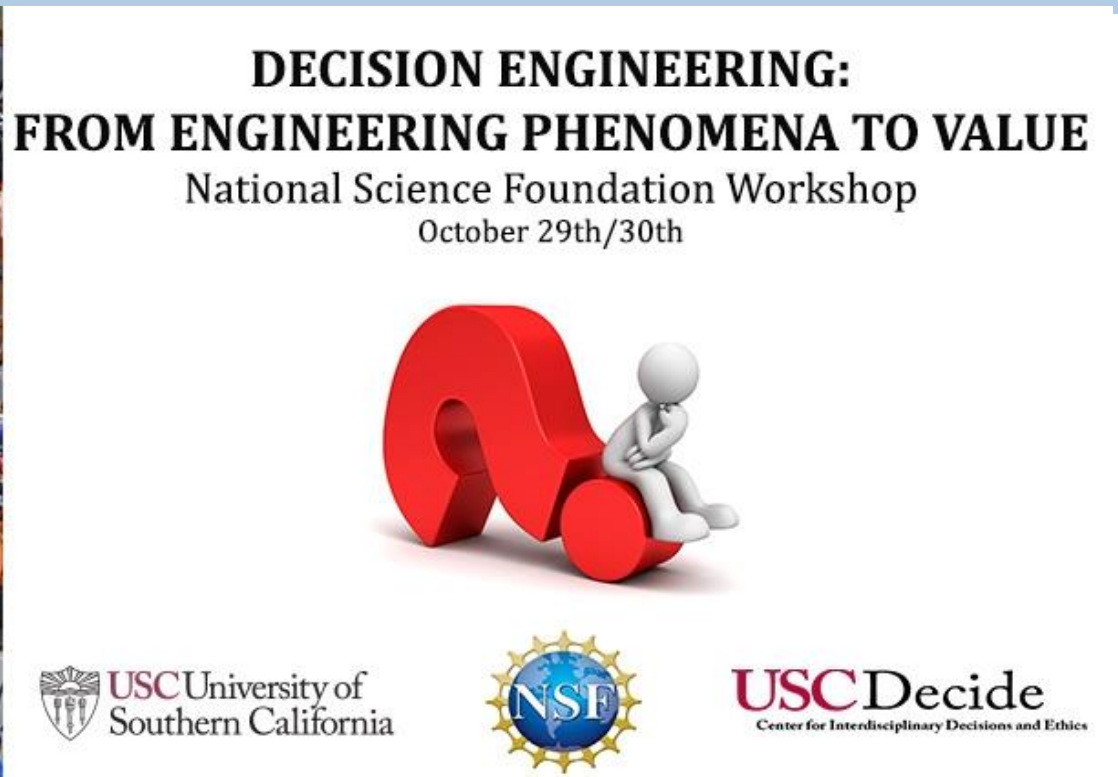
http://www.youtube.com/watch?v=JRCxZA6ay3M&lr=1&uid=75HjFw2U3ipbrDj3ara7bg

# There is still work that needs to be done

Decision analysts need to continue to work more closely with other fields!

# Decisions in Medicine

# Decisions in Systems Engineering




- Systems Engineering Community
  - Have many misconceptions about decision analysis
  - Would embrace the opportunity to learn and work with decision analysts.
- Better understanding of value functions and structural models is needed.

# *Approximate vs. Fundamentally Flawed Decision Making Method*

# Example 1

Automobile Design with Customer Feedback

( Based on a True Story)

# Project Design Using Customer Feedback

An automobile company was interested in designing its new automobile in the early 2000s.

It considered three design elements

- Number of cylinders (4/6)
- Size (small/medium)
- Transmission type (manual/auto)

# The company conducted a survey

They received feedback from three major categories of customers.

# Customer Feedback:

## Group A : Family Sedan Folk

**Size:** Strongly prefers medium size car to small.
They will not buy a small car.

**Transmission:** Prefers automatic transmission to manual
(but might buy the manual).

**Engine:** Prefers 6 cylinders to 4
(but might buy 4).

# Customer Feedback:

## Group B: Sports Folk

**Size:** Prefers small size to medium.
( but might buy a medium car)

**Transmission:** Strongly prefers manual to automatic transmission.
(they will not buy automatic).

**Engine:** They prefer 6 cylinders to 4
(but might buy 4).

# Customer Feedback:

## Group C : Big City Folk

**Size:** Prefers small size to medium.
( but might buy a medium car)

**Transmission:** Prefer automatic transmission to manual.
(but might buy manual).

**Engine:** Strongly prefer 4 cylinders to 6
(they will not buy 6).

# Summary of Customer Feedback

| | Small Car | Medium Car | Auto | Manual | 6 Cylinders | 4 Cylinders |
|---|---|---|---|---|---|---|
| Results | Group A will not buy it,<br><br>Groups B,C prefer it | | Group B will not buy it,<br><br>Groups A, C prefer it | | Group C will not buy it,<br><br>Groups A, B prefer it | |

# Summary of Customer Feedback

| | Small Car | Medium Car | Auto | Manual | 6 Cylinders | 4 Cylinders |
|---|---|---|---|---|---|---|
| Results | Group A will not buy it,<br><br>Groups B,C prefer it | | Group B will not buy it,<br><br>Groups A, C prefer it | | Group C will not buy it,<br><br>Groups A, B prefer it | |

**Final design:**

A small car.

Automatic transmission.

6 cylinder engine.

# Project Design Using Customer Feedback

**Final design**

**A small car.**
**Automatic transmission.**
**6 cylinder engine.**

Group A will not buy it because of its size.
Group B will not buy it because of its transmission.
Group C will not buy it because of the cylinders in the engine.

**The company designed a car that nobody would buy!!!**

# And the list of methods goes on…

Quality Functional Deployment

Six Sigma

Design by requirements

..

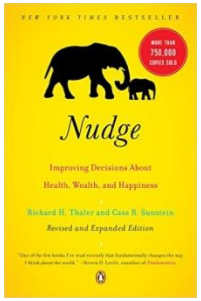
# There is still work that needs to be done

Decision analysts need to reach out to senior leadership in enterprises and the government  to gain further support

# Obama Signs Executive Order

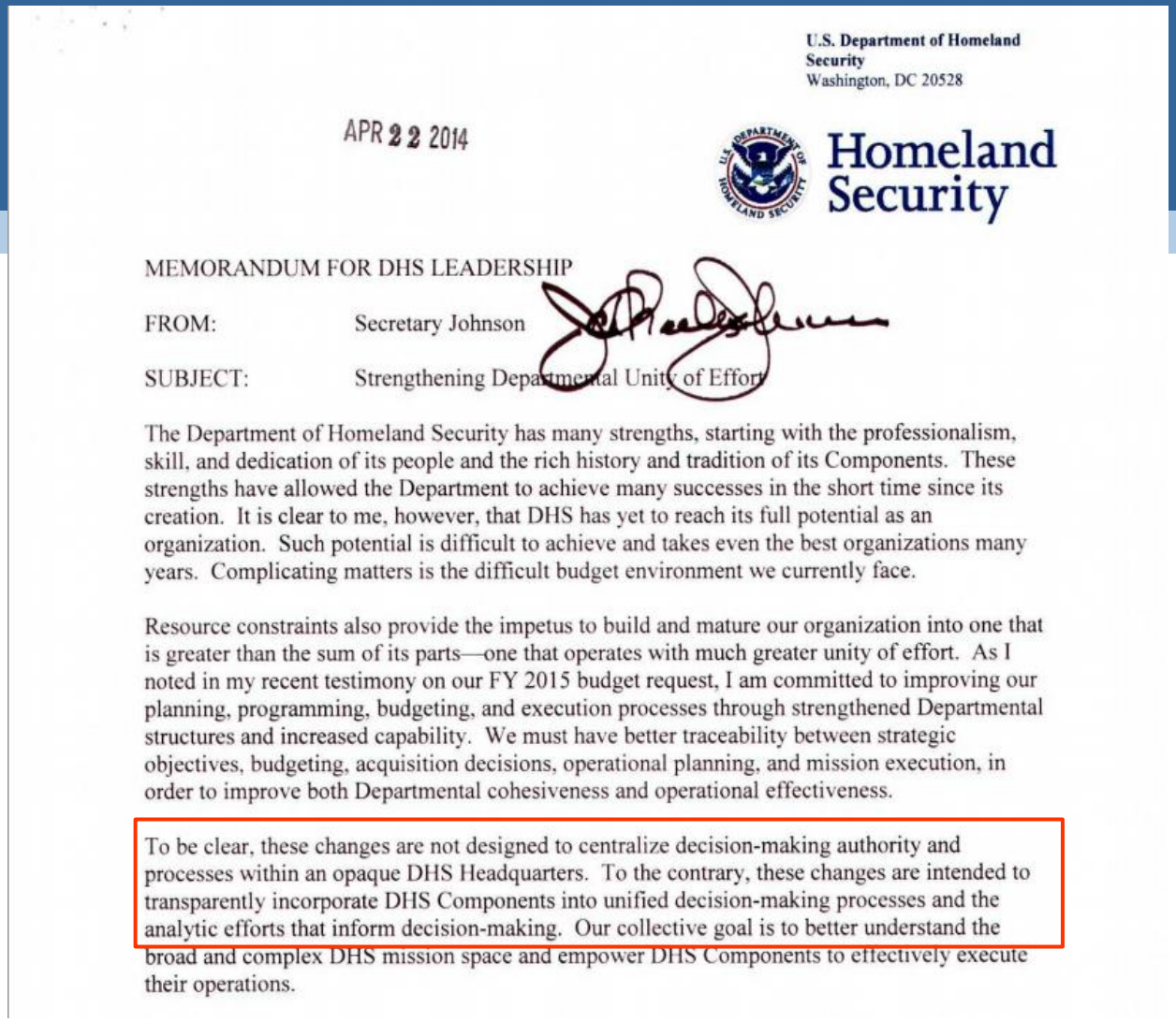
- *"Behavioral science insights—research insights about how people make decisions —not only identify aspects of programs that can act as barriers to engagement, but also provide policymakers with insight into how those barriers can be removed through commonsense steps, such as simplifying communications and making choices more clear."*
- *"When these insights are used to improve government, the returns can be significant*."

https://www.whitehouse.gov/the-press-office/2015/09/15/fact-sheet-president-obama-signs-executive-order-white-house-announces




Barack Obama, September 15, 2015

# Getting Senior Leadership Involved



U.S. Department of Homeland Security
Washington, DC 20528

APR 22 2014

Homeland Security

MEMORANDUM FOR DHS LEADERSHIP

FROM: Secretary Johnson

SUBJECT: Strengthening Departmental Unity of Effort

The Department of Homeland Security has many strengths, starting with the professionalism, skill, and dedication of its people and the rich history and tradition of its Components. These strengths have allowed the Department to achieve many successes in the short time since its creation. It is clear to me, however, that DHS has yet to reach its full potential as an organization. Such potential is difficult to achieve and takes even the best organizations many years. Complicating matters is the difficult budget environment we currently face.

Resource constraints also provide the impetus to build and mature our organization into one that is greater than the sum of its parts—one that operates with much greater unity of effort. As I noted in my recent testimony on our FY 2015 budget request, I am committed to improving our planning, programming, budgeting, and execution processes through strengthened Departmental structures and increased capability. We must have better traceability between strategic objectives, budgeting, acquisition decisions, operational planning, and mission execution, in order to improve both Departmental cohesiveness and operational effectiveness.

To be clear, these changes are not designed to centralize decision-making authority and processes within an opaque DHS Headquarters. To the contrary, these changes are intended to transparently incorporate DHS Components into unified decision-making processes and the analytic efforts that inform decision-making. Our collective goal is to better understand the broad and complex DHS mission space and empower DHS Components to effectively execute their operations.

# Large Enterprises Adopting a Unity of Effort Approach

- What does unity of effort mean for decision making?

A Decision Analysis View of Unity of Effort:

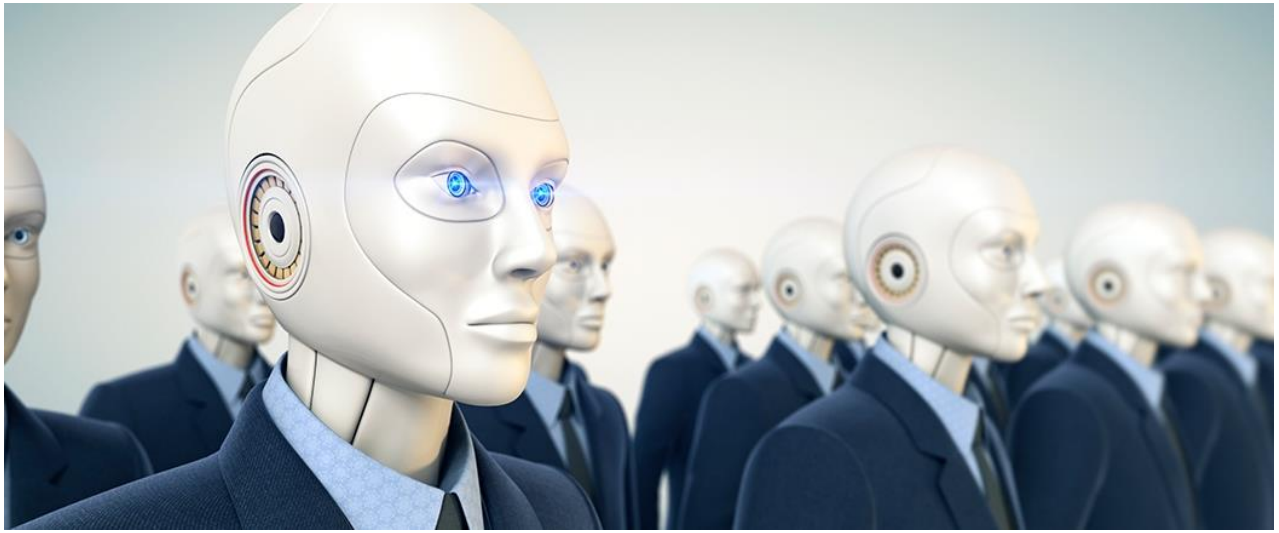
"Unity of Effort" does not mean that all components should do the same things. The nature of their work is different. It means, that when faced with the same decision alternatives, the different components should make the same decisions".

Conversation with Jeh Johnson,
United States Secretary of Homeland Security

Be clear about trade-offs
Use a coherent decision-making method
…

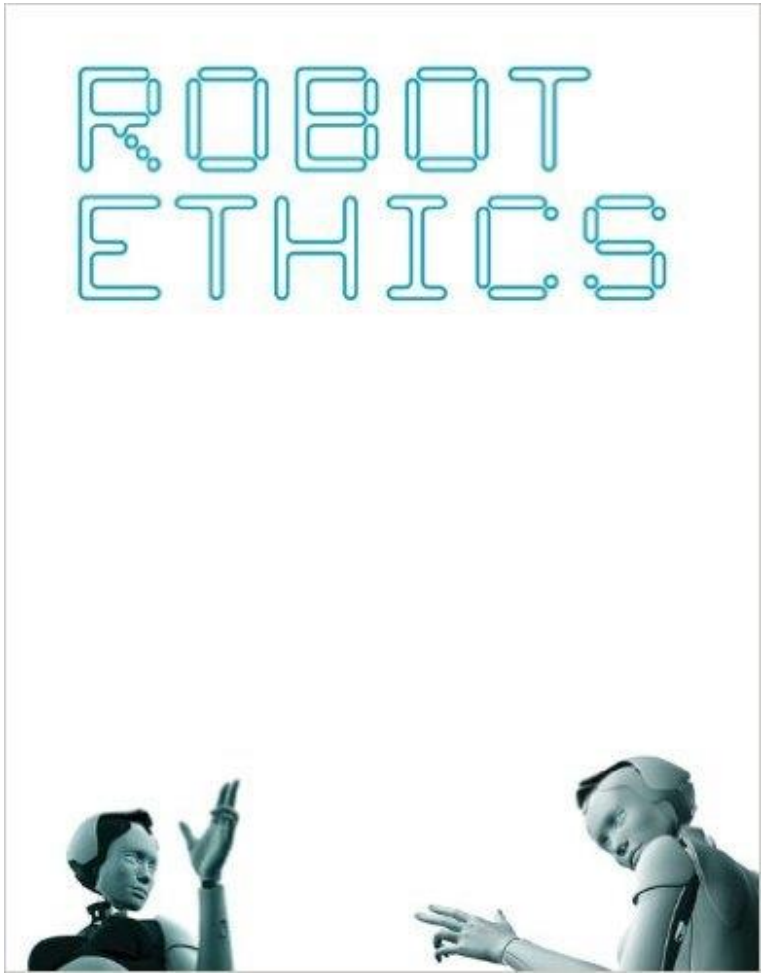
# The Very Near Future ..

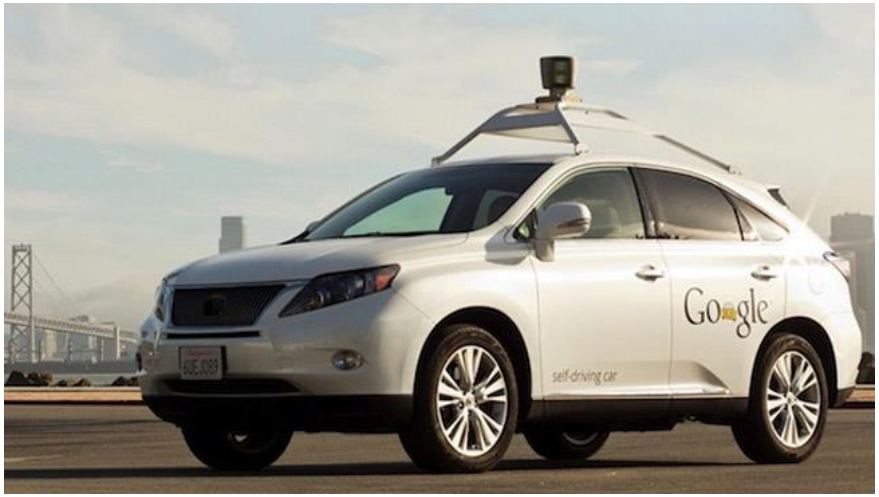
# Decision Making and Artificial Intelligence



Decision Analysis Inside

# The Ethics of Robotics




With great powers..
Comes great responsibility!

Decision Analysis Inside

# Decisions and Ethics

TECHNOLOGY

## *Elon Musk and Stephen Hawking Among Hundreds to Urge Ban on Military Robots*

By DANIEL VICTOR JULY 27, 2015

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Elon Musk and Stephen Hawking, along with hundreds of artificial intelligence researchers and experts, are calling for a worldwide ban on so-called autonomous weapons, warning that they could set off a revolution in weaponry comparable to gunpowder and nuclear arms.

In a letter unveiled as researchers gathered at the International Joint Conference on Artificial Intelligence in Buenos Aires on Monday, the signatories argued that the deployment of robots capable of killing while untethered to human operators is "feasible within years, not decades." If development is not cut off, it is only a matter of time before the weapons end up in the hands of terrorists and warlords, they said.

Unlike drones, which require a person to remotely pilot the craft and make targeting

Navy robotics engineers are working to develop autonomous tools that can integrate with other technologies. But in field tests, the autonomous future still seems far away. By Zackary Canepari, Drea Cooper and Emma Cott on May 6, 2015.

Watch in Times Video »

Embed

*New York Times, July 2015*

# Decisions with Large Data Sets

Decision Analysis Inside

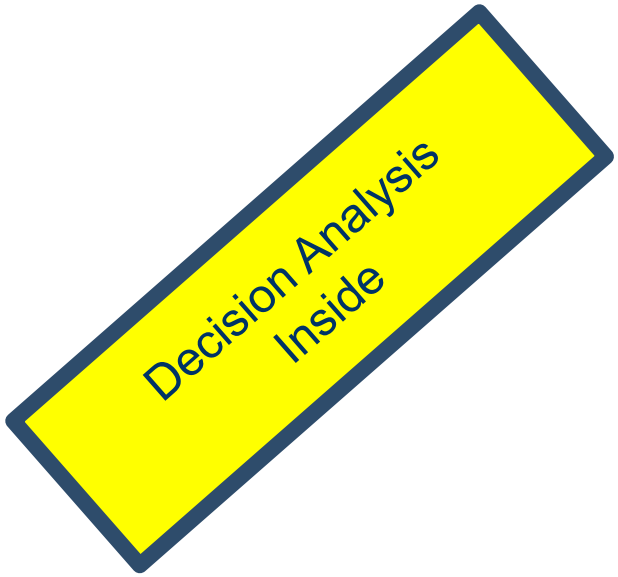
# Decisions and Ethics : Data, Privacy, and Security

With great powers comes great responsibility!

Decision Analysis Inside

# While the field of decision analysis will be

Manifested in a variety of different fields in the very near future, …



# *The Foundations will Remain the Same!*

*Thank You !*