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17 July 2018

Measuring the Value of Future Research

David Bangert

Hindsight is a wonderful thing

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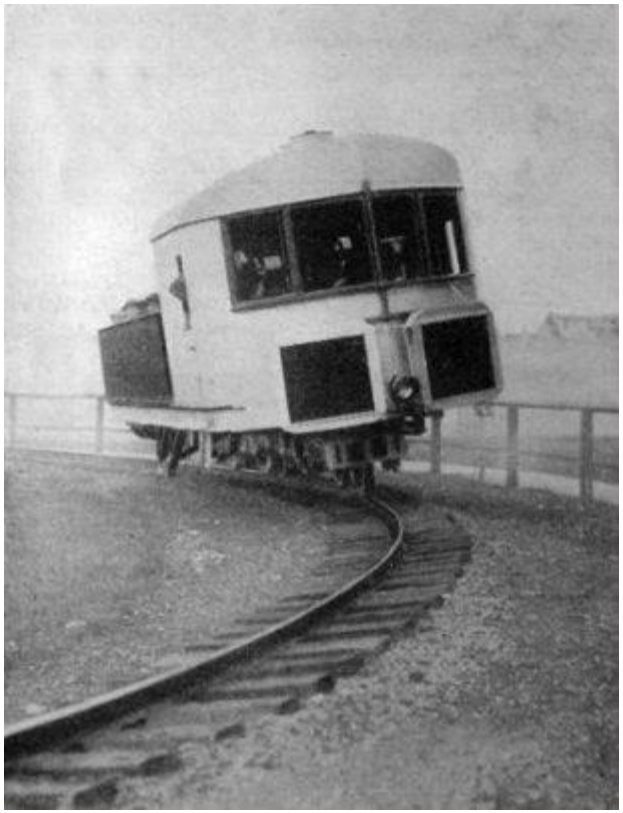

Brennan's Monorail

What might have been?

The winners are obvious now….but weren't then

Late 19th century shipping

1930s long distance aviation

November, 1931 EVERYDAY SCIENCE AND MECHANICS 647

Airport-Docks for New York

The hardest thing in aerial travel, nowadays, is not to fly, but to get quickly to and from the airport; especially in such cities as New York. An architect, Harry B. Brainerd, has worked out a solution in connection with the great docks which will be built for the new huge liners. Roofing shown, will afford landing space for airplanes; while the great covered docks will serve also as hangars for dirigibles, as shown in the central slip above. Passengers can transfer almost instantaneously from ship to plane, by using the elevators. Between the slips, the available dock space will be utilized by offices, factories and warehouses. The projected port is to be 1,025x1,700 feet, pier buildings 115' wide, 200' high.

The nuclear age

Failed military technologies (a small selection)

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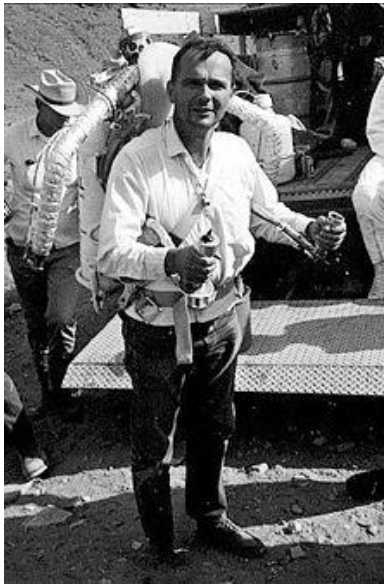
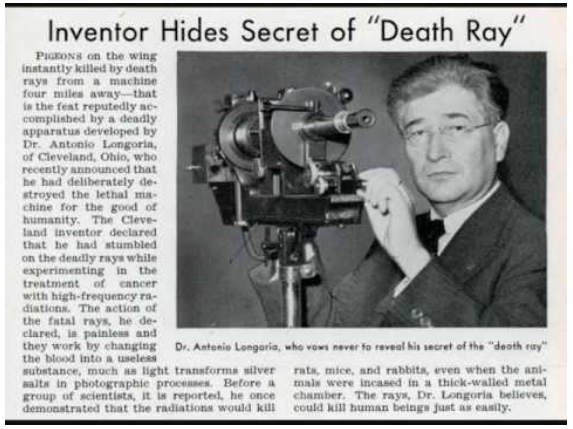
USS Macon, flying aircraft carrier



Bell rocket pack

RAH-66 Comanche Stealth Helo.

Gyro jet rocket propelled bullets



Inventor Hides Secret of "Death Ray"

PIGEONS on the wing instantly killed by death rays from a machine four miles away—that is the feat reputedly accomplished by a deadly apparatus developed by Dr. Antonio Longoria, of Cleveland, Ohio, who recently announced that he had deliberately destroyed the lethal machine for the good of humanity. The Cleveland inventor declared that he had stumbled on the deadly rays while experimenting in the treatment of cancer with high-frequency radiations. The action of the fatal rays, he declared, is painless and they work by changing the blood into a useless substance, much as light transforms silver salts in photographic processes. Before a group of scientists, it is reported, he once demonstrated that the radiations would kill rats, mice, and rabbits, even when the animals were incased in a thick-walled metal chamber. The rays, Dr. Longoria believes, could kill human beings just as easily.

Dr. Antonio Longoria, who vows never to reveal his secret of the "death ray"

The Death Ray of the 1930s

Research Studies

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- Dstl are running a programme called Emerging Technologies for Defence (ETD), which is designed to assess potential technologies and recommend action
- Polaris Consulting Limited (Polaris) were commissioned to determine if a Cost-Benefit Analysis (CBA) approach would be a useful adjunct to this process – formerly called DAACR (Defence Agility, Adaptability and Cost Reduction) process
- Arke Limited were also commissioned to conduct a parallel study into CBA, as the problem was seen as very challenging
- Both studies have now reported; this paper discusses Polaris' findings but both have provided valuable insights to Dstl, and further joint work between Polaris and Arke is now planned
- This paper cannot discuss the actual technologies assessed and instead discusses an illustrative (eg not real) example
- Thanks are extended to Dstl, who funded the study which underpins this paper

This is not an easy problem to tackle

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- The method must be flexible enough to deal with technologies which may:
  - be mature in a few years, or out to 2045,
  - range from scientifically unproven to very mature (TRL 1 to TRL 9),
  - replace or augment current systems, or represent a revolution in military affairs,
  - be new systems, platforms, software, materials or approaches to integration,
  - be very limited in their military application, or pervasive.
- Most technologies will be developed in civil markets and then adopted by the military, although some may be developed purely for military use
- Dozens, or hundreds, of candidate technologies may be considered in a single year
- The key is *not* to pick ‘winners’ but to recommend practical action for the MOD
- **Cost matters**: a technology must provide a positive cost-benefit or an effectiveness able to justify its cost

An illustrative example

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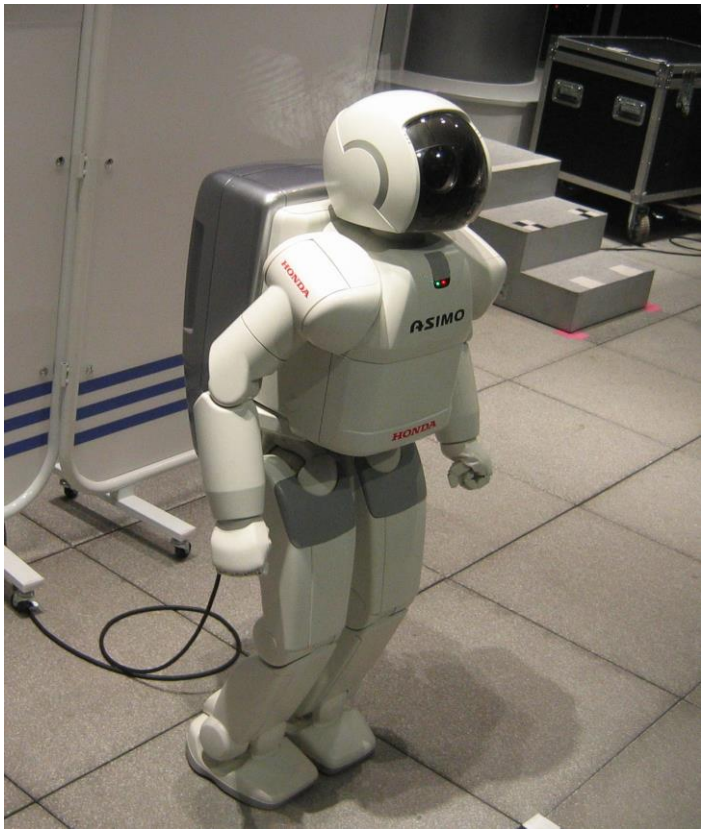
- A semi-autonomous battlefield platform capable of operating in adverse conditions, building on advances in robotics and machine intelligence, fielded in 2030-40



Asimo robot, Image Credit: Poppy, CC BY-SA 3.0

Scale, scope and characteristic of a technology

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1. Definition of the Technology

- Is it scientifically possible?
- Is it plausible that the technology will be developed?
- What is its TRL?
- Will it be developed through civil applications and then applied to defence?
- Where will it be developed – globally, in the West, elsewhere?
- What are the likely costs of its development in the civil domain?
- What evidence exists regarding the development of the technology?

Making a technology work is only part of the problem

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2. Barriers, opportunities and context

- A new technology *must* be scientifically possible and achievable in terms of engineering 
- But it *must* also be:
  - Acceptable to society  ?
  - Legal  ?
  - Affordable ?
  - Cost-effective ?
  - Able to use current infrastructure, or operate with little infrastructure, or be *very* affordable 
  - Secure for military use ?
  - Not overtaken by rival technologies ?

Setting boundaries

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3. Military Use Cases

- Many new technologies have so many applications that it is difficult to get a handle on them
- Therefore, specific use cases must be selected for evaluation
- For this concept, three use cases may be defined:
  - Defence Explosive Ordnance Disposal (DEODS) is a vital capability for Defence. Semi-autonomous robots could REPLACE many of the current EOD vehicles.
  - Evacuation of Casualties could be improved through the use of semi-autonomous robots.
  - Operation in extreme environments could be greatly improved through their use.
- These cases are deliberately conservative and avoid the issues of legality and safety

It’s (almost) all about the money

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4. Financial benefits and costs

- The Whole Life Cost (WLC) of the technology must be estimated:
  - For the military use cases under consideration
  - Across research, development, manufacture and deployment in-service
  - Against a baseline of the current way the use cases are delivered (unless the technology provides a new capability)
- The baseline cost is calculated
- The costs of the new technology are estimated parametrically
- The (financial) benefits of the new technology are estimated against the baseline, across all the Defence Lines of Development (DLoDs), such as:
  - Personnel
  - Logistics
  - Equipment

Although effectiveness matters as well

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5. Operational Effectiveness

Military Function	Score (Use Case/General)	Comment
Close Combat		Illegal and unacceptable to society
CBRN Defence	2/2	Potential issues with illegality
Explosive Ordnance Disposal	2/8	Could greatly enhance current EOD operations
Cyber Operations & Cyber Situational Awareness	(V)	May offer opportunities for enemy action
Intelligence & Situational Awareness		
Presence, Influence, Coercion, Deterrence & Diplomacy		
Medical & Personnel Evacuation and Recovery	2/2	Potential to make personnel evacuation safer
Logistic Support, Lift & Refuelling	-/2	Potential to improve current operations
Equipment Recovery & Repair	-/2	Potential to improve current operations
Public Order		
Humanitarian Assistance & Disaster Relief		
Operating in extreme environments	2/8	Improvements in limited use cases; with great potential for exploitation
Total	**8/24**	

Valuing a future technology

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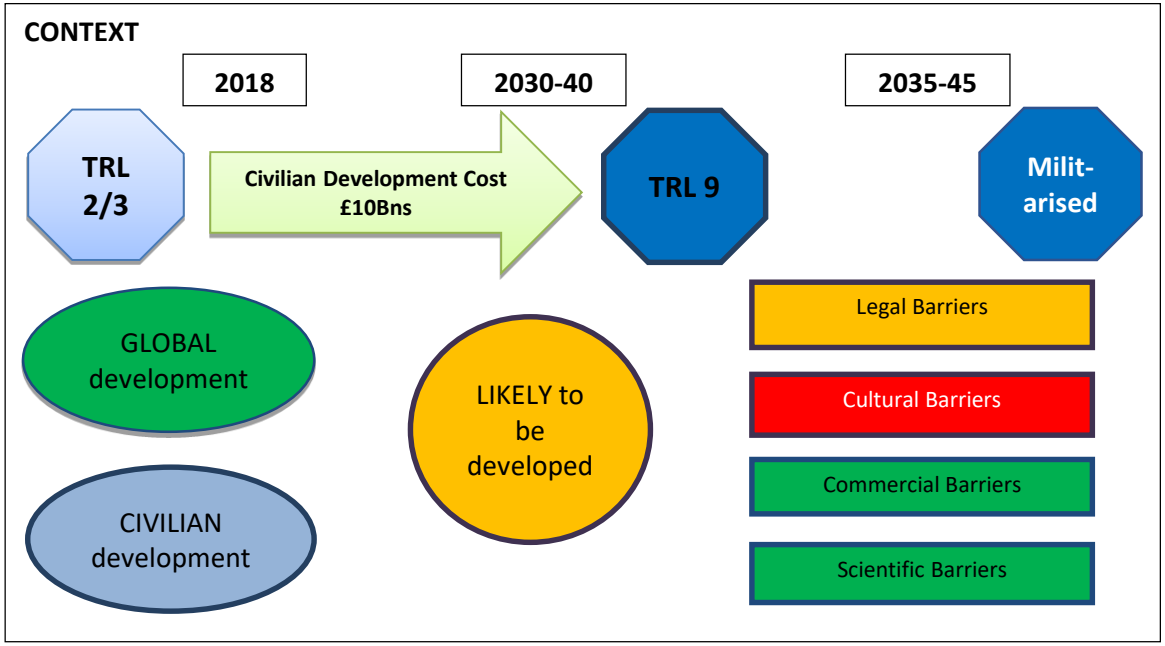
6. CBA and CEA

- Cost Benefit Analysis (CBA) is a financial valuation of the WLC of a technology for the selected use cases
- Cost Effectiveness Analysis (CEA) is a comparison of the WLC with the change in Operational Effectiveness (OE) of the selected use cases
- Both are valid and complementary approaches to understanding the value of a technology
- It is also important to understand the ‘extensibility’ of a technology beyond the use cases
- It is equally important to understand the impact of legal and societal realities on the ‘extensibility’

Dashboard



7. Dashboard

USE CASE(S)

Defence Explosive Ordnance Disposal (DEODS) is a vital capability for Defence. Semi-autonomous robots could **REPLACE** many of the current EOD vehicles.
Evacuation of Casualties could be improved through the use of semi-autonomous robots.
Operation in extreme environments could be greatly improved through their use.

COST-BENEFIT
Costs: adaption for military use to cost **£1-10Bns**
Production Costs: £100m - £1Bn
Support costs over 20 years: £100m - £1Bn
WLC: £100m - £1Bn
Financial benefits: savings of **£100m-1Bn** (arising from a reduction in vehicle numbers and personnel costs)
Cost-benefit: neutral

OPERATIONAL EFFECTIVENESS IMPACT
Use Cases: transitional impact on DEODS, casualty evacuation and operating in extreme environments (total score 8)
Extended: transformational impact on non-combat operations (total score 24)
Vulnerabilities: in Cyber

MILITARISATION
The key cost drivers for militarising are:
- Ruggedisation
- Electronic countermeasures
- Cryptography
- Communication links

Stage 1 Use Cases

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7. Dashboard (Continued)

MODERATE CONFIDENCE

NEUTRAL COST-BENEFIT

INCREASED OE

VERY HIGH POTENTIAL

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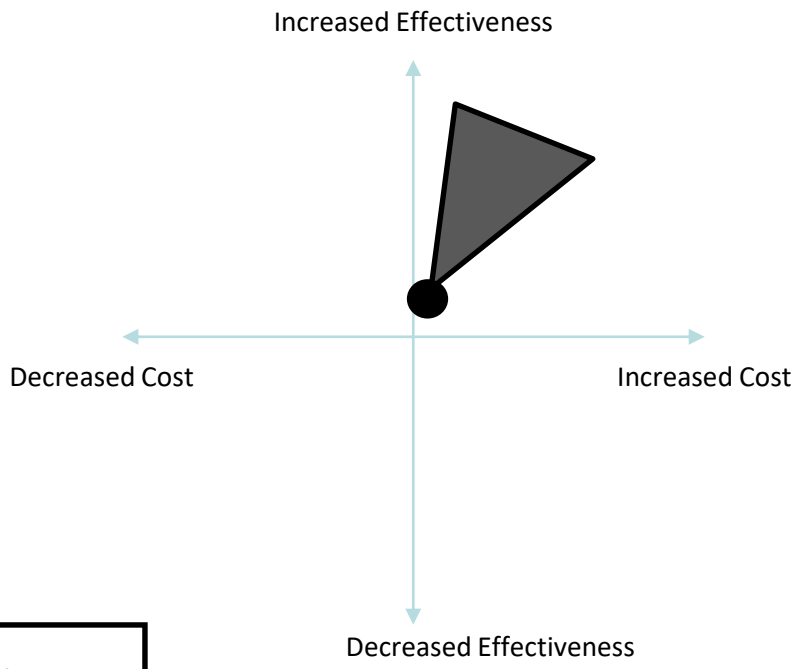
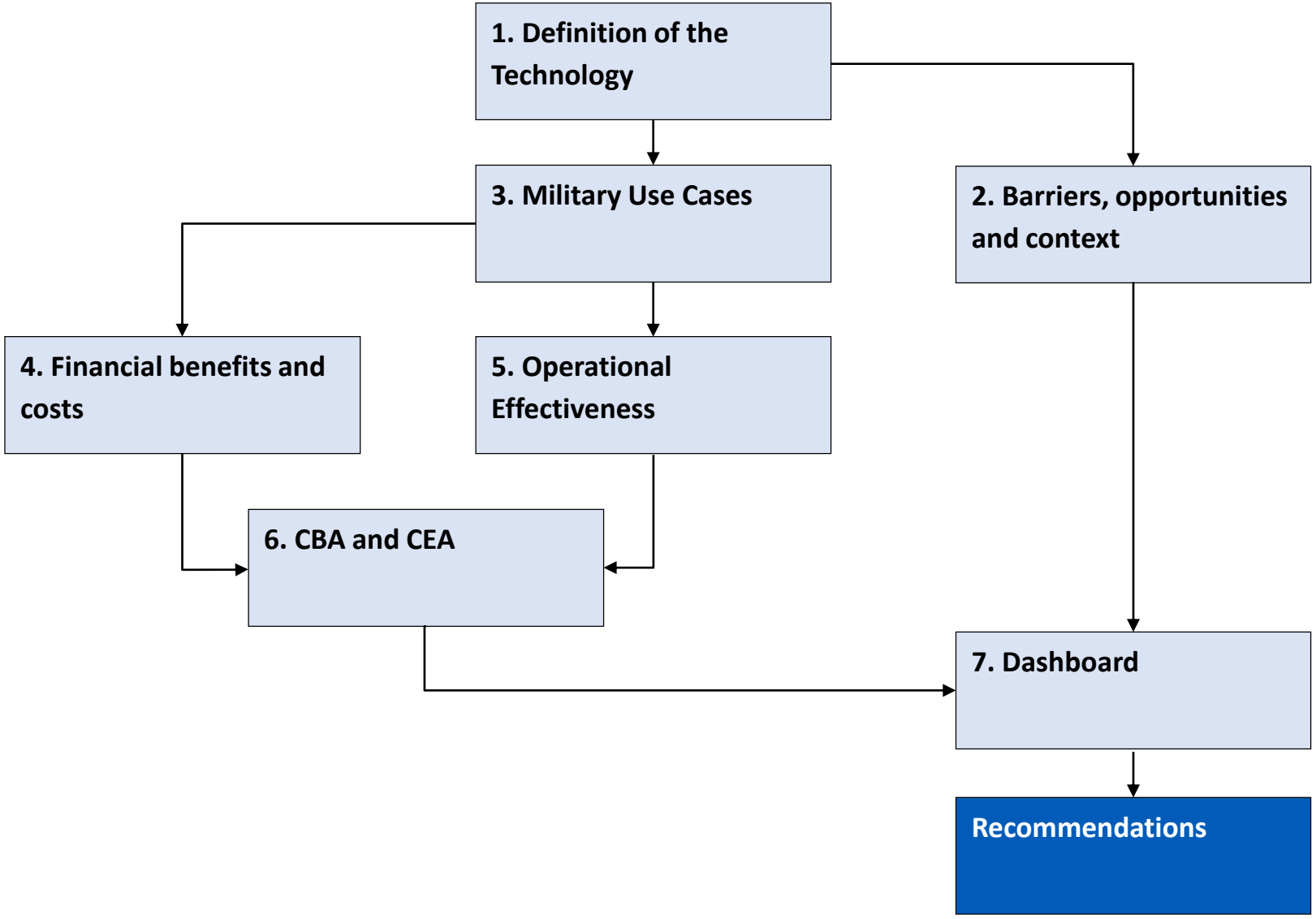


PROPOSED ACTION(S):

- **INTERVENE THROUGH DASA**
- **MARKET ASSESSMENT**

Method


1. Definition of the Technology
3. Military Use Cases
2. Barriers, opportunities and context
4. Financial benefits and costs
5. Operational Effectiveness
6. CBA and CEA
7. Dashboard
Recommendations

So what?

- To support a decision on future investment, such as:
  - Technology Watch
  - DASA call(s)
  - Market analysis
  - Directed funding
- *Can we build it? Do we want to? What are the alternatives? What are its vulnerabilities?*