

Army Science & Technology



Technology Wargaming Overview

Federal Foresight Community of Interest



DESIGN • DEVELOP • DELIVER • DOMINATE
SOLDIERS AS THE DECISIVE EDGE



- Enables Army Science & Technology (S&T) to identify game-changing technology that could impact Army capabilities in the far future(2035-2040), executed in the Office of the Deputy Assistant Secretary of the Army for Research and Technology (ODASA R&T).
- Ensure comprehensive technology reconnaissance by crowdsourcing technology concepts from underutilized non-DoD traditional organizations and entities. Mitigate cognitive bias within the Army/Army S&T. Leverage creative abilities from a diverse audience
- Analyze crowdsourced capabilities to inform Army S&T Program Objective Memorandum (POM) and create a “here to there” narrative illustrating basic S&T investments now for Army capabilities in 2035-2040



Technology Wargaming Overview

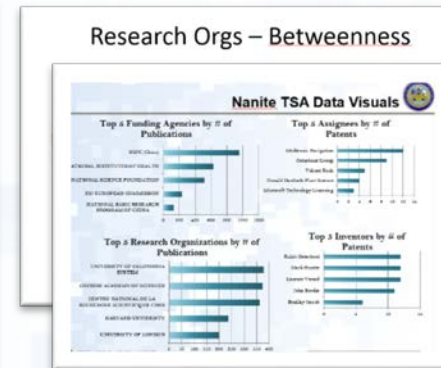
- Crowdsource future capabilities from the Army S&T enterprise, academia, and non-traditional DoD thinkers
 - Mitigates risk of cognitive bias's within the Department of the Army by leveraging the creativity and insight of non-traditional DoD individuals and organizations
 - Executed through in-person and online ideation exercises
- Analyze potential technologies using bibliographic-based data analytics (universities, personnel, countries performing the research)
- Through SME review create a functional decomposition of a potential capability
- Assign probabilities and perform Monte Carlo Simulation to create a here-to-there narrative for how basic science advances will produce an Army capability through a Technology Sequence Analysis (TSA)
- Provide broad future S&T context in Annual Trends Report

"...The elite amateurs were on average about 30% more accurate than the experts with access to classified information...the full pool of amateurs also outperformed the experts. The most careful, curious, open-minded, persistent and self-critical...did the best."¹

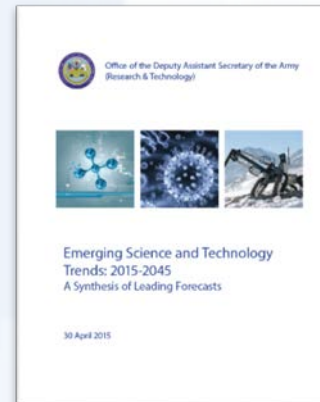
Crowdsourcing



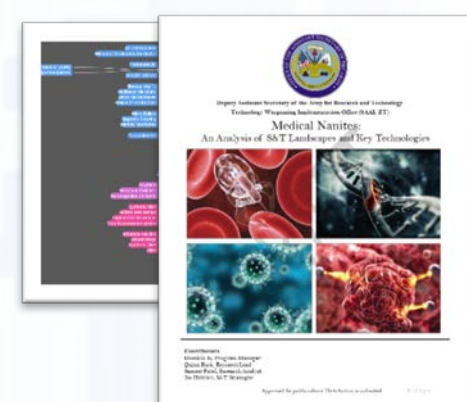
SME-Informed Bibliometric Search



S&T Trends Report



Deep Dive Analysis



¹ Zweig, J. (2015, September 25). The Trick to Making Better Forecasts. Retrieved November 20, 2015, from <http://www.wsj.com/articles/the-trick-to-making-better-forecasts-1443738583>

Execution

Broad meta-analysis
of S&T trends

Web-based
crowdsourcing events

SME ideation
exercises



Office of the Deputy Assistant Secretary of the Army
(Research & Technology)



Emerging Science and Technology
Trends: 2015-2045
A Synthesis of Leading Forecasts

30 April 2015

NANOBOTS THAT SEEK PEOPLE AND CLEAR PATH

OVERALL RATING

UTILITY TECHNICAL FEASIBILITY NOVELTY

NANOBOTS THAT SEEK PEOPLE AND CLEAR PATH

OVERVIEW

What Would Be Some Applications?

DISCUSSION

INNOVATION

COMMENTS

Ecosystem in a Box

Synthetic Biology + Climate Change

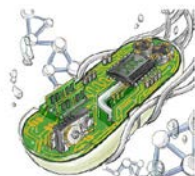
Ecosystem in a Box (EiB) is a concept that involves creating customizable, synthetically derived microbial communities that are engineered to reproduce a discrete ecosystem function that facilitates elemental cycling of carbon, nitrogen, oxygen, iron, etc. These synthetic ecologies could influence climatic conditions through modulation of key processes such as carbon sequestration or reduction of other greenhouse gases. The microbial consortia would be engineered to be self-sustaining using synthetic biology engineering approaches and would have a kill switch to inactivate the community if desired. The organisms could be produced in an inert form (freeze-dried) and introduced into the desired environment in a contained manner to allow for chemical exchanges but not biological exchange. Synthetic, programmable ecosystems could be used to cleanup contaminants, enhance soil fertility, or even colonize alien landscapes. Currently synthetic biology is limited to known model organisms. Significant research in non-model environmental bacterial systems and communities is needed to be able to develop synthetic biology tools and systems to exploit these natural resources. Advances in genome engineering and design will also be required and novel computational biological models that describe and predict microbial community composition and function will be critical.

soil fertility and promote agriculture, or colonize alien landscapes. Currently, this capability and associated technology does not exist. Such capability would be transformative, revolutionizing the way Army generates energy, cleans up waste, and sustains operations. This same approach could be extended to manipulation of the human microbiome, providing soldiers with enhanced capabilities such as added protection from toxins or ability to metabolize new substrates.

economic pressures that China will face to support its growing population, they may continue to invest in biotechnologies like synthetic communities to reap some of the benefits that were outlined above. It is unlikely that this technology could be improved with off-the-shelf components. However, because of the exchange of ideas and materials in scientific academia, it may be possible to advance quicker than anticipated.

CHALLENGES

There are a number of technical barriers to overcome for ecosystem in a box to become a reality. More basic research is needed for non-model environmental microorganisms. Novel technologies are needed to interrogate microbial communities, specifically the ability to create knockout communities where microbial community components are selectively removed and then added back to a community system. New predictive computational biological models are needed that can accurately reproduce microbial community dynamics and function over space and time. This effort would have to be carefully directed and monitored so as to avoid some of the present day concerns regarding GM and Geoeengineering. Synthetic communities have the potential to adversely impact normal biosphere function and as a result these systems would have to be contained. The US is a leader in biotechnology and will continue to dominate, however China is making significant investments in this area as well. Because of the



INNOVATION

Synthetic portable ecologies could be formulated to provide energy, cleanup contaminants, restore

ODASA (BAT) | SME IDEATION EXERCISE

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24



- Background

- Integrates 14 S&T Forecasts by government agencies in the US and UK, industry leaders, international institutions, and think tanks
- Covered trends over the 2015-2045 time frame

- Key Takeaways

- Data revealed 20 common emerging S&T trends and 3 cross-cutting non-S&T Trends
 - 14 “core” S&T trends with potential for significant impact for Army operations
 - 6 additional trends with potential for moderate impact for Army operations
 - 3 non trends: tensions over privacy, impacts of climate change, rise of China as technological rival





S&T Themes

- Autonomous Systems
- 3D and 4D Printing
- Analytics
- Human Augmentation
- Mobile and Cloud Computing
- Future Medicine
- Cyber
- Energy
- Changing Nature of Work
- Internet of Things
- Food and Water Technology
- Quantum Computing
- Social Technologies
- Directed Energy
- Education
- Materials
- Synthetic Biology
- Interface
- Transportation and Logistics



Example Card



Food and Water Technology

Over the next 30 years, access to food and water will become a crucial driver of global tension and technological innovation. Population growth and climate change are putting pressure on food production and fresh water supplies. Drought is already affecting access to drinking and irrigation water in many parts of the world, causing ripple effects across many unstable regions. Roughly 25% of current farmland is already degraded from overfarming, drought, and air/water pollution. Under optimistic forecasts, prices for staple grains could rise by 30% over the coming decades. Food and water, long taken for granted in the developed world, will become a major priority for innovation, and could become a major flashpoint for conflict.

36% Concurrence

4% Share

ENABLING S&T



Transgenic Crops

Splicing genes from one plant species into the DNA of another species can provide crops with new traits such as drought tolerance, the ability to fix nitrogen from the air, and pest/disease resistance.



Precision Agriculture

Technologies like robotic automation and micro-irrigation, which improves water delivery to crops by 32-95% will make farming more resource efficient and productive.



Water Technology

In addition to improved desalination technology, development is underway on filtration systems that can produce potable water from greywater sources.



Alternative Food Sources

Closed-system hydroponics, vertical urban farms, and other new technologies are enabling crops to be grown without access to arable land.

SIGNALS



"BoniRob" is a lightweight agricultural robot being developed by German firm Amazone. BoniRob is capable of working in swarms to complete common farming tasks such as weeding and fertilizer application.



Scientists at Kansas State University are working on a heat-tolerant strain of wheat that could increase yields in hot regions by up to 35%



A UK-based team of engineers has developed a low-cost, portable desalination technology powered by renewable energy. The Desolanator used solar energy to desalinate up to 15 liters of water per day. Each unit costs around \$450 and is designed to operate for up to 20 years.



Today, the world's poor get by on 5-10 liters of water per day, while members of the global middle and upper class use 50-150 liters daily.

IMPACT



Social

Food and water are essential to human life, and disruptions to these vital resources could prompt erosions of trust in civil governments, rioting, and hoarding.



Political

Resource management is likely to become an important focus for domestic and international politics.



Economic

Food and water shortages could worsen economic instability and exacerbate class divisions.



Environmental

Genetically modified organisms (GMOs) have the potential to boost agricultural yields. However, the environmental impact of GMOs is uncertain.



Defense

Food and water crises represent dangerous flashpoints for conflict. Some of the world's poorest regions are the most vulnerable to food and water shortages. Food and water infrastructure could become a critical target for future adversaries.

Without mitigation, by 2045 or sooner, around 3.9 billion people – over 40% of the world's population – are likely to be experiencing water stress.

UK Ministry of Defense (MoD2013)

In the future, geopolitical tensions over access to strategic water resources could become more systemically impactful, and water shortage coupled with poverty and societal instability could weaken intra-state cohesion.

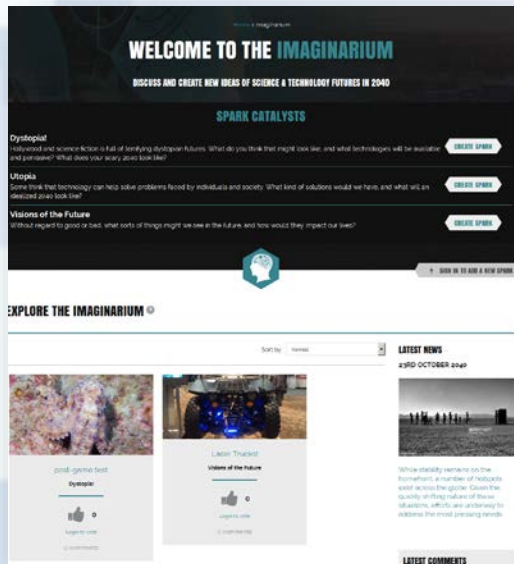
World Economic Forum (WEF)

Transgenic technologies—which enable the transfer of genes from one plant species to another to produce a plant with new or improved traits—hold the most promise for achieving food security in the next 15-20 years.

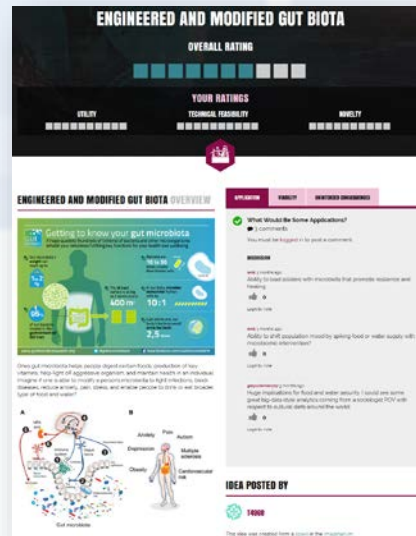
National Intelligence Council (GT2030)

Online Ideation Exercises

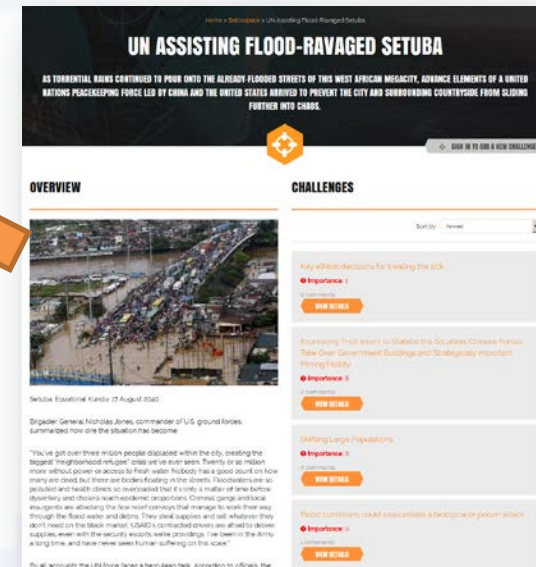
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Imaginarium



Workshop



Battlespace

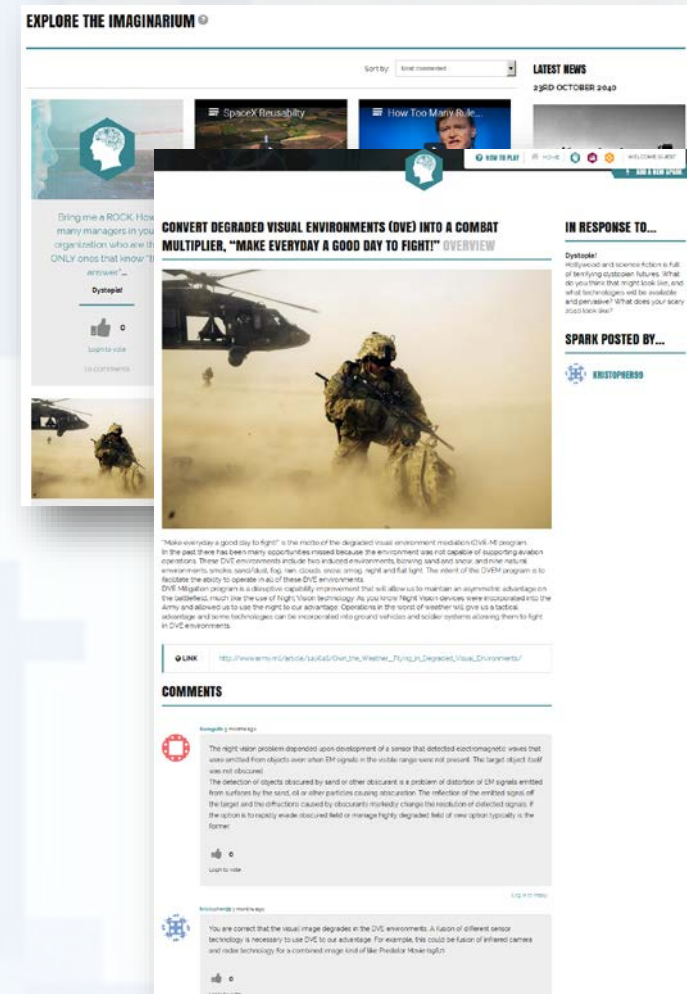
Imaginarium

Purpose

- Place to offer quick ideas about future trends, technologies or capabilities
- Minimum of title and short description; images, links, or video encouraged
- Meant to be light, quick, and easy to read (e.g., Pinterest)

Results

- 43 Sparks submitted and covered a wide variety of topics
- 83 comments submitted on those 43 sparks



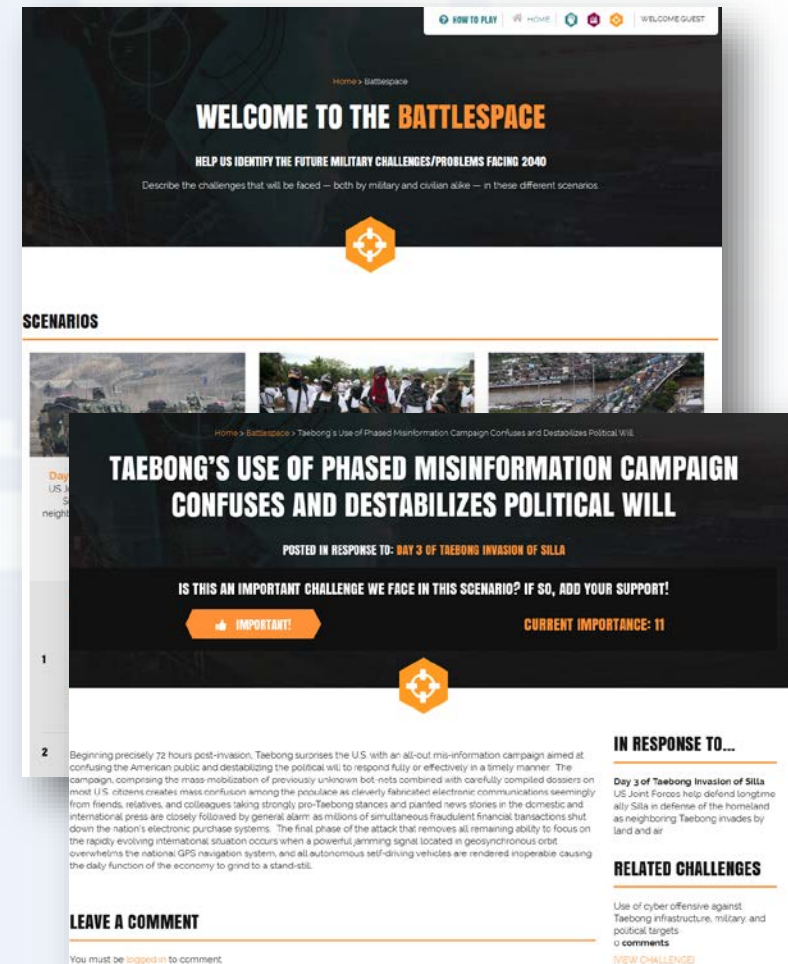
Battlespace

Purpose

- Lists scenario-based news stories in style of an online news outlet (e.g., BBC, CNN)
- Three fictional but realistic scenarios:
 - Narcowarfare in South America
 - Ground war in Asia
 - Environmental disaster in Africa
- Players apply workshop ideas against the scenario
- Players fill in what they see as difficult challenges. Updates can be tagged as “important”

Results

- 28 total challenges
- Top rated challenge “...Use of Phased Misinformation Campaign Confuses and Destabilizes Political Will”



Purpose

- Intended focus area for participants to debate/vet/discuss potential Army capabilities
- Ratings used to get quick numerical sense of participants Comments in free form or based on Application/Viability/Unintended Consequences
- Ideas promoted from sparks or submitted direct to workshop

Results

- 31 ideas and 28 Workshop Challenge Questions answered

The screenshot displays a workshop interface for 'ENGINEERED AND MODIFIED GUT BIOTA'. It features a 'HOW TO PLAY' section, a 'WELCOME QUEST' section, and a 'LATEST COMMENTS' section. The main content area shows a 'YOUR RATINGS' section with three categories: UTILITY, TECHNICAL FEASIBILITY, and NOVELTY, each with a set of five bars for rating. Below this is an 'ENGINEERED AND MODIFIED GUT BIOTA OVERVIEW' section with a 'GETTING TO KNOW YOUR GUT MICROBIOTA' infographic. The infographic includes statistics such as '100-300 Billion bacteria in your gut', '10:1 ratio of bacteria to human cells', and '400m² surface area'. It also lists 'Benefits of gut microbiota' and 'Challenges of gut microbiota'. The 'IDEA POSTED BY' section shows a post by 'T4998' with a comment about 'Huge implications for food and water security'.



Technology Wargaming Ex4 Infographic

EX3 Infograph sent to participants

ARMY S&T IDEATION EX3

REGISTER A NEW ACCOUNT

46%

CONVERSION RATE
86 accounts
40 active players

TOP USERS

Most well-rounded: **sliphery**

- Led Spark creation - 8 sparks
- Led Challenge creation - 3 Challenges
- Submitted 5 Ideas
- Submitted 6 Comments

Top Idea creator: **T4968**

- 11 Ideas

Top Commenter: **Paumanok**

- 25 Comments

IMAGINARIUM

43 SPARKS
83 COMMENTS

BATTLESPACE

28 Total Challenges 25 Comments across all challenges

- 9 Challenges for Taebong Invasion of Silla
Top Rated with 11 votes: "Taebong's Use of Phased Misinformation Campaign Confuses and Destabilizes Political Will" by MVP user "sliphery"
- 5 Challenges for San Madora Cartel War
Top Rated with 8 votes: "Out of Desperation, San Madoran Government Unilaterally Legalizes Drug Production, Distribution, and Use"
- 7 Challenges for Setuba Flood
Top Rated with 8 votes: "Expressing Their Intent to Stabilize the Situation, Chinese Forces Take Over Government Buildings and Strategically Important Mining Facility"

WORKSHOP

31 Ideas
17 Comments
28 Workshop Answers:

- 6 answers for "How realistic is this to happen by 2040?"
- 11 answers for "What Are Some Unintended Consequences?"
- 11 answers for "What Would Be Some Applications?"

125

TOTAL COMMENTS

COMMENTS UPVOTED

35

MOST REALISTIC: 3D PRINTED BUILDINGS

Buildings would contain all systems required by a relocated or refugee population with water, sewage, electrical, air handling, foundations, and shelter systems. System would be able to produce multiple shelter in rapid succession to address need. Other robotic systems would lay infrastructure like pipe, electrical, and roads.

MOST INVENTIVE: SPACE BASED LIGHTING

With the democratization of space delivery systems, the Army could use a space-based reflector to redirect a small percentage of the light down to earth to illuminate a specific location. A number of uses, from increased sunlight exposure for agriculture, to illumination for crowd control could be envisioned, to search and rescue operations for a downed pilot, to a non-lethal tool for disrupting enemy operations (a wide-area flashbang).



EX3 Concept Art from crowdsourced ideas

EX3 Concept Art from crowdsourced ideas



SME Driven Ideation

- Play by email ideation using engineers and scientists from the Army's research and development community
- Each SME provided 5 S&T trends and 5 socio-political trends and asked to generate a new idea for a technology combining two or more trends
- Intended to induce new ideas using constrained inputs to think beyond cognitive biases and produce creative ideas

Green Death: Entomological Warfare

Energy • Sustainable Cities • Demographic Patterns • Global Inequality • Constrained Budgets • Climate Change

OVER the next 30 years urban footprints grow and the majority of the world's population will live in urbanized areas. Transportation of resources will become increasingly difficult and costly, exacerbated by the depletion of natural resources. Cities will become increasingly sustainable with large dependence on engineered plants/vegetation that will be specialized to "indigenous" zones. Plants will be critical to sustained air quality, food, water as well fuel. Industry will drive innovation and resistance to natural pests will be a common, with advancements towards increasing efficiency of growth and performance. Our understanding of plant genetics will continue to advance. Similarly synthetic biology will advance to create highly specialized insects that can target and feed on plants and vegetation. The more engineered plants are, the more costly, creating a structure that correlates with trends in global inequality that could be exploited to further exacerbate political and social tensions through targeted entomological warfare leading to civil unrest.

CHALLENGES
Potential adversaries could have some technology. It could be p engineers and propagate resist however, if highly specialized to environment, this may not have long to social/ethics of genetic safety are clearly a concern if it properly.

INNOVATION
This technology would prevent adversary overmatch through protection against pest generation bio warfare. In the event of offensive capabilities, one would have a unique advantage over adversaries not possessing this protection. This capability could be used to further exacerbate political and social tensions through targeted entomological warfare leading to civil unrest.



COAS&A (R&T) | SME IDEATION EXERCISE

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Accurate 90-Day Micro-Weather Forecast

Internet of Things • Mobile & Cloud Computing • Individual Empowerment • Climate Change

By 2045, mobile devices will be a staple across the globe, will be laden with sensors, and will have a complete capacity similar to that of today's supercomputers. Army mobile communication will be in lock-step with commercial capabilities (i.e. will overcome its current 15 year technology gap) and will use a transparent rather than trusted supply chain to ensure the technology is affordable and can be rapidly updated. Mobile device sensors will be used to collect weather data and will publish that information to a tactical cloud computing capability. The tactical cloud will have reach back to larger supercomputers in CONUS, which will provide 90 day 99% accurate micro-weather forecasts at a resolution of 0.01 square kilometers in 10 minute increments; the tactical cloud, 10 day forecasts in 30 minute increments; the off-line mobile device, 10 day forecasts in 1 hour increments. In off-line mode, the latter will produce forecasts based on the last information downloaded from the tactical cloud and a history of observations gathered by the mobile device itself.

CHALLENGES
In exchange for posting tagged data, this local cloud capability will distribute 10-day weather forecasts to the participating mobile devices. These forecasts will be 99% accurate to one square kilometer of resolution in one-hour increments. Businesses which greatly depend on the foreknowledge of weather (e.g. hotels, airlines, cruise ships) will be able to buy an enhanced service - a 30-day weather forecast accurate to one square kilometer in 30-minute increments. The private mobile device data collected by participating private local clouds will be forwarded to the Army.

INNOVATION
The Army's tactical cloud capability will be able to discern the nature of the observation (e.g., whether the device is indoors or outside, in shade or in direct sunlight; where the device is located via GPS) in order to tag the data appropriately for assimilation with information reported by all participating private mobile devices to a local cloud computing capability.

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COAS&A (R&T) | SME IDEATION EXERCISE

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City Scape

Analytics • Mass Urbanization

City Scape is a collection of sensors and analytics that enable a real time view of living entities at a city-level scale. Data collected includes position and simple biometrics for each entity that enable tracking individuals through complex multi-story building structures, and over large areas. City Scape tracks millions of entities using a combination of overhead and localized sensors combining technologies that do not exist today but imagine combining GIM, ground penetrating radar, and radiation imaging or radio signals/nuclear sensors, and inert materials in water that accumulate in living organisms like memory in fish giving a 3D image with bio signs that can be logged over time to characterize the behavior and location of individuals. This data is used to identify threats and potential collateral damage to a location and empowers soldiers to more safely control challenging urban situations, and act decisively.



CHALLENGES
The ability to view entities through buildings on a large scale does not currently exist. If it did exist, it would be a significant tactical advantage, but would require likely a major investment in infrastructure to be put in place making it more difficult for adversaries to implement. Small-scale implementations might be possible. Techniques for avoiding detection, manipulating data, and taking biometrics would be likely threats to success.

INNOVATION
As population increases and people move into larger mega-cities the density of people provide an environment where tactical and enemy forces will be entrenched in close proximity with large numbers of noncombatants in locations where traditional kinetic attacks are infeasible without significant collateral damage. This will place an increased emphasis on loitering on-the-ground and door-to-door operations, which place our troops in significant risk in environments where the adversary has a significant advantage. The ability to monitor situations at stand-off distances and only engage with extreme precision and high confidence attacks.

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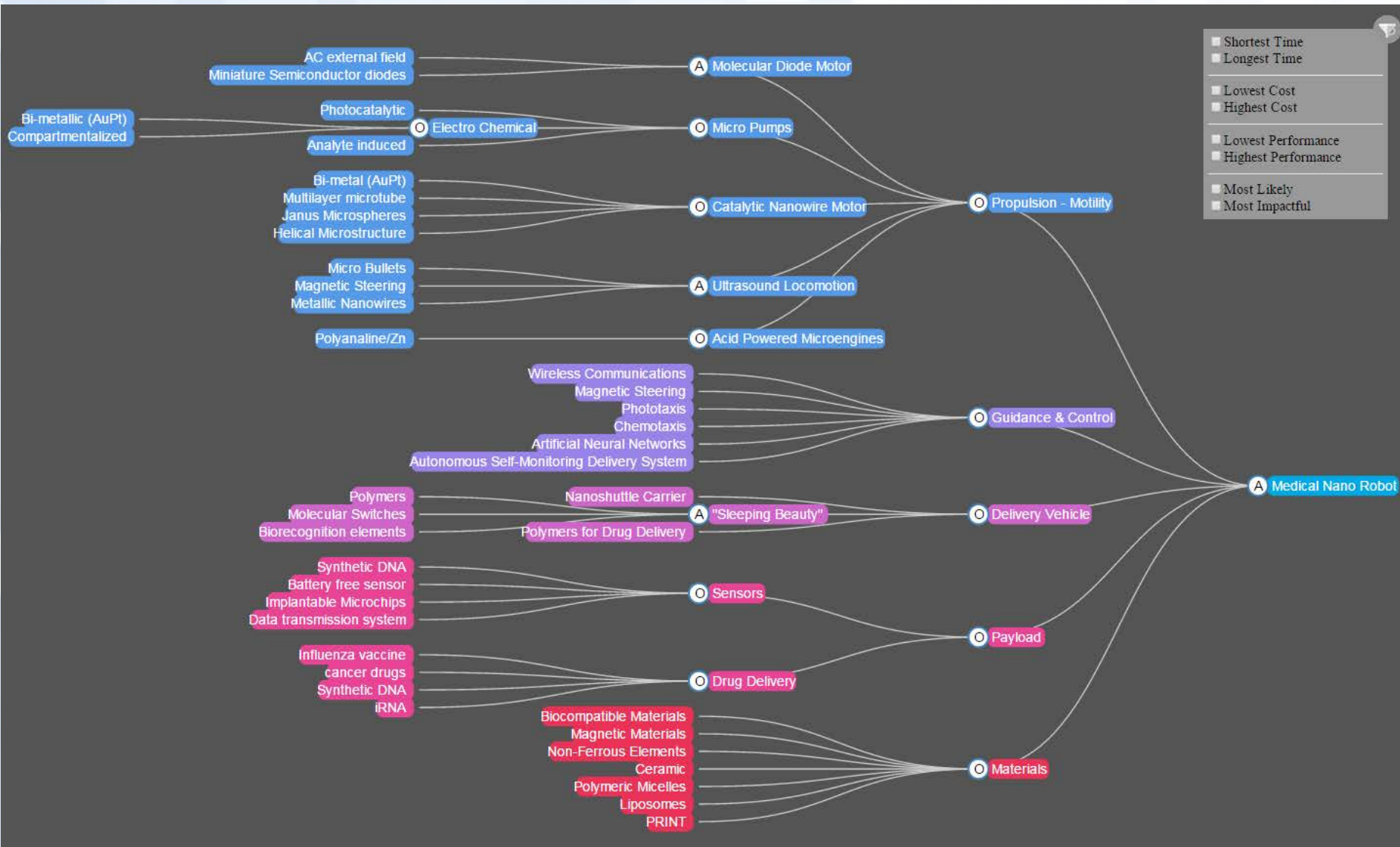
COAS&A (R&T) | SME IDEATION EXERCISE

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Backup



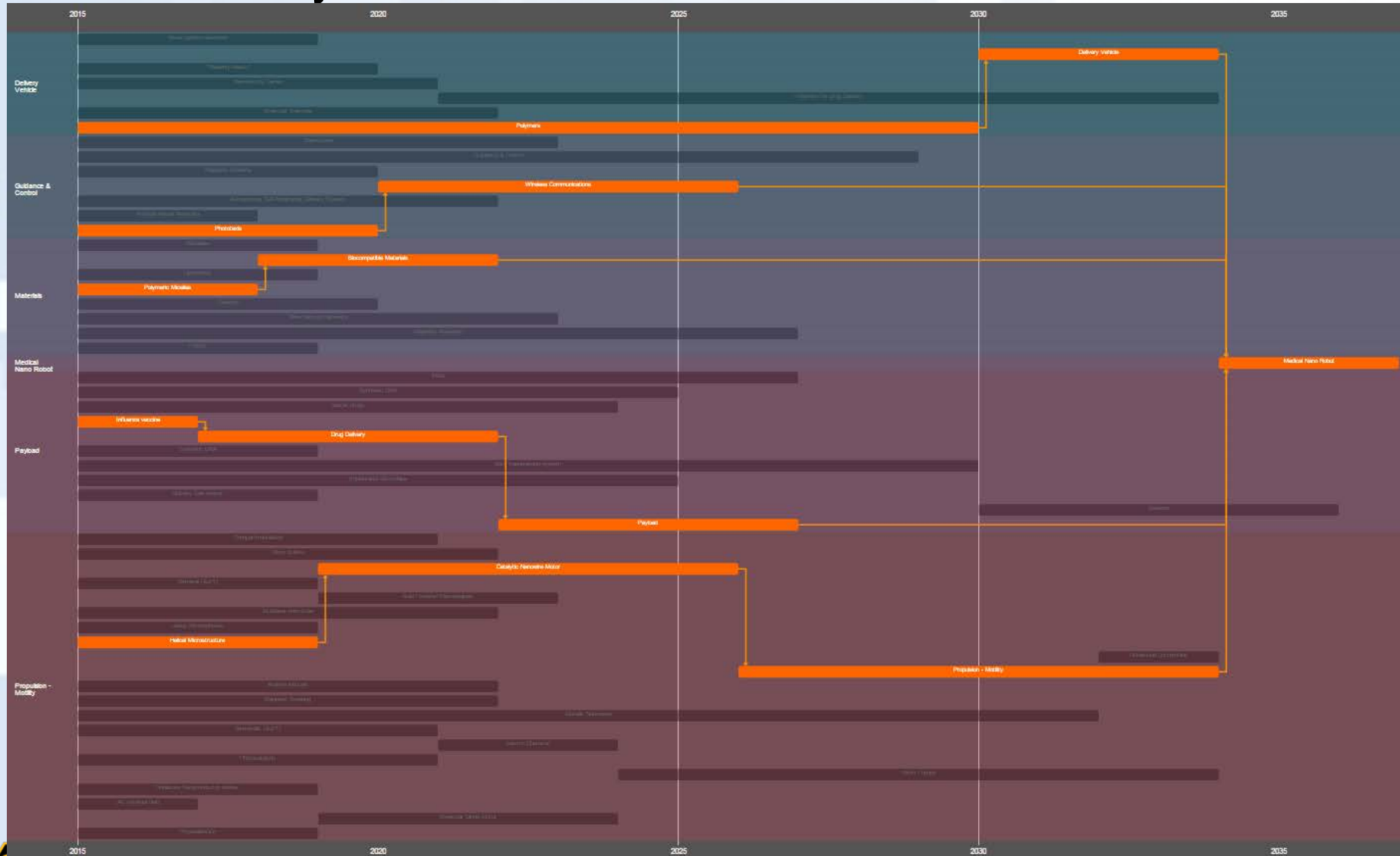
Medical Nanites TSA System View





Medical Nanites TSA Timeline View

- Most Likely Path - 2038





Nanite TSA Research Data

Name	Position	Affiliation	Background
Dr. Mark Davis	Prof. Chemical Engineering	Cal. Tech	Nanoparticle therapeutics; nanomedicines
Dr. Andrew Ellington	Prof. Biochemistry	Univ. of Texas	Molecular Biosciences; DNA research
Dr. Shana Kelley	Prof. Chemistry	Univ. of Toronto	Electrochemical nucleic acids; Microchips; Ex vivo clinical diagnostics
Dr. Yamuna Krishnan	Prof. Chemistry	Univ. of Chicago	Synthetic DNA devices; DNA nanomachines
Dr. Sylvain Martel	Assoc. Prof. Computer Engineering	Montreal Polytechnique	Remote microsurgery; nanorobotics; drug delivery to combat cancer
Dr. Ayusman Sen	Prof., Chemistry	Penn St. Univ.	Nano and micro pumps and motors; Chemical catalysts as motors
Dr. Alexander Stengh	Asst. Prof. Neurology	Northwestern Univ.	Geneticist; investigating novel brain cancer treatments; iRNA research
Dr. Bill Tang	Biomedical Engineering Dept.	Univ. California, Irvine	Remote in vivo diagnostics; micro-implantable devices
Dr. Orlin Velev	Prof. Chemical and Biomolecular Engineering	North Carolina State Univ.	Innovative colloidal materials; Nanostructures wth electrical and photonic functionality
Dr. Szu Wang	Prof. Materials	Univ. California, Irvine	Fabrication of functional nanostructures; development of novel polymers
Dr. Albert Yee	Prof. Chemical Engineering and Material Science	Univ. California, Irvine	Materials science - polymers and nanotechnology

- Preliminary Publication/Patent Research:
 - Search term: ((nanite* OR nanorobot* or nano*) AND medic*)
 - 16162 publications, 36 patents



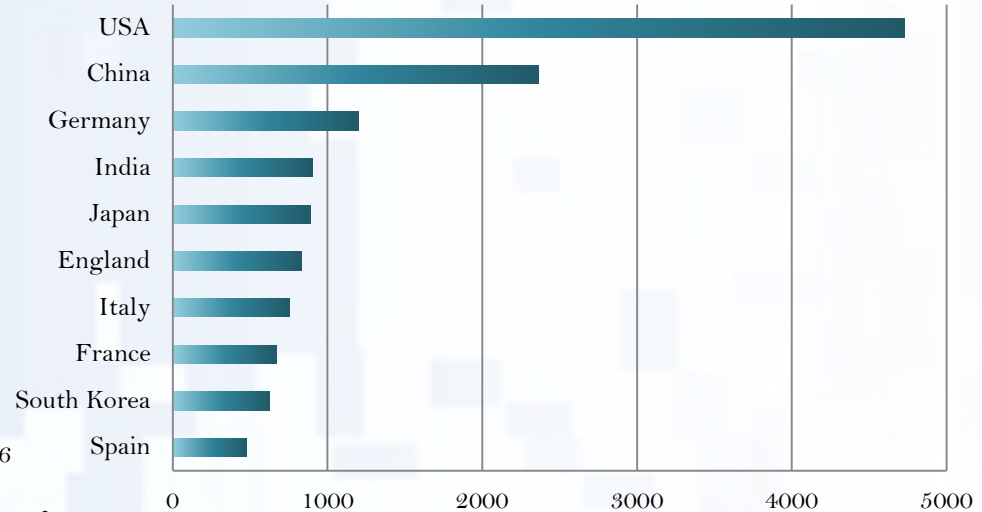


Nanite TSA Data Visuals

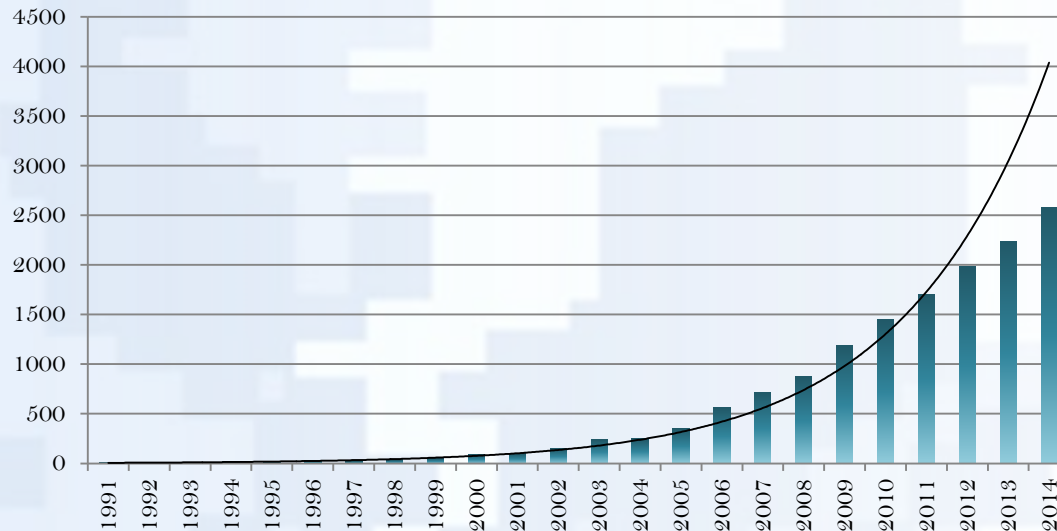
Patents Over Time



Top Research Countries By # of Publications



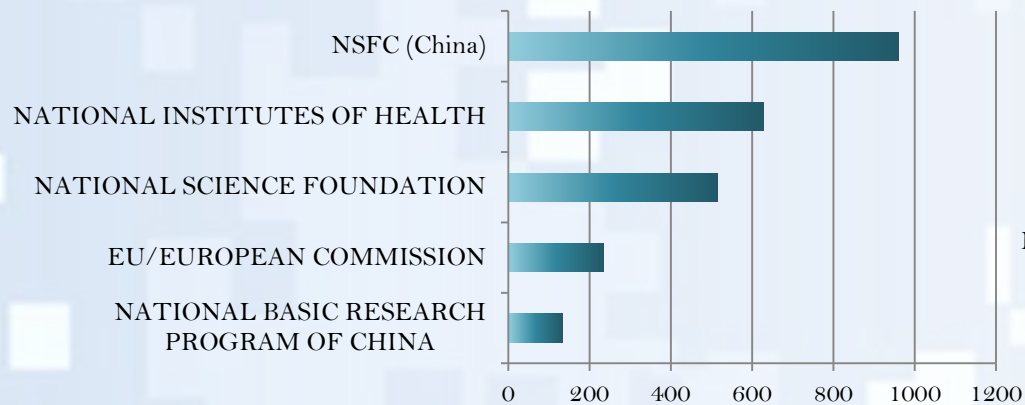
Publications Over Time



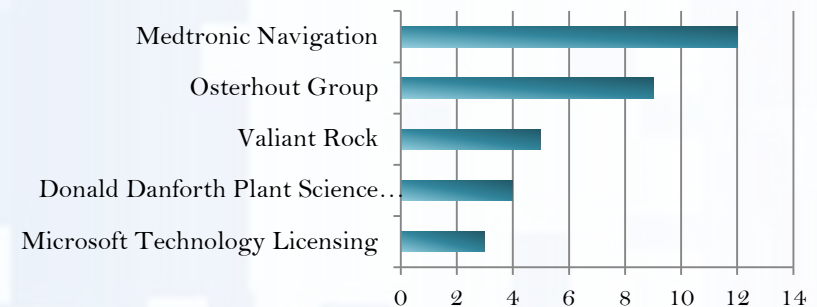


Nanite TSA Data Visuals

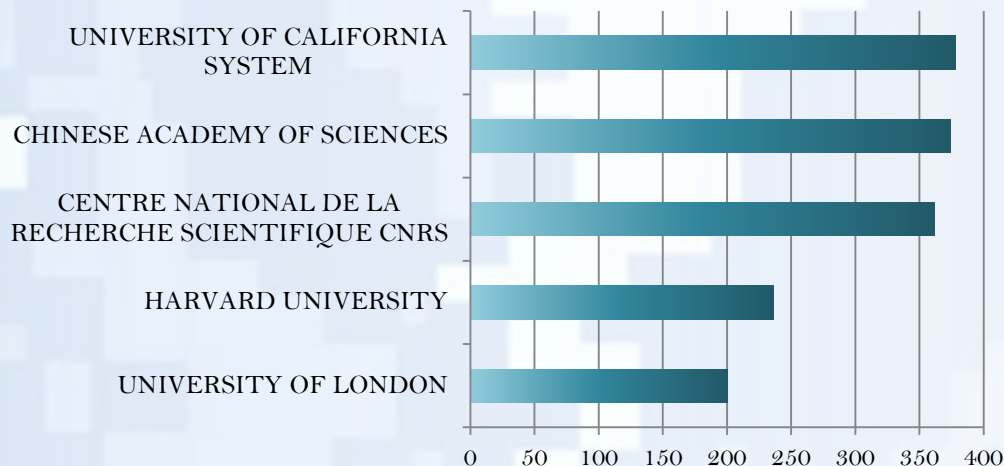
Top 5 Funding Agencies by # of Publications



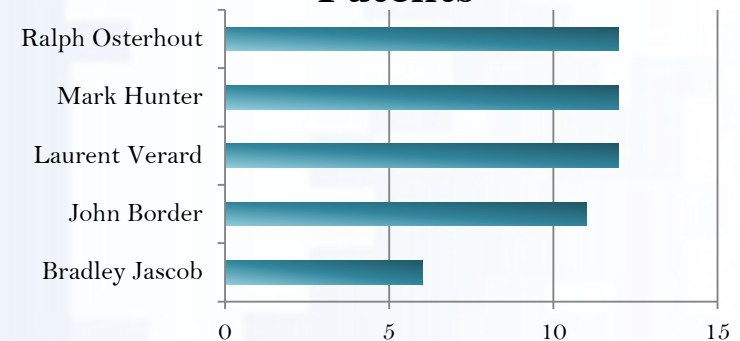
Top 5 Assignees by # of Patents



Top 5 Research Organizations by # of Publications

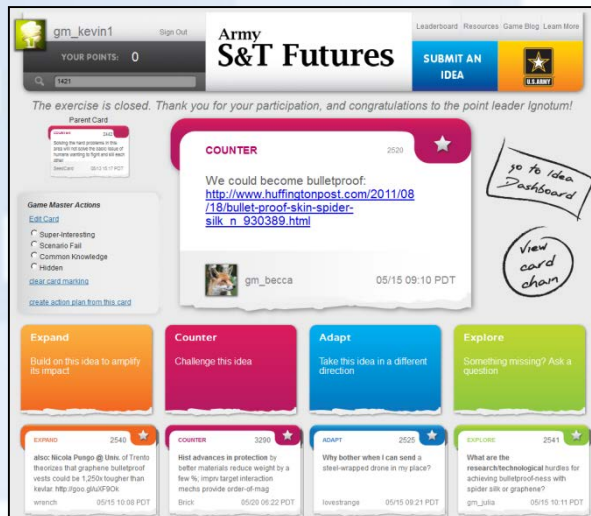


Top 5 Inventors by # of Patents

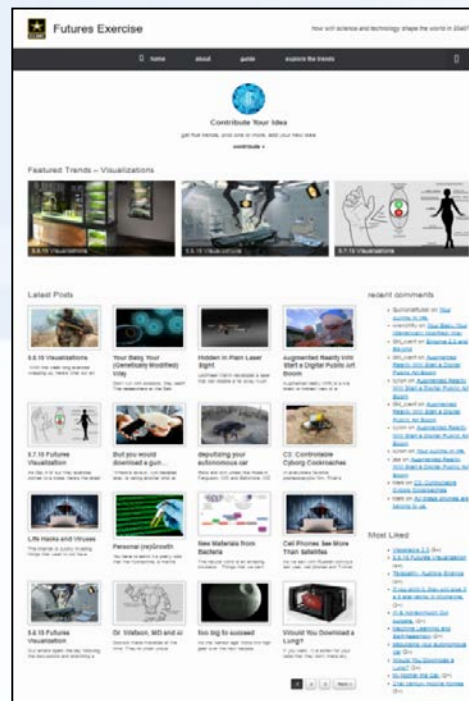


Crowdsourcing/Ideation Platform

Purpose: Provide an intuitive platform for engagement of “non-traditional” technical, tactical, and creative communities not normally involved in the Army S&T planning process



2014 - MMOWGLI



2015v1.0 – Blog Style



2015v2.0 – Ideo Style



Video

Link to Background Video

<https://vimeo.com/126458402>

Link to site

<http://futures.armyscitech.com>

