Megatrends Reshaping C2
&
Implications for S&T Priorities

17th ICCRTS
Paper 066

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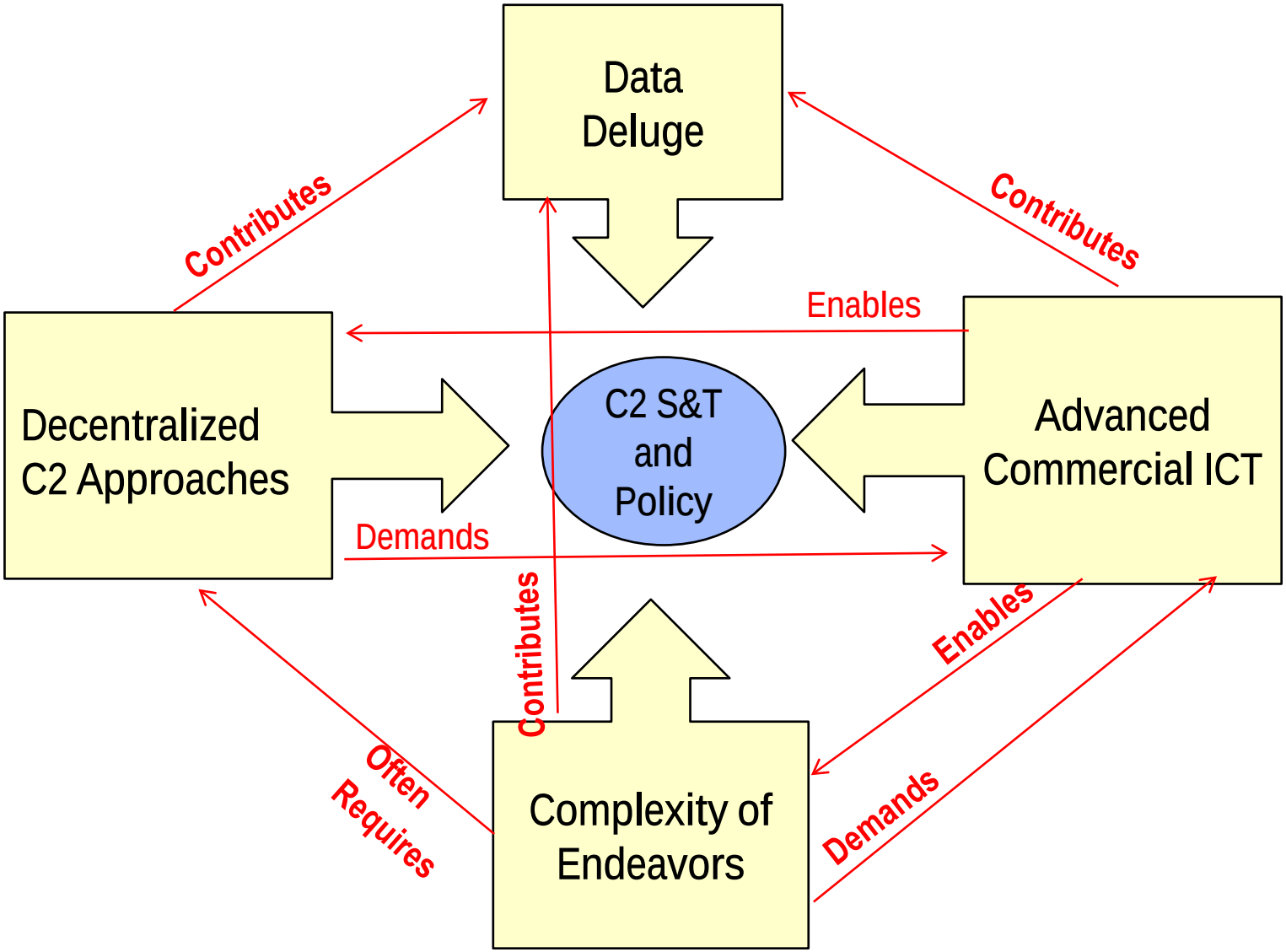
C2/C4ISR Sits at the Nexus

- C2 (C4ISR) sits at the nexus of multiple cutting-edge technologies:
  - Information processing
  - Information sharing & Collaboration
  - Network science
  - Social networking
  - Multimedia
  - Ubiquitous computing
  - Wired, Wireless, & Satellite Communications
  - Sensors
  - Imaging
  - Underlying electronics
  - ……
- C2 (C4ISR) is uniquely impacted by the technological revolution of the past 2 decades

http://www.oldthinkernews.com/wp-content/uploads/2010/12/technological-revolution.png

Megatrends Reshaping C2



Megatrend #1

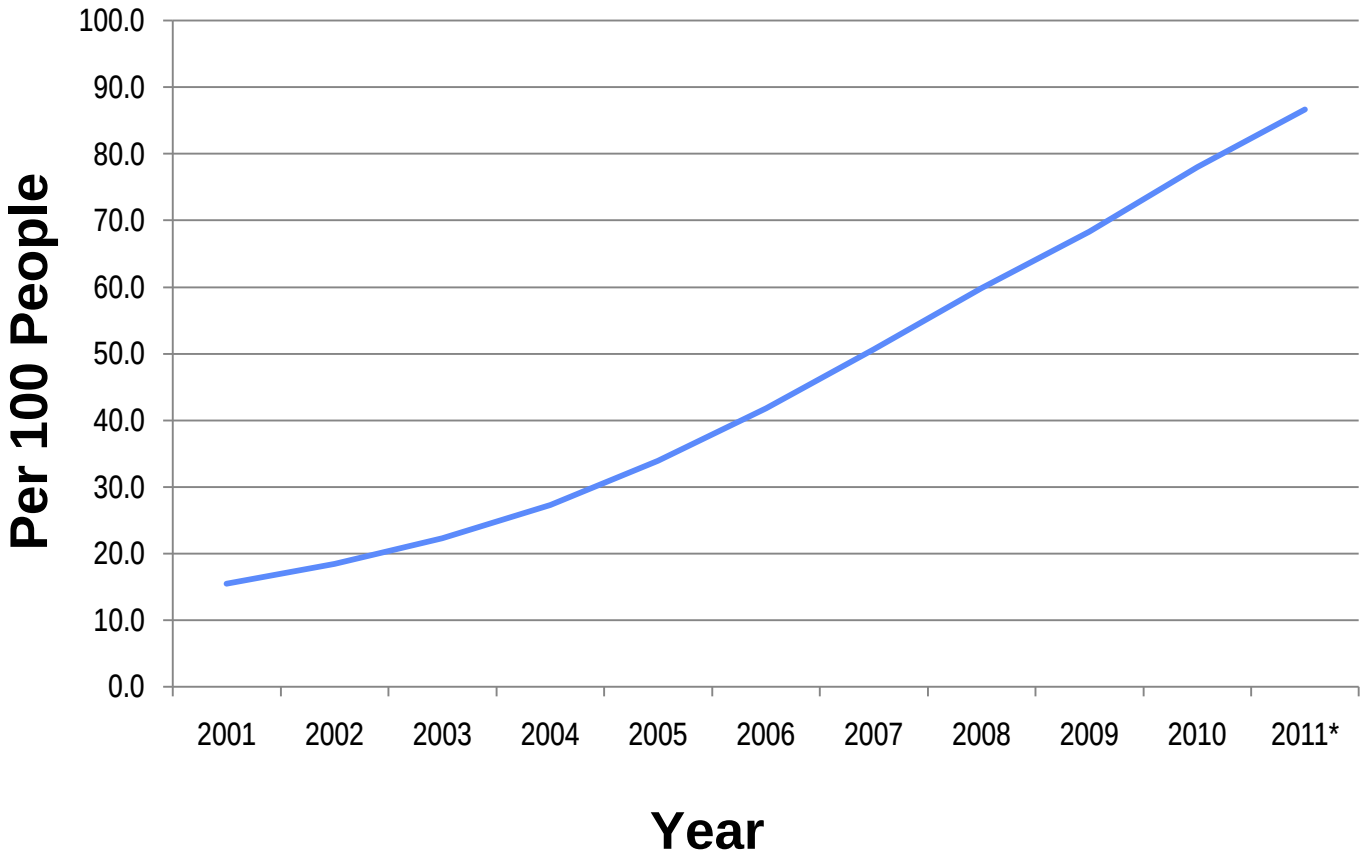
Advanced Commercial ICT

First, Consider Mobile Phones

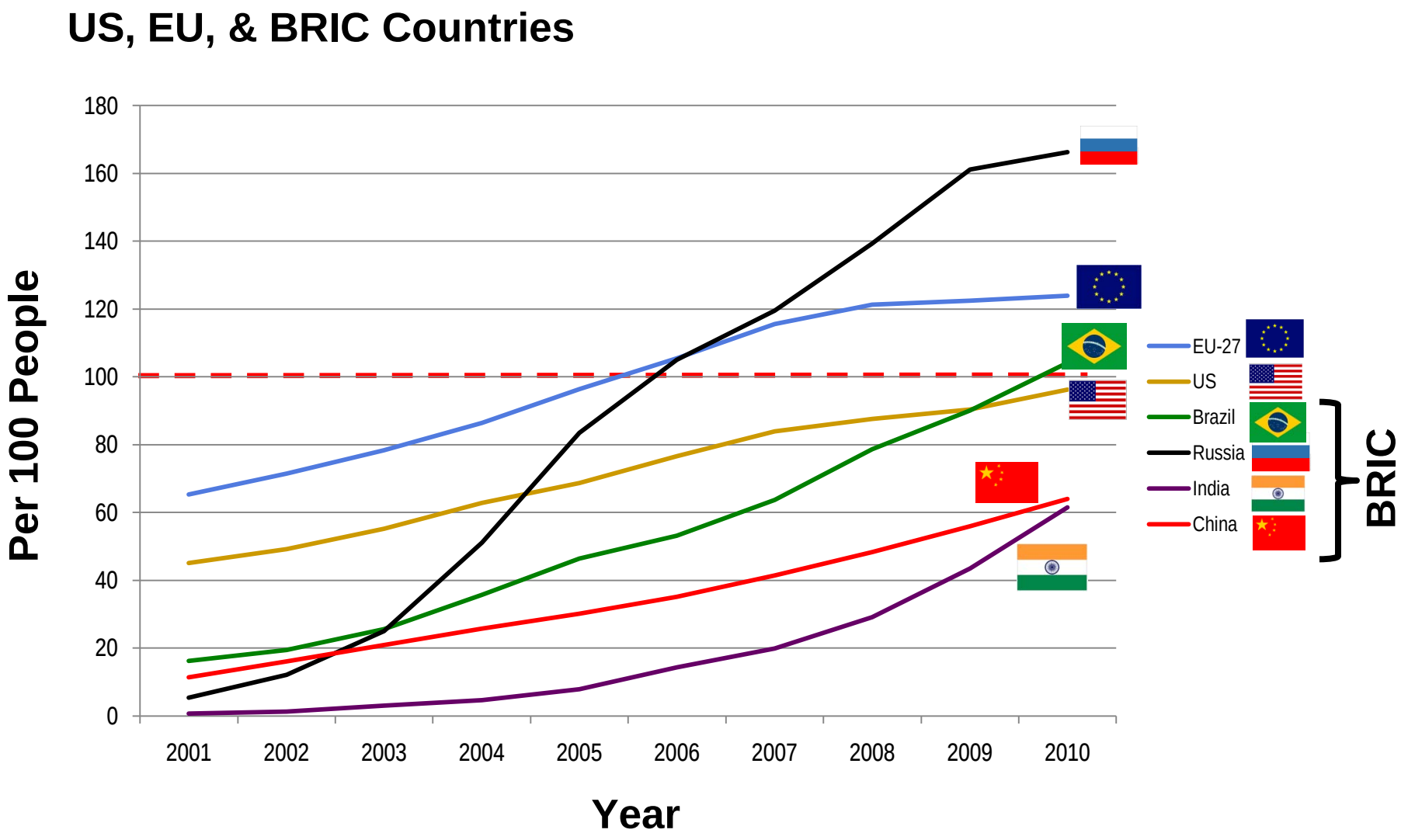
- A mobile phone embodies many of the most important technological and socio-technological trends of the past twenty years:
  - Powerful computing
  - Connectivity
  - Imaging
  - Digital Multimedia
  - Low price for advanced capability
  - Widespread diffusion
  - Extremely rapid progress

http://i52.tinypic.com/dy55ao.jpg

Mobile Telephone Subscriptions in the World

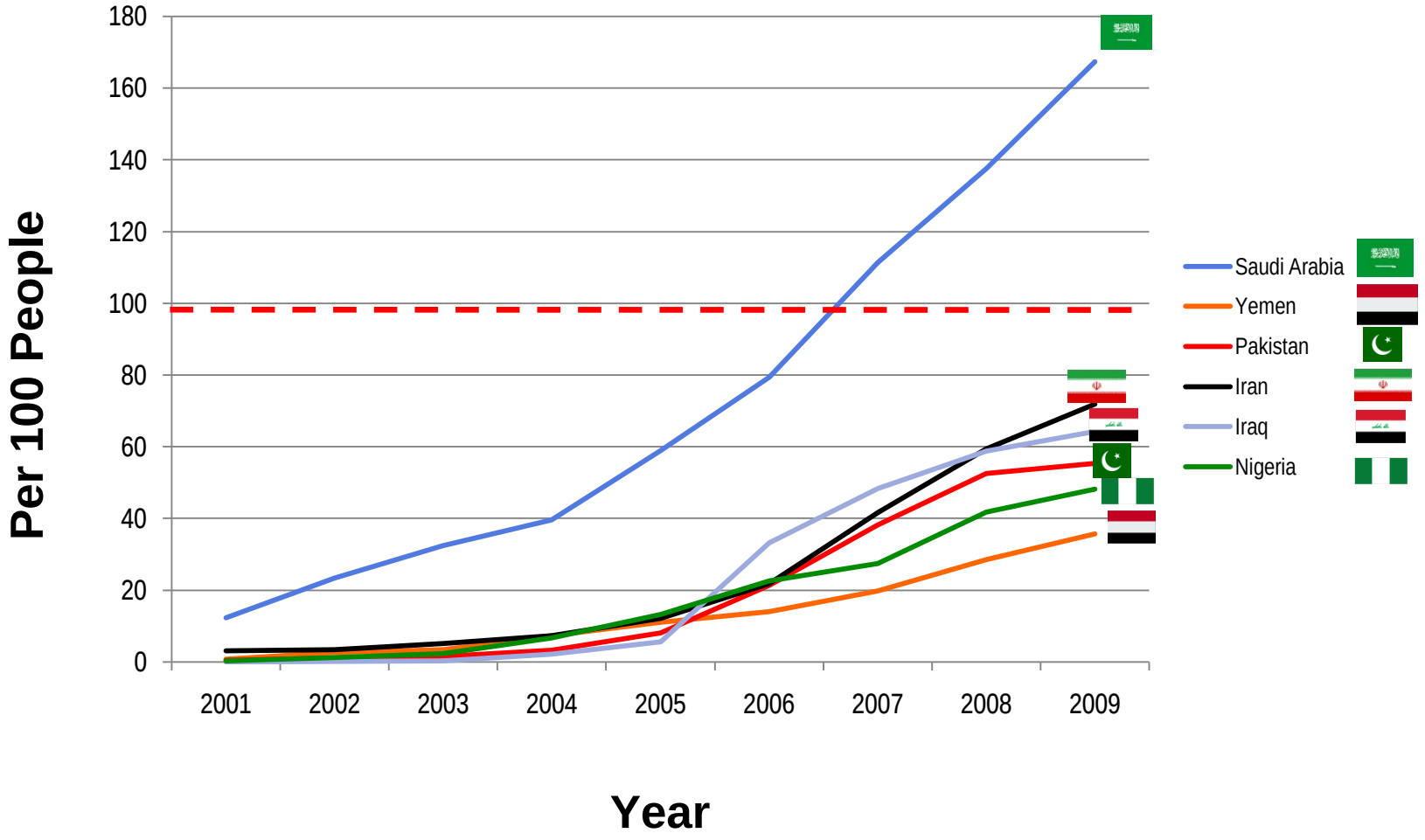


Mobile Telephone Subscriptions



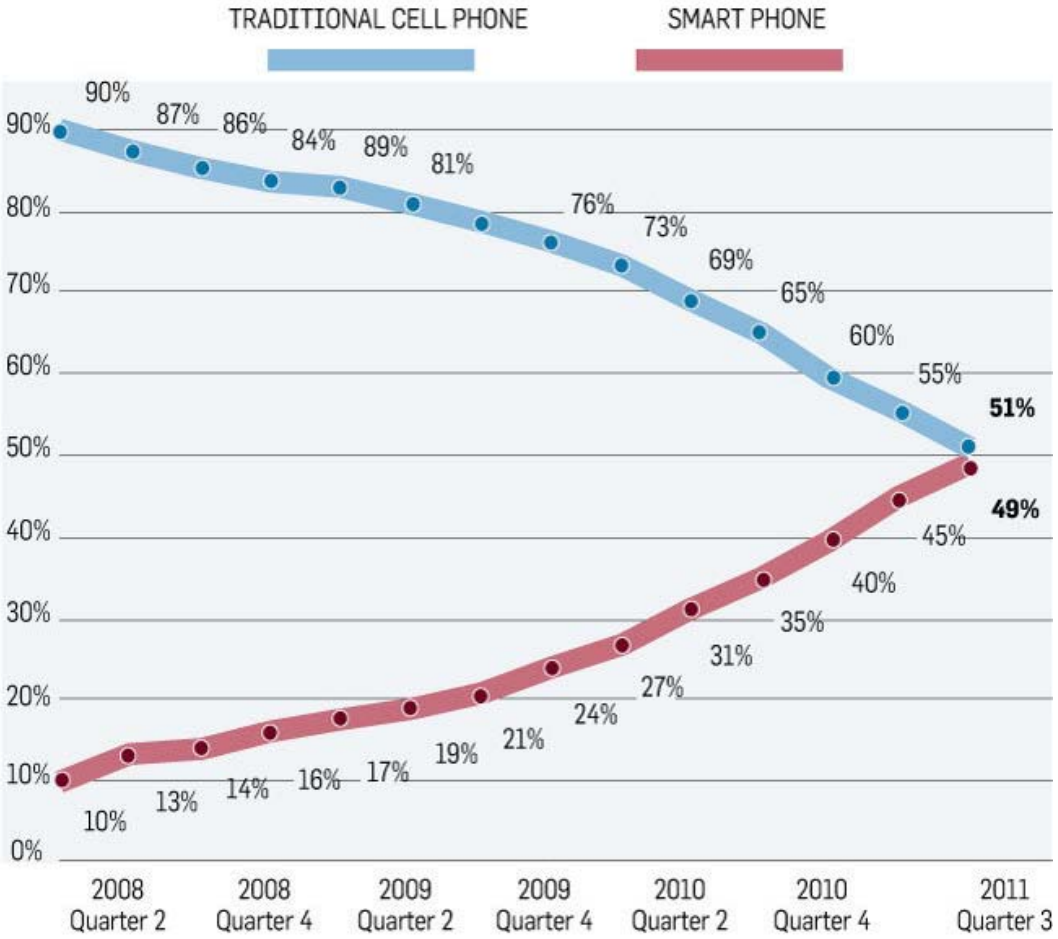
Mobile Telephone Subscriptions

Other Countries of Interest



Phones are also Increasingly Powerful

- Smartphones less than 10% of US market at start of 2008; nearly 50% by end 2011



http://media.nj.com/business_impact/photo/iphonesjpg-01a3c51253810e8e.jpg

- For *new* shipments, end 2011: Smartphones 65% in US, about 30% global

Phones are also Increasingly Powerful

3.4 MFlops

http://www.cisl.ucar.edu/computers/gallery/cray/images/cray1.jpg

- CRAY-1 Supercomputer, fastest in the world in 1979

258.7 MFlops

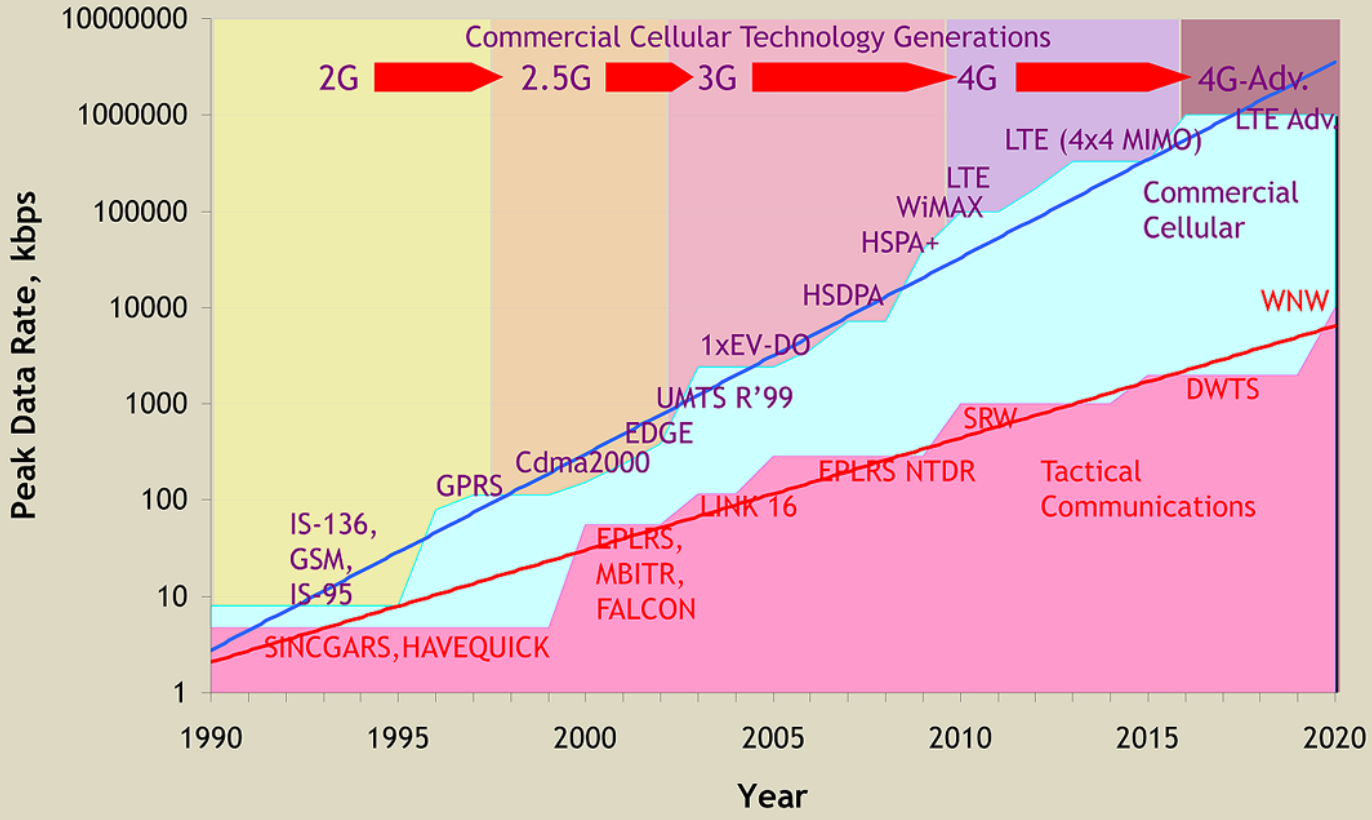
http://i52.tinypic.com/dy55ao.jpg

- LG P999 Smartphone, 2012

Greene Computing (2012). LINPACK Top 10. http://www.greenecomputing.com/apps/linpack/linpack-top-10/ - Retrieved 15 February 2012.

Dongarra, Jack (2007). Frequently Asked Questions on the Linpack Benchmark and Top500. ftp://www.netlib.org/utk/people/JackDongarra/faq-linpack.html - Retrieved 22 February 2012.

Commercial vs Military Wireless Data Rates

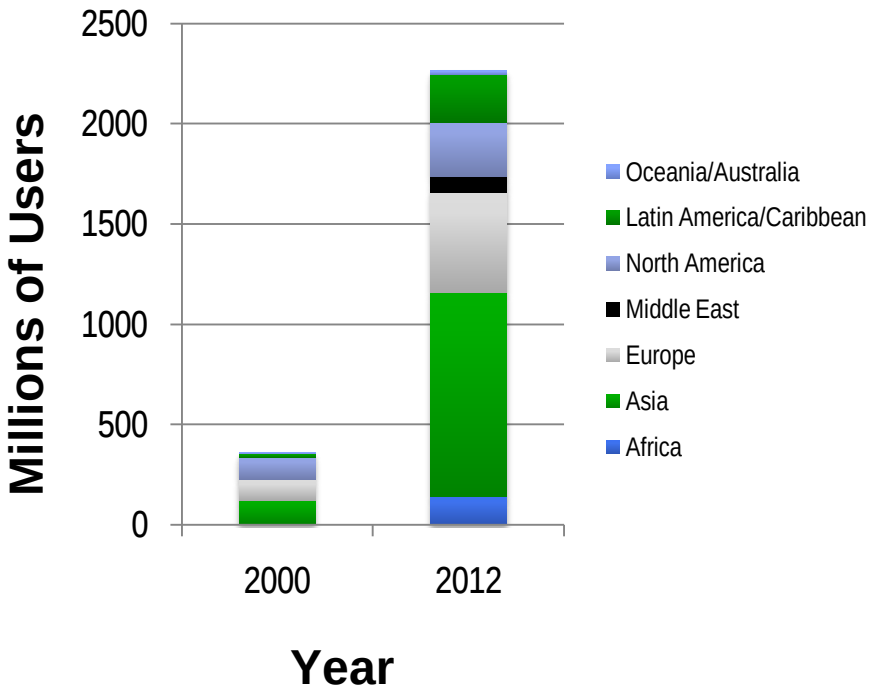


The Commercial Marketplace is Driving Innovation at an Accelerated Pace vs. the DoD market. The DoD should Leverage this Innovation More Effectively

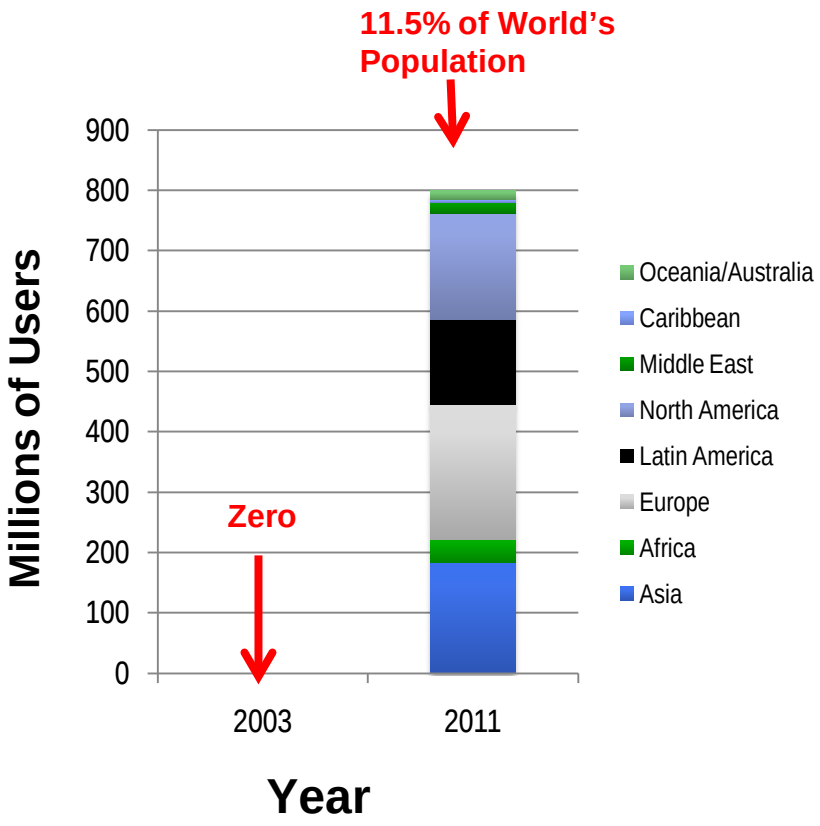
- From a presentation by General Peter Chiarelli ("VCSA's Thoughts") at AUSA ILW Winter Symposium and Exposition, 25 February 2010.

Internet

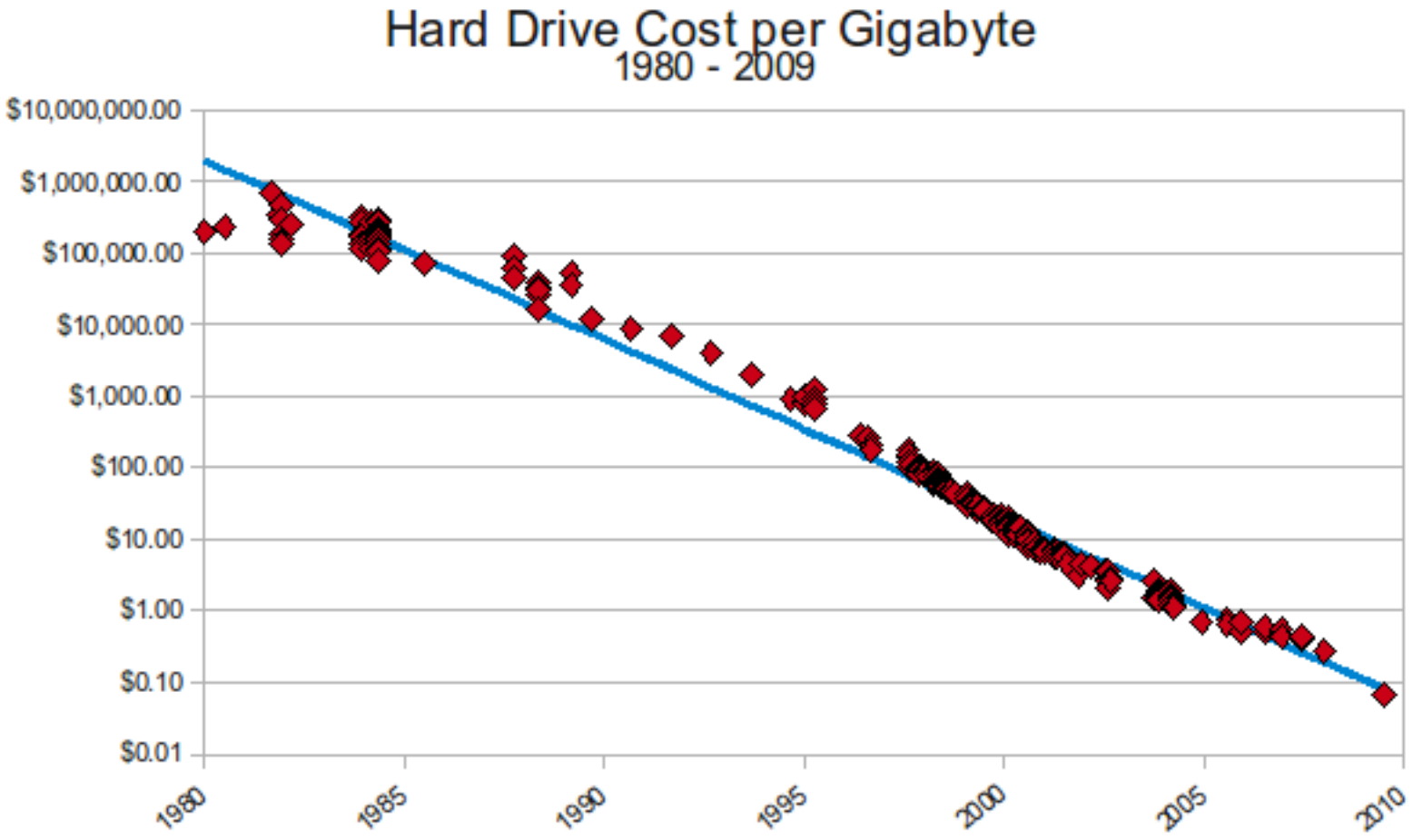
Internet Users



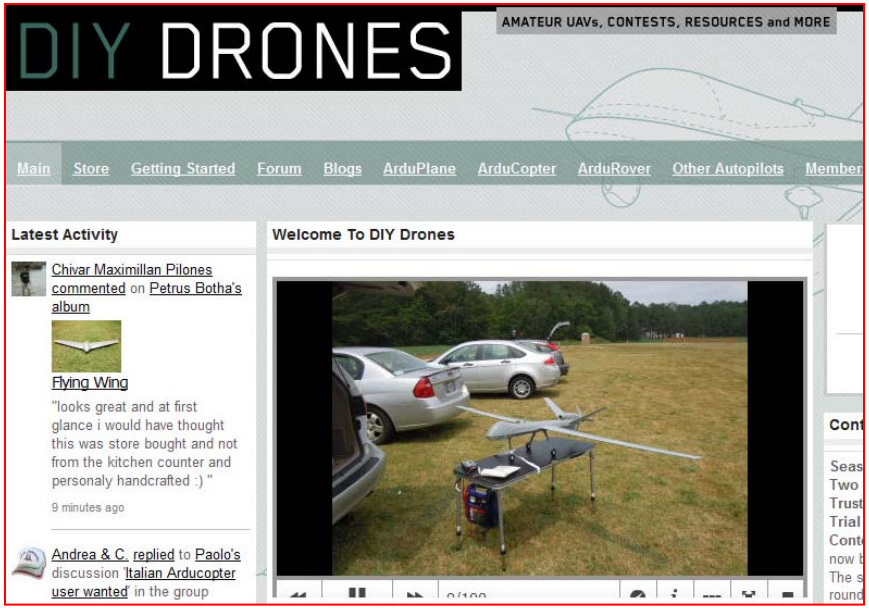
Facebook Users



Cost of Hard-Drive Storage



Personal UAV Drones



Full ArduPilot Mega kit (soldered, code loaded and ready to fly) from Udrones!
Price: $299.95 Buy at Udrones

The ArduPilot kit contains:

-The Arduino compatible ArduPilot Mega platform!
-The IMU sensor shield, better known as the"Oil Pan" Revision H!
-The Mediatek GPS with the basic adapter!
- 1x EM-406/uBlox/MTK Adapter Cable 5 cm! more info

PhoneDrone Board for Android
Price: $99.99 ADD TO CART

SPECIFICATIONS

- 8 Input&output PWMs
- Native USB host master (MAX3421)
- Native USB slave (Atmega32-au)
- Arduino Compatible
- Atmega2560 as main controller
- Atmega32-u2 as FTDI substitute and PPM encoder
- Three spare serial ports to communicate with other boards (including APM)
- Build-in 5V-2A switched power regulator (input range 6V - 36V)
- Build-in 3.3V LDO power regulator
- Android TM compatible...
- All Atmega2560 pins exposed.
- High quality PCB is ROHS/lead free, Gold immersed.
- Dimensions: 4" x 1.6" more info

Micro Compact Super Vision CCD Camera
Price: $99.99 ADD TO CART

Mini high resolution CCD camera, ideal for FPV day/night flight applications! ;-) more info

Programmable CCD Camera 480TV
Price: $129.95 ADD TO CART

This is a great camera for low light conditions. It has a Back Light Compensation (BLC) function that can be set as needed. The Shutter, Gamma, AGC and White Balance features are adjustable, making this camera adaptable to several lighting conditions. Ideal for FPV night flight applications! ;-) more info

Super HAD CCD Camera 1/3 Sony 520TV Lines
Price: $139.95 ADD TO CART

Mini high resolution CCD camera, ideal for FPV day/night flight applications! ;-) more info

So What's the Point?

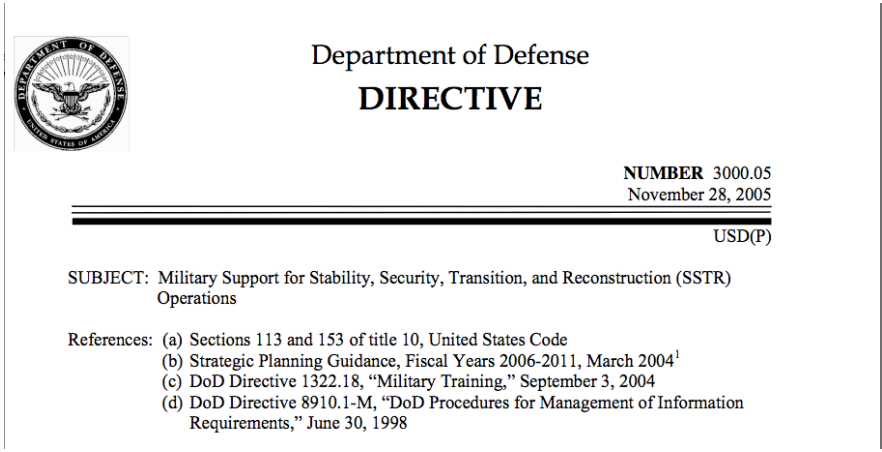
- *The computing and connectivity technologies essential to C2 are available to almost anyone*
  - Individuals, non-state actors, and governments
  - Friend and foe alike
- Under some conditions, adversaries making full use of advanced commercial ICT can potentially outmaneuver a large, modern military using legacy ICT
- Young people joining the military are used to advanced commercial ICT
  - Creating, processing, transmitting, & sharing large amounts of multimedia data is second-nature
  - Legacy C2 systems may appear quaint at best
- This Megatrend also enables and reinforces the others

Megatrend #2

Complex Endeavors

Complex Endeavors

- Mission space for military operations evolving & expanding
- Alliances & coalitions to pursue objectives
- Coalitions may also become involved in peacekeeping, nation-building, disaster relief
- Collaborate with military & civilian entities in host country, plus international organizations, NGOs, private foundations
- Advanced ICT increases no. of potential actors



Department of Defense
DIRECTIVE

NUMBER 3000.05
November 28, 2005

USD(P)

SUBJECT: Military Support for Stability, Security, Transition, and Reconstruction (SSTR) Operations

References: (a) Sections 113 and 153 of title 10, United States Code
(b) Strategic Planning Guidance, Fiscal Years 2006-2011, March 2004[1]
(c) DoD Directive 1322.18, "Military Training," September 3, 2004
(d) DoD Directive 8910.1-M, "DoD Procedures for Management of Information Requirements," June 30, 1998

US DoD Directive 3000.05, 2005: *Military Support for Stability, Security, Transition, and Reconstruction Operations.*

From an almost exclusive focus on traditional combat operations, DoD has expanded the scope of its missions to include stabilization, reconstruction, peace keeping and humanitarian disaster relief.

Complex Endeavors = New Problems

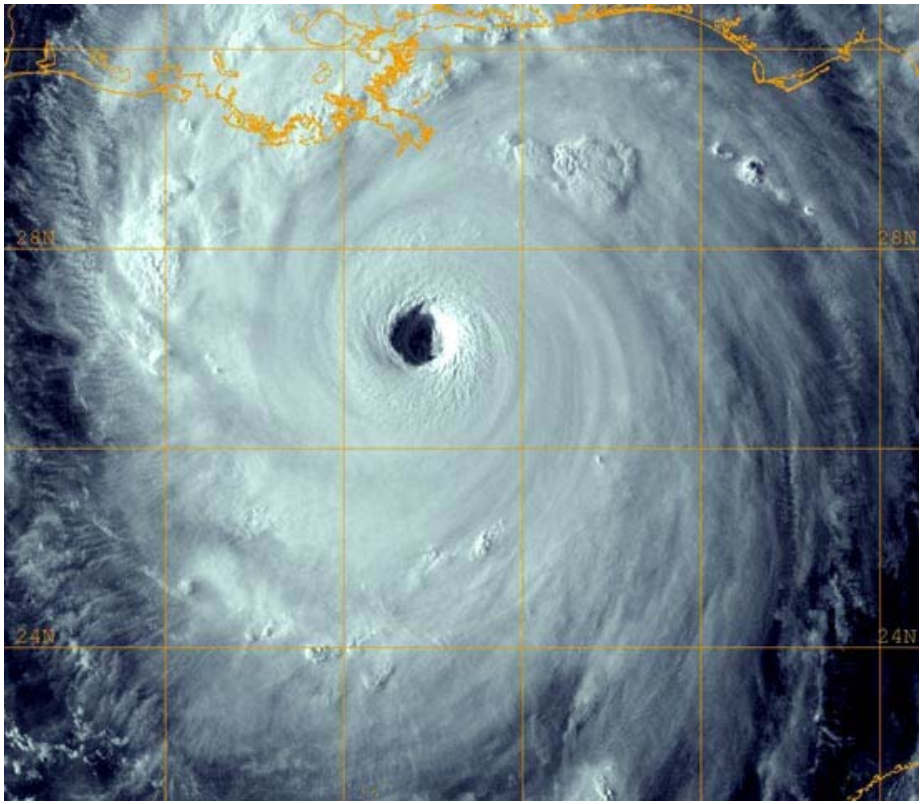
- Multiple independent chains of command
- Intents and priorities not fully aligned
- Differing perceptions of same situation
- Can slow down decisionmaking & ability to take action as fast as necessary

http://timemanagementninja.com/2012/01/10-bad-meeting-behaviors-to-avoid/

Hurricane Katrina, 2005

"The Katrina network was so large that there was a failure to fully comprehend all of the actors actually involved (partly because of a large voluntary component), the skills they offered, and how to use these capacities. One study counted over 500 different organisations involved in the weeks after landfall [Comfort, unpublished data]."

--Moynihan, Donald P. (2009) *The Response to Hurricane Katrina*. Geneva, Switzerland: International Risk Governance Council.



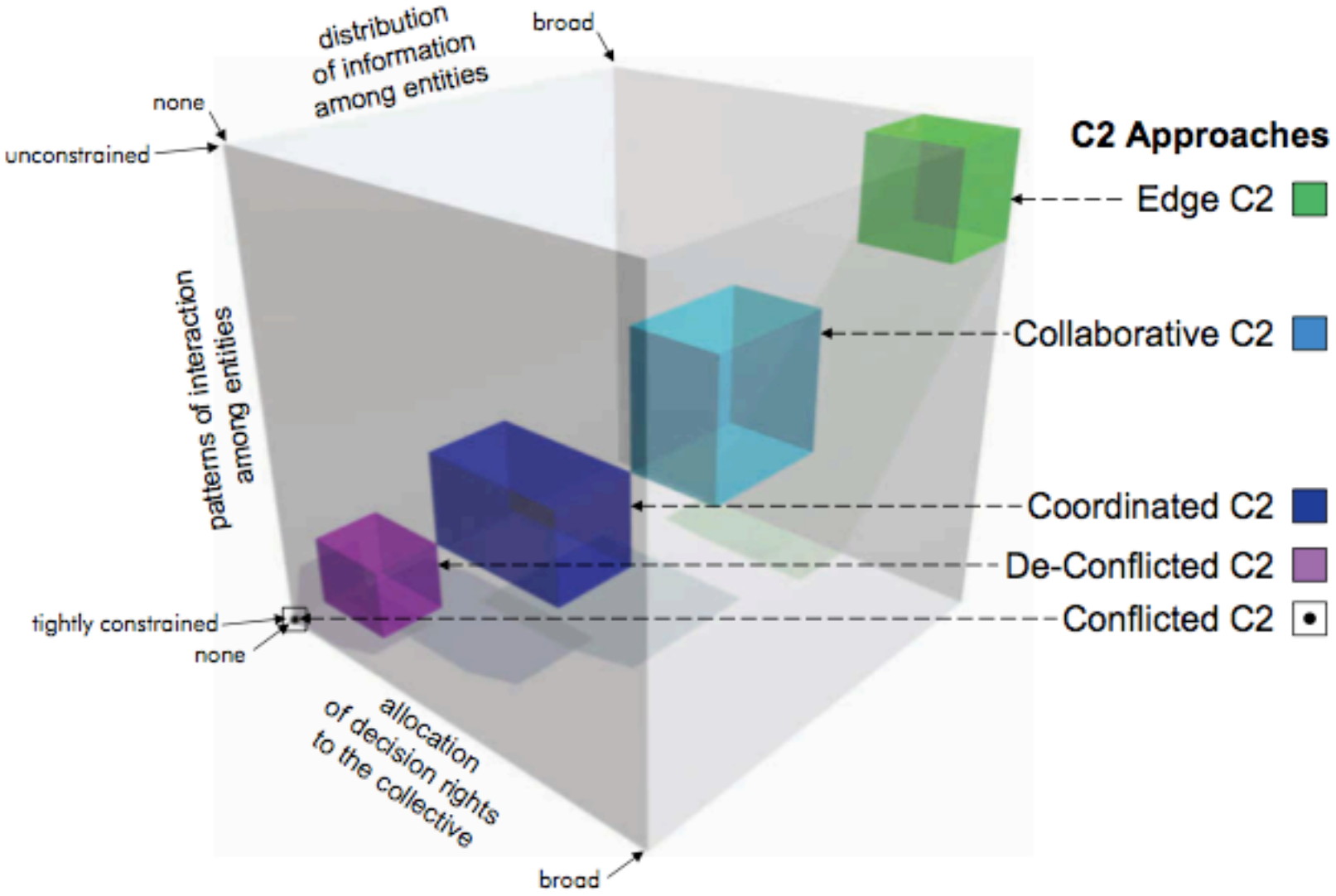
http://www.hurricanekatrina.com/

Indian Ocean Tsunami, 2004

- Militaries from 11 countries involved
- Each had a different relationship with the Indonesian Government
- NATO study noted several examples of lack of shared intent
- Hundreds of NGOs
  - NATO Study: Meetings “Unwieldy” and “a shambles.”

http://www.coast.dpri.kyoto-u.ac.jp/images/research/tsunami.jpg

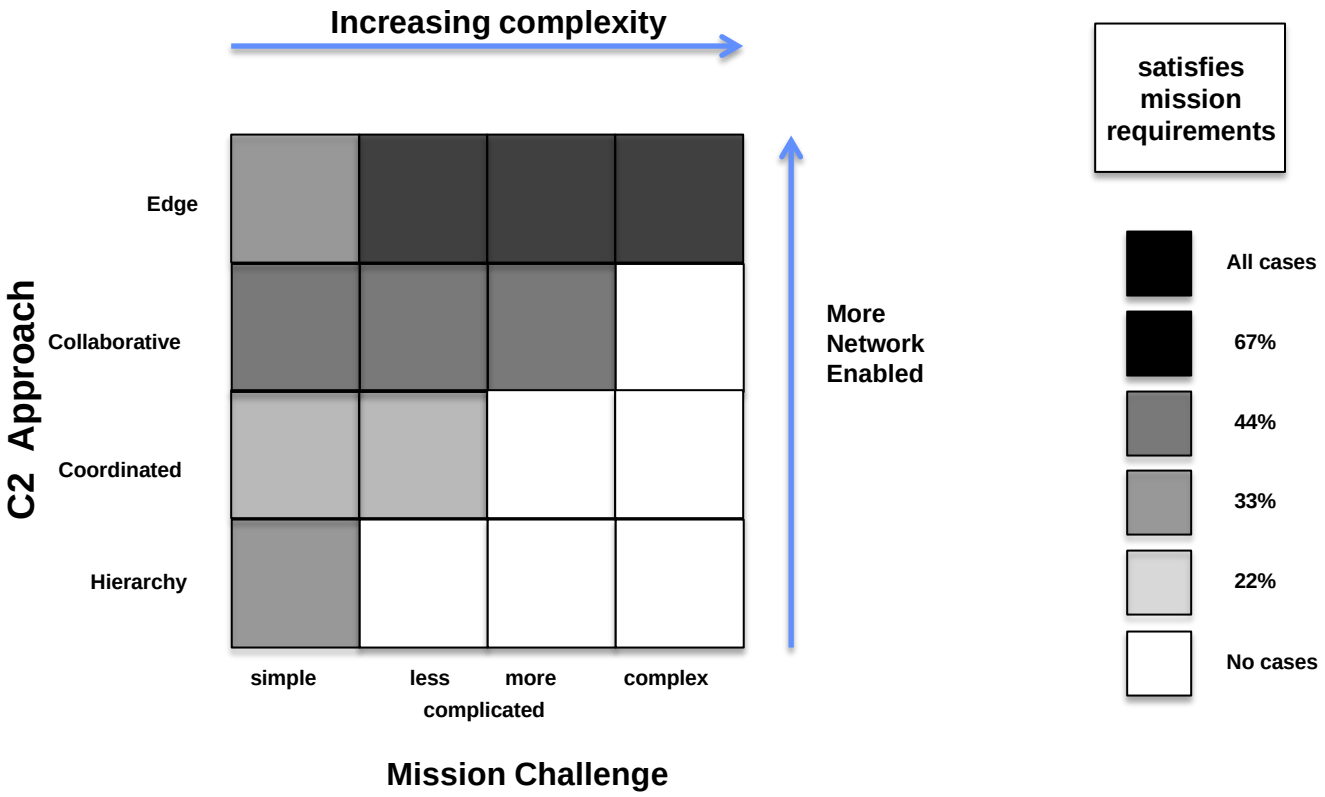
C2 Approaches in Collective Endeavors



Experiments on Complex Endeavors

- abELICIT experiments, DoD CCRP
- Agents presented with mission challenges that varied by
  - Nature of the mission
  - Mission requirements
  - Difficulty of the problem (cognitive complexity)
  - Level of noise in the available information
  - State of communications and social network
- "Task": Correctly identify parameters of attack (who, what, when, and where)
- Major experimental treatment: C2 Approach adopted
- Success:
  - Achieve specified minimum level of shared awareness & understanding
  - Timeliness (time to first correct solution)
  - Average correctness (shared awareness)

Complex Endeavors Can Demand Decentralized (Edge) C2



Unpublished results from experiments conducted in preparation of *The Agility Advantage* (Alberts, 2011).

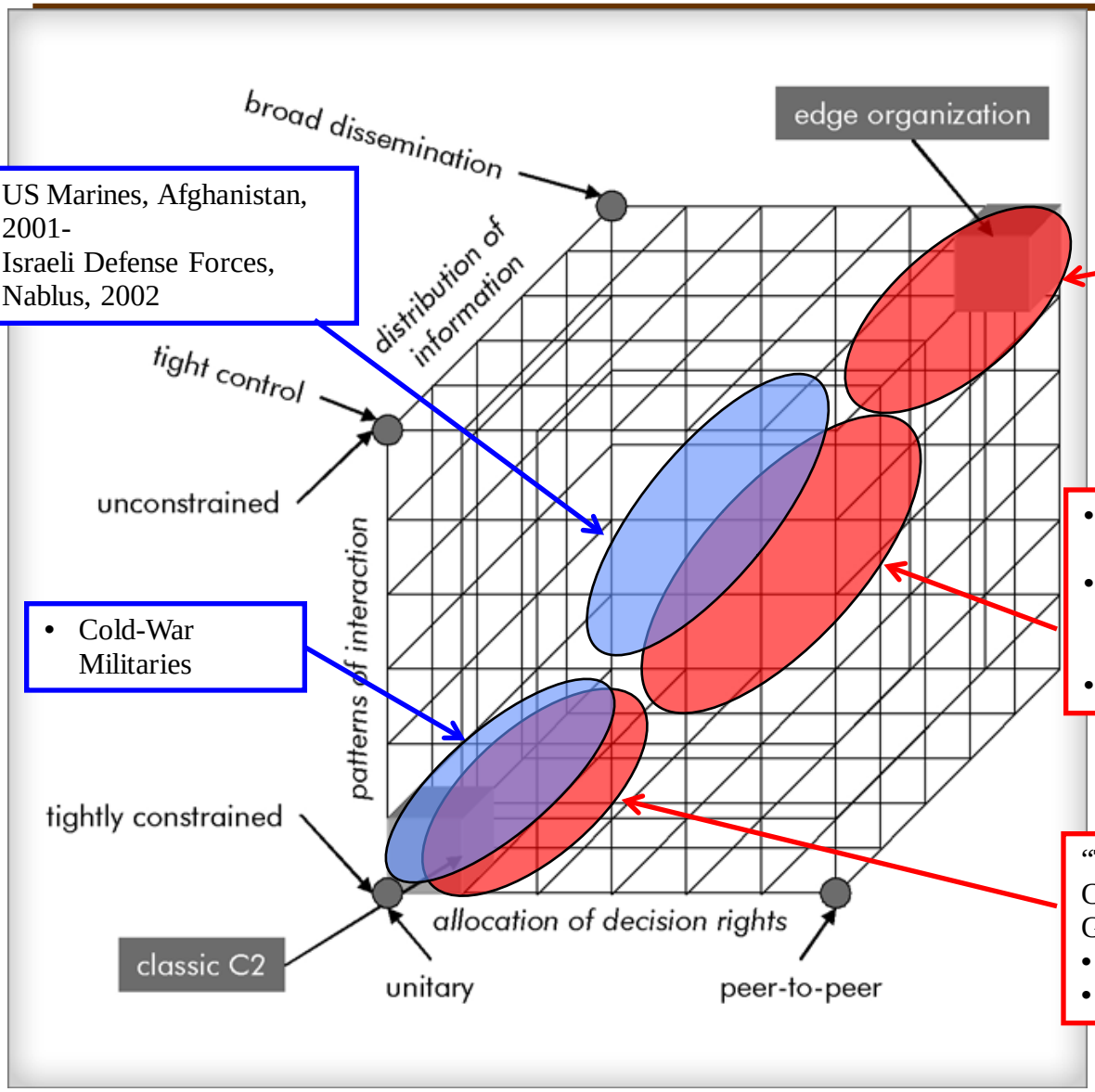
Megatrend #3

Decentralized Approaches to C2

Decentralized C2—Drivers

- Often demanded by Complex Enterprises
  - There may be no obvious hierarchy
- Dynamic, uncertain environments
  - Not always sufficiently understood & controlled using hierarchical approaches
- Small Units with Big Responsibilities
  - E.g., US Marines in Afghanistan
    - Large battlespace, roughly 200 x 200 miles
    - Patrolled by regiment
    - 10 years ago would have been whole division
    - Batallion was once the smallest unit doing independent operations
    - Now companies; Even platoons (Afghanistan)
    - Mission command Doctrine
- Nimble decentralization of certain adversaries
- Enabled by Widespread Advanced Commercial ICT
- Doctrinal Support—Mission Command

Approach Space – Individual Entities



- US Marines, Afghanistan, 2001-
- Israeli Defense Forces, Nablus, 2002

- Cold-War Militaries

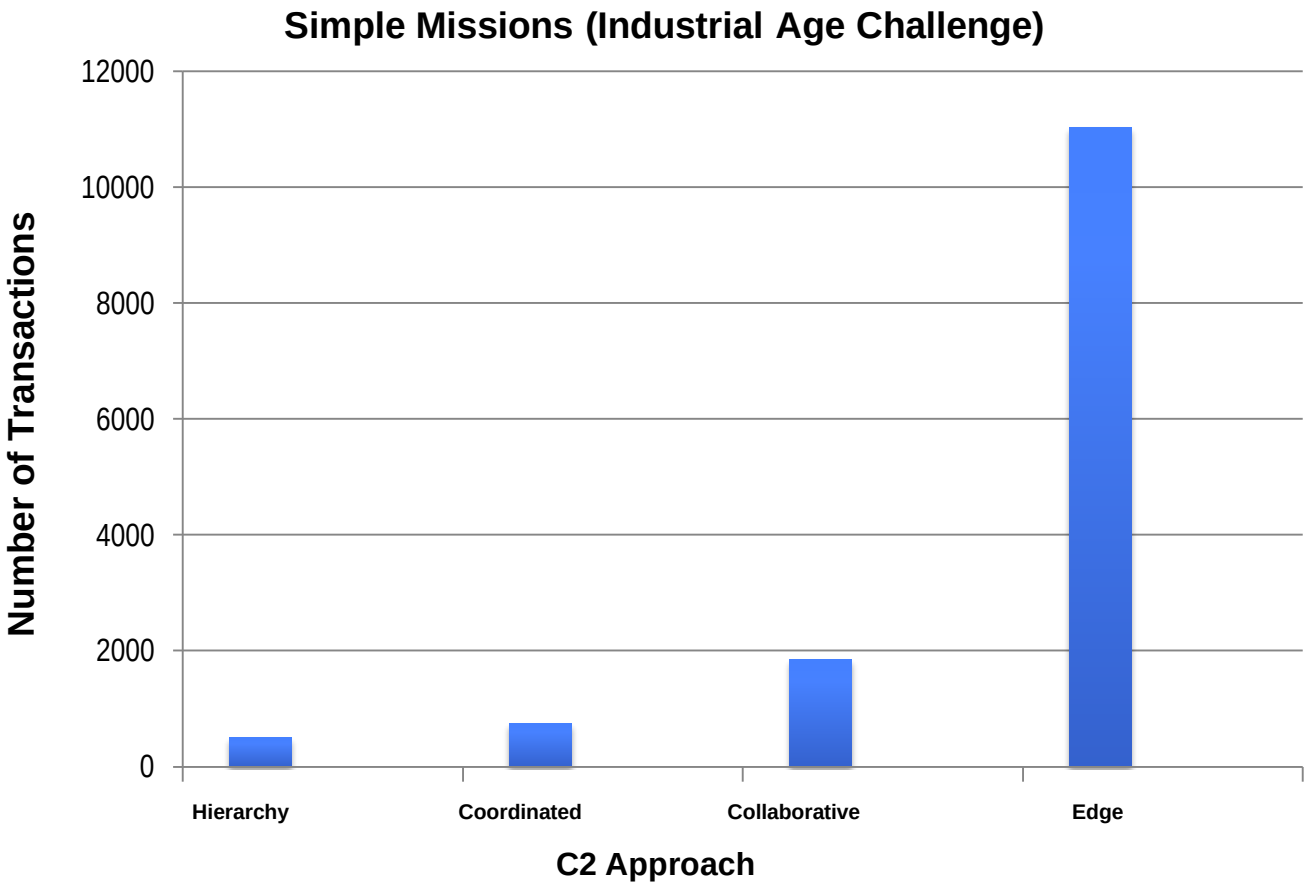
21st Century Internet/CellPhone Enabled Groups
- Al-Qaeda (9/11)
- Jemah Islamiya
- Grassroots Jihadi Networks (Madrid, 2004)
- "Leaderless Resistance" Cells

- IRA Splinter Groups under law-enforcement pressure
- Some insurgencies, e.g. Palestinian groups, Nablus, 2002
- Hezbollah (2006)

"Traditional" 20th Century Terrorist Groups
- Provisional IRA
- ETA

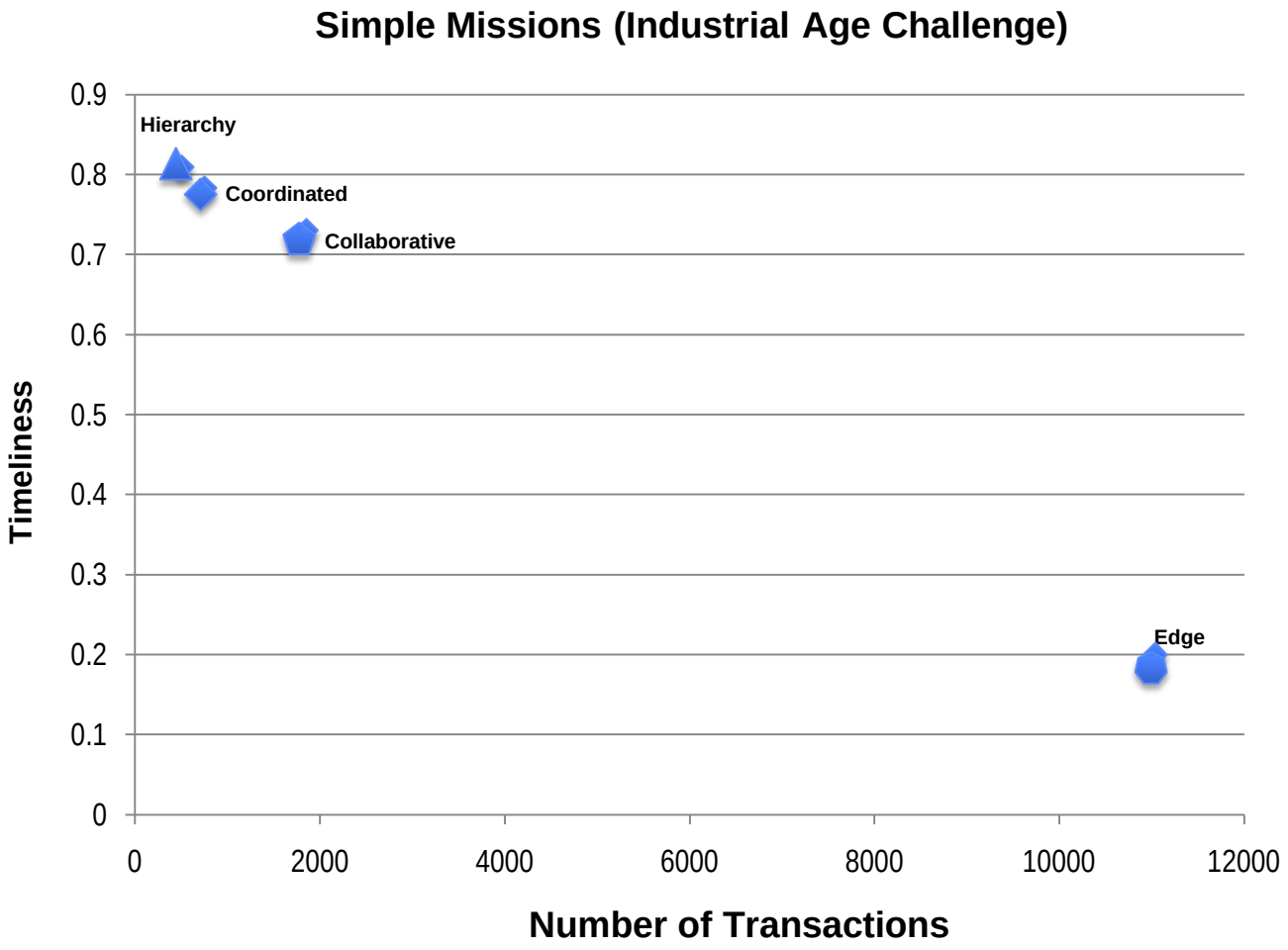
IRA = Irish Republican Army
ETA = *Euskadi Ta Askatasuna* (a Basque separatist group)

But Decentralized C2 Increases the Number of Information Transactions, which can be a Burden



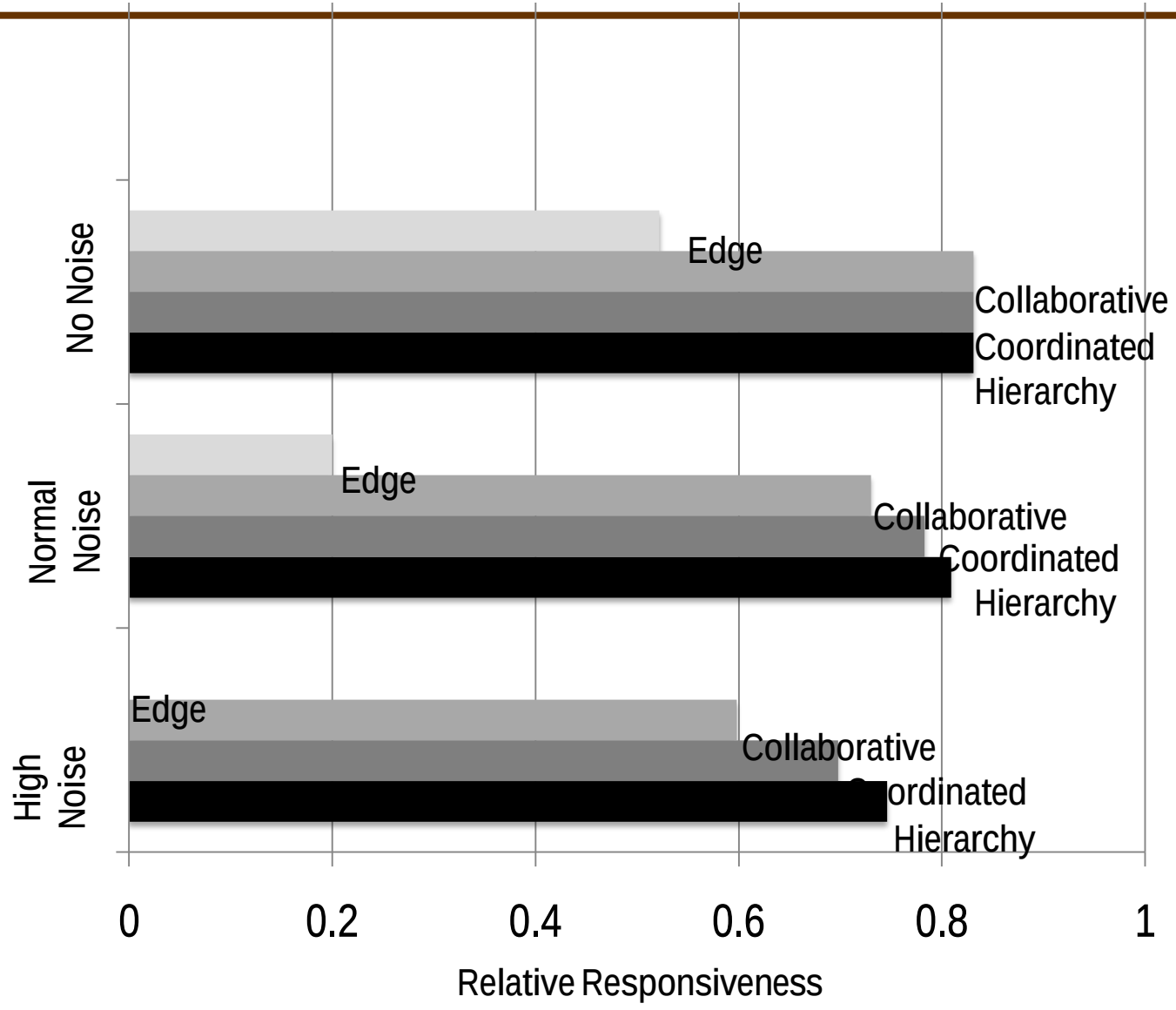
Unpublished results from experiments conducted in preparation of *The Agility Advantage* (Alberts, 2011).

And Decentralized C2 May Not Always Yield Timely Solutions



Unpublished results from experiments conducted in preparation of *The Agility Advantage* (Alberts, 2011).

Decentralized C2 Susceptible to Noise



Unpublished results from experiments conducted in preparation of *The Agility Advantage* (Alberts, 2011).

Megatrend #4

The Data Deluge

Data Deluge

- Illustrative anecdote from a Marine Officer
- March to Baghdad, 2003
- ~3 weeks, no email
- On arriving in Badhdad, 1,600+ messages waiting for him
- *Frustration*:
  - Could have used some of those messages
  - But if he had received all his email, would never have been able to separate the useful from the useless, especially under stress of combat

http://econintersect.com/wordpress/wp-content/uploads/2011/08/paper-pile.png

Persistent Wide Area Surveillance

- Raw data rates of hundreds of Mbps, more in future
- Who will view and analyze all the video?
- "You can have 180 people looking at one [...] feed"

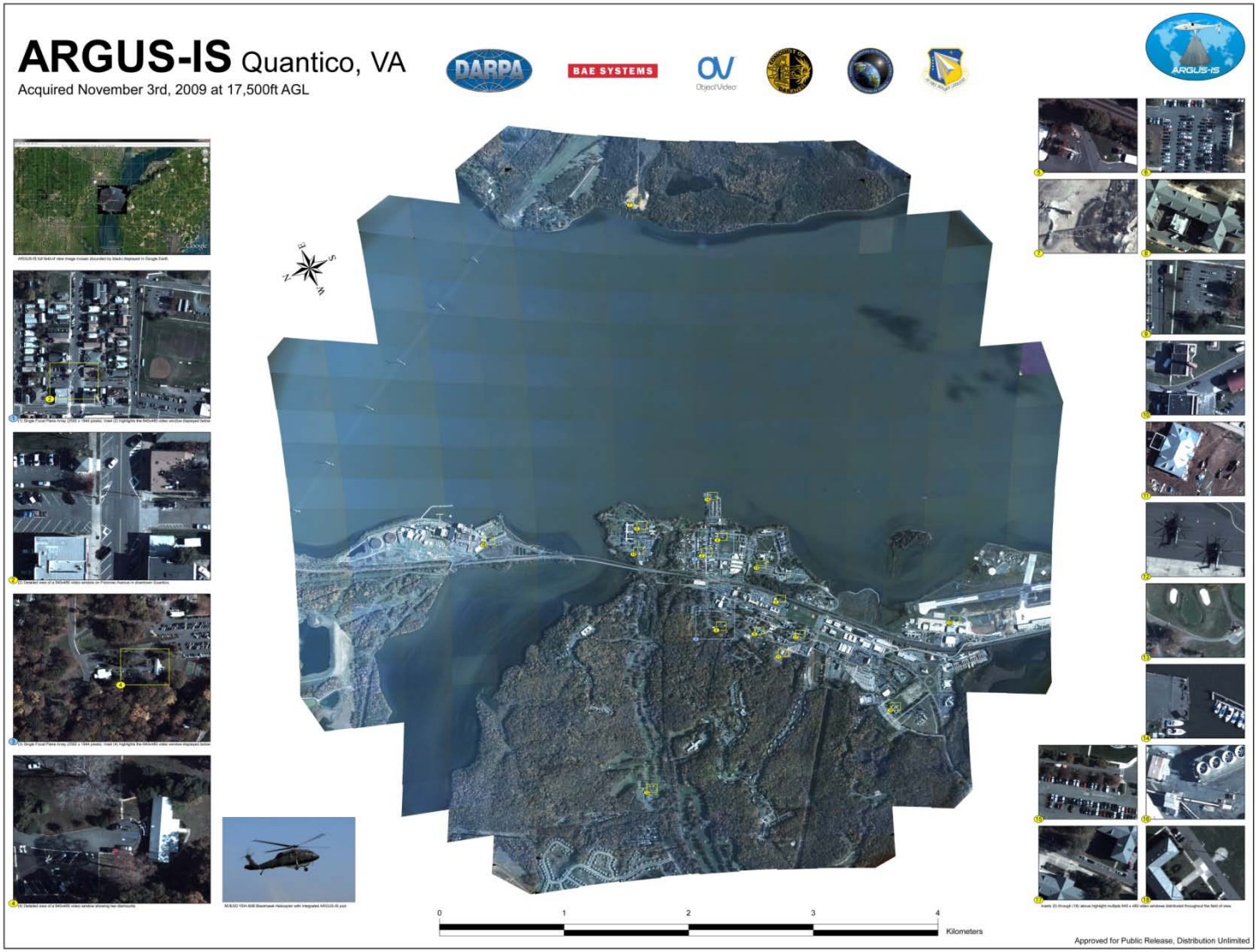
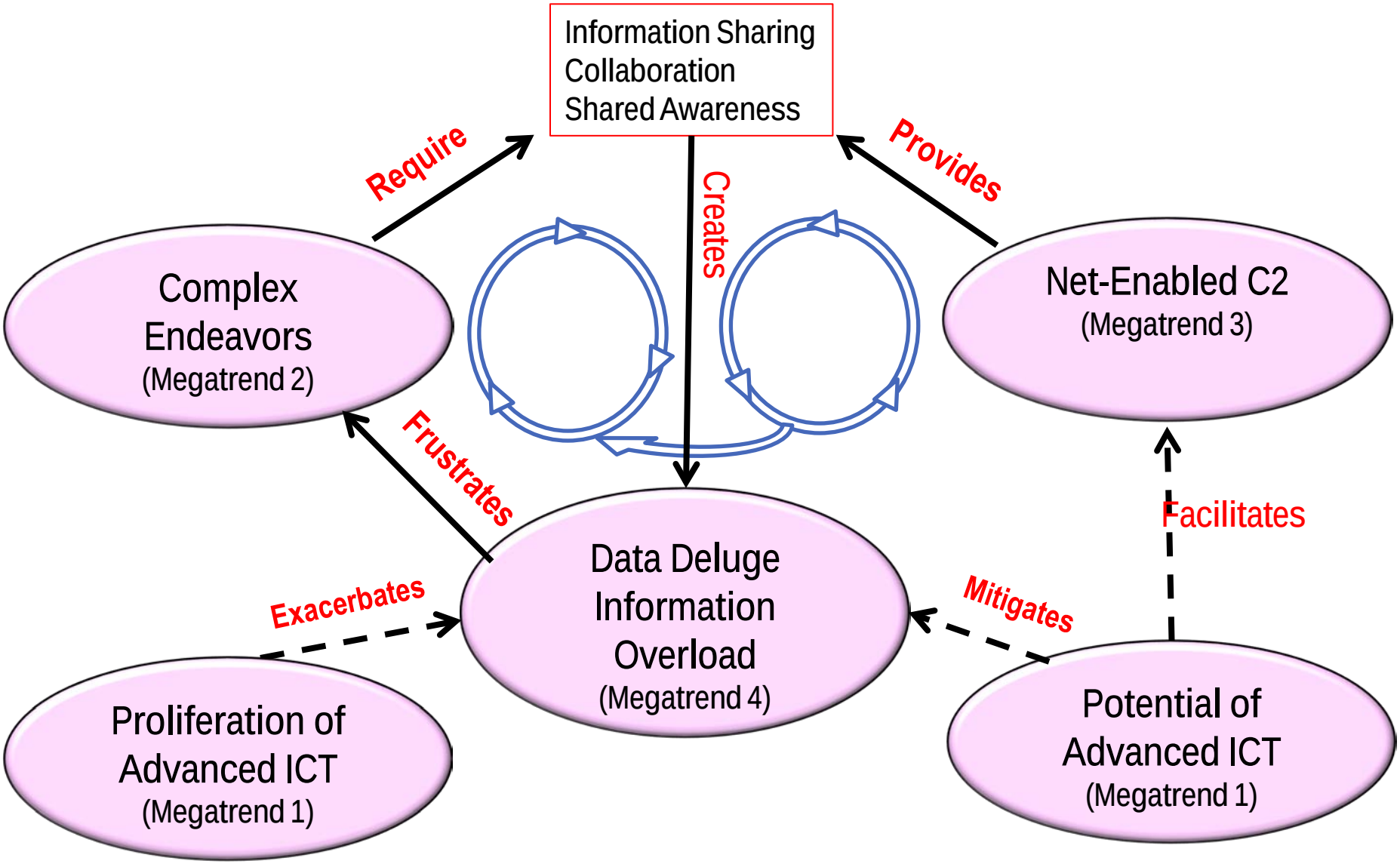


Image from BAE Systems, shown on Aviation Week Website

http://www.aviationweek.com/aw/blogs/defense/index.jsp?plckController=Blog&plckBlogPage=BlogViewPost&newspaperUserId=27ec4a53-dcc8-42d0-bd3a-01329aef79a7&plckPostId=Blog%3a27ec4a53-dcc8-42d0-bd3a-01329aef79a7Post%3a881370e5-a10f-46be-bab0-bf60fa08b425&plckScript=blogScript&plckElementId=blogDest

The Information Conundrum

The information-sharing behavior we need is also the behavior that holds us back



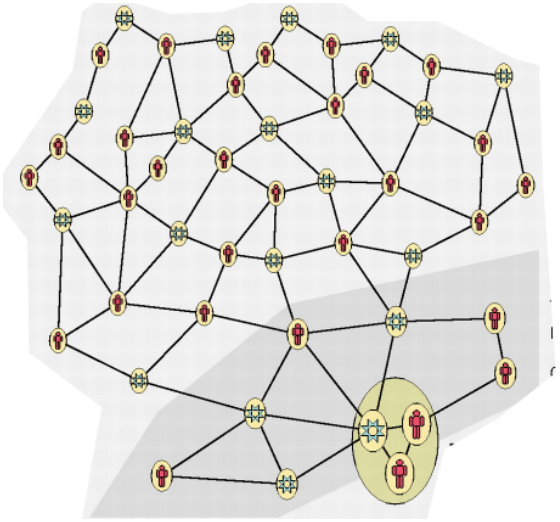
Some Possible S&T Priorities

Priority Areas

- Not listed in order of importance
- Not all-inclusive
- High level - not specific projects
- Inter-related and should be pursued in an integrated fashion
- Some priorities already being partially pursued
- Interdisciplinary & should involve engineers, computer scientists, psychologists, cognitive scientists, etc.
- *We can buy the gizmos like everyone else—we need to know how to use them better than everyone else*

Priority: Understanding Net-Enabled Approaches to C2

- "The future of command and control is not command and control"
- Explore organizational forms with the rigor of science
- Explore fundamental behavior of interconnected and interdependent sociotechnical networks
- Major issue: How do you allocate decision rights?
  - In hierarchies, allocation is fixed; in net-enabled organizations it is dynamic & emergent
  - What does that mean? How can it be planned and accounted for?
- How are decision rights expressed? Orders only? Or…?

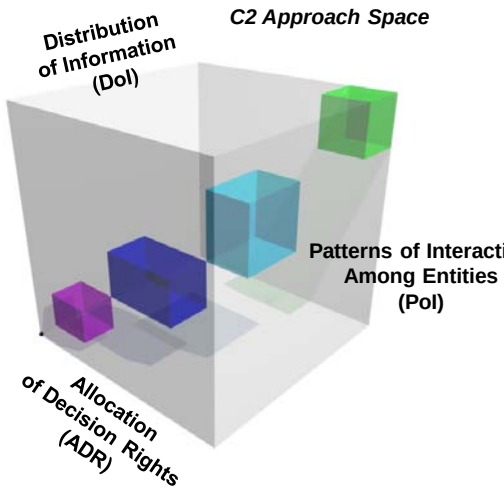


http://www.bmj.com/highwire/filestream/419891/field_highwire_fragmt_image_l/0.jpg

Research Project Example

NEC2 Research - Coherence of C2 Approach

- The Allocation of Decision Rights (ADR)is one of the three inter-dependent variables that define a "C2 Approach" and is "controllable"
- Given that the other two dimensions are, at least in part, uncontrollable variables, an appropriate choice of ADR is a function of PoI and DoI
- The effectiveness of a particular approach to C2 is a function of how "coherent" it is (balance of ADR, PoI, DoI)



Hypothesis: Inappropriate matches among the allocation of decisions rights, patterns of interactions or distribution of information will significantly reduce the effectiveness of a C2 Approach potentially rendering it ineffectual.

Approach: Explore with agent-based experimentation by varying ADR, PoI and DoI and measuring the ability to generate shared understanding that is consistent with ADR

Priority: The Information Conundrum

- S&T:
  - Understand how to fine-tune net-enabled approaches to shape their behaviors so that enough information is found, processed, and shared to satisfy mission requirements, ***and no more***.
    - Possible approach: explore forms of self-regulating information sharing & collaborative behaviors that are informed by shared awareness of the state of the Enterprise, to include an awareness of the state and performance of the communications networks, information flows, and the state of task progress.
  - Better software tools for sorting needed information from "noise" and automated assistants to perform information posting and sharing tasks.
  - Semantic processing of structured and unstructured text

http://1.bp.blogspot.com/-NKyLLPWex4I/TuI7c4BF59I/AAAAAAAABdI/eRbwF2sQ0hg/s1600/knob.jpg

Priority: Discover how to Operationalize C2 Agility

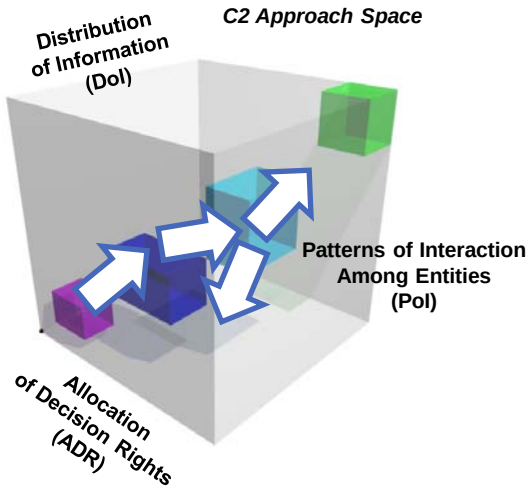
- Theory has been sketched, but not fully understood
- Must test extant theory & systematically explore the enablers and the inhibitors of agility.
- Extensive instrumentation of real-world situations in order to observe C2 behaviors
- Further experiments in C2 approaches using human participants.
- Development of integrated simulation environments that span the entire OODA loop.

http://www.maxdogphotos.com/Agility.jpg

Research Project Example

Operationalize C2 Agility

- No “one size fits all” C2 Approach. Different approaches to C2 are appropriate for different missions and circumstances.
- US Forces must be capable of adopting a variety of C2 Approaches to meet the variety of mission challenges they face
- An entity’s ability to utilize a particular C2 approach is a function of education, training, experience, systems capabilities, quality of awareness and shared awareness.
- C2 Agility is the ability to adopt an appropriate C2 Approach as a function of the mission and circumstances. This includes changing one’s approach as circumstances change.



Hypothesis: Agile Entities (ones that can adjust ADR, PoI, and DoI dynamically in response to changing circumstances) will out perform those that are less agile.

Approach: Explore with agent-based experimentation – Validate results with human-in-the loop experiments. Identify enablers /impediments of C2 Agility

Priority: Understand Trust

- TRUST can either enable success or guarantee failure.
  - Lack of trust can freeze information in place
  - Appropriate trust assessments can move the right information along to the right places efficiently
- Especially important in light of Megatrend 1, which has made ICT capability ubiquitous & available to adversaries
- New, fundamental research required to
  - Elucidate how individuals and groups form trust assessments
  - Understand how they act in light of these assessments
  - Understand consequences of given levels of trust on the information sharing dynamics of networked entities
  - Understand how trust is built, & if that process can be accelerated in distributed environments
  - Understand how trust can be degraded, in order to protect against such degradation, or to visit degradation upon an adversary.
  - Learn to select the most effective approach to C2 based on trust levels

http://www.maxdogphotos.com/Agility.jpg

Priority: Understand Trust (2)

- An important dimension of trust is information/data quality
- C2 data quality is uniquely important compared to commercial enterprise data quality because of the potential lethality of mistakes
- Much research on general aspects of data quality, but little directed towards C2
  - e.g., Automated provenance handling
    - But still very difficult to determine if a document has been copied or combined, unless it has been under version control for its entire existence.
    - "Ringing" problem in intel/situation reports
  - Need to consider the various types of C2 data when considering how to capture C2 quality features.
    - e.g., Quality features of raw data may be very different from a command message or a situation report
  - Can one provide appropriate metadata along with every data item so that the data becomes self-describing and self-protecting?
    - How best to accomplish this within the constraints of limited bandwidth, processing power, intermittent service in a disruption-tolerant and robust fashion?
- Network-level information quality metrics—multiple consumers
  - Understand effect of information quality on choice of optimal C2 approach, optimal level of decentralization

Paramount Pictures

Priority: Tame the Data Deluge

- All priority topics above address aspects of Megatrend 4, the Data Deluge.
- But there are additional areas of research more directly related to filtering & processing of large volumes of data.
- E.g. Processing & analysis of large video streams
  - On-board processing close to the sensor
    - What processing is needed?
    - What features should be retained, and what should be discarded?
    - How much should be saved, given the limitations of transmission bandwidth and on-board storage?
- How much should be analyzed immediately, and how much should be archived?
- Given limitations in number & quality of human analysts, more research is needed in automated pre-analysis, particularly in automated incremental change detection.
- Optimal video compression algorithms.
  - Commercial standards, e.g. MPEG family and ITU H.264, ideal for scenes in movies & TV
  - Not necessarily optimized for the requirements of image registration and intelligence exploitation.

http://images.surfbang.com/wp-content/uploads/2010/06/surfing-desktop-wallpaper-12.jpg

Priority: Embrace Commercial Technology

- Research needed to create, manage, & analyze full tradeoff space between COTS & purpose-built ICT
  - What can be purchased and integrated? What must be purpose built?
  - What is permanent equipment, and what can be considered disposable?
  - What is secure enough? When? Can it be predicted automatically?
- Even in security, there is some convergence of needs between military & commercial
  - Some commercial products can be highly secure.
  - Blackberry smartphone secure enough to scare Saudi Arabia
- Can S&T make commercial products LPE?
- U.S. military recognizes many of these issues, & is pursuing lines of research into incorporation of commercial ICT, such as integrating cellular phones into military environment, and encouraging the widespread development of smartphone “apps.”
  - Uneven progress; policy & culture interfere

OTHER - BACKUP

IDA

JCA

US Joint Staff's Joint Capability Areas

- Force Application
- Logistics
- Protection
- Force Support
- Corporate Management & Support

Command and Control

Organize
- Establish & maintain unity of effort with mission partners
- Structure organization to mission
- Foster organizational collaboration

Understand
- Organize information
- Develop knowledge & situational awareness
- Share knowledge & situational awareness

Planning
- Analyze problem
- Apply situational understanding
- Develop strategy
- Develop courses of action
- Analyze courses of action

Decide
- Manage Risk
- Select actions
- Establish rule sets
- Establish intent & guidance
- Intuit

Direct
- Communicate intent and guidance
- Task
- Establish Metrics

Monitor
- Assess compliance with guidance
- Assess effects
- Assess achievement of objectives
- Assess guidance

C2

C3, C4

Net-Centric

Information Transport
- Switching and Routing
- Wireless Transmission
- Wired Transmission

Enterprise Services
- Core Enterprise Services
- Information Sharing/Computing
- Position Navigation and Timing

Net Management
- Optimized network functions & resources
- Deployable, scalable & modular networks
- Spectrum Management
- Cyber Management

Information Assurance
- Secure Information Exchange
- Protect data and networks
- Respond to Attack/Event

Building Partnerships

Communicate
- Inform domestic and foreign audiences
- Persuade partner audiences
- Influence adversary & competitor audiences

Shape
- Partner with governments & institutions
- Build capabilities & capacities of partners & institutions
- …

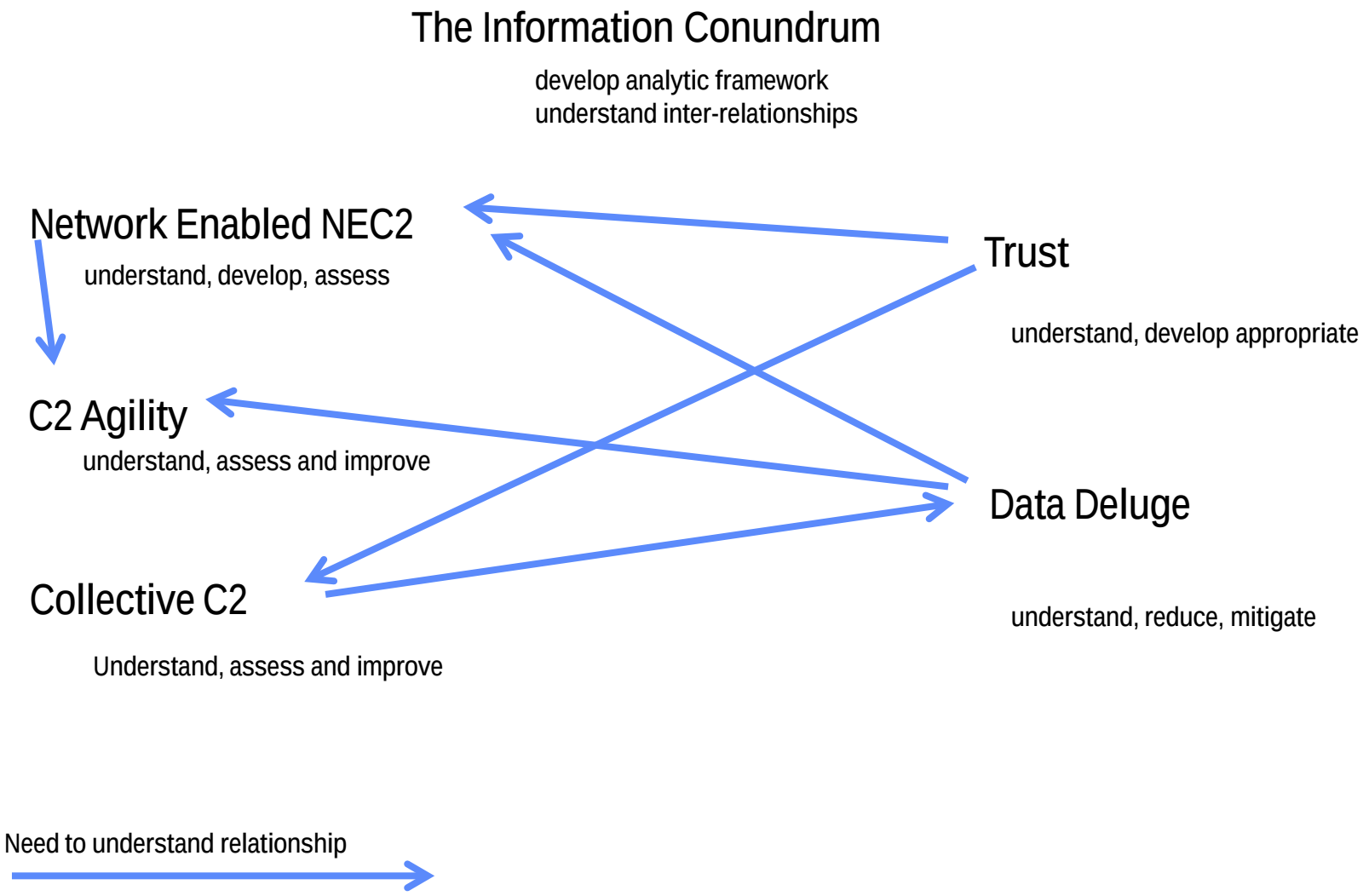
Battlespace Awareness

Intelligence, Surveillance, & Reconnaissance (ISR)
- ISR planning and direction
- Collection
- Processing/Exploitation
- Analysis & Production
- ISR Dissemination

Environment
- Collect
- Analyze
- Predict
- Exploit

C3I, C3ISR, C4I, C4ISR

C2 S&T Priorities



Priority: Embrace Commercially-Inspired Innovation Practices

- Identify pressing needs
  - Minimize formalism
  - Direct contact with users in theater and/or exercises
- Fill needs quickly
  - Maximize COTS use when appropriate
  - Take advantage of what users are already doing
  - Does not have to be perfect
- Deploy “at risk” if necessary
  - Fast-track certification
- Deploy as stand-alone if necessary
  - Integrate later
  - Don’t let a need for immediate integration with existing systems stifle development & innovation
  - Insurgents & terrorists adopt technology “catch as catch can”
- Use R&D scientists & engineers for what they’re best at
  - Tapping into applicable R&D storehouse of knowledge that developers may not be fully aware of
  - Suggesting & prosecuting new R&D threads for the longer term
- Dedicated development teams for continual refinement
  - Constant user feedback
  - Take advantage of user-generated innovation

http://www.davidamoya.com/wp-content/uploads/2011/02/Fast_Track1.jpg

Doctrinal Support

- Term comes from *Auftragstaktik*, 19th century Prussian concept
- Decentralized command concept
- Commander gives orders in a manner that ensures that subordinates understand
  - His intentions
  - Their own missions
  - Context of those missions
- Mission command is not synonymous with net-enabled decentralized C2
  - But it can provide a fertile soil for edge organizations to grow
  - And it can be facilitated by net-centric technologies
- Explicit part of US, UK, Canadian, & other allied doctrine
- Example

Count Helmuth von Moltke

"Mission command and control tends to be decentralized, informal, and flexible. Orders and plans are as brief and simple as possible, relying on subordinates to effect the necessary coordination and on the human capacity for implicit communication—mutual understanding with minimal information exchange. By decentralizing decisionmaking authority, mission command and control seeks to increase tempo and improve the ability to deal with fluid and disorderly situations."

USMC MCDP 6 (1996)