



Around The Bend



PMH Enterprises LLC

Peaceful

Complex

Disordered



New Security Risks



Asynchronous and Asymmetric Conditions and Circumstances

Radical Azimuths

Branches and Sequels

Tangents

Unclear Directions

Non-linearity

Exceptional Dynamism

**Generating Ideas And Describing Conditions About The Evolving Future
DOI: 07/09/2018**

The original version of this presentation was delivered on 10 January 2000

Future Conditions



With apologies to Niels Bohr, Danish Physicist (1885 – 1962), and numerous others to which this idea is attributed:

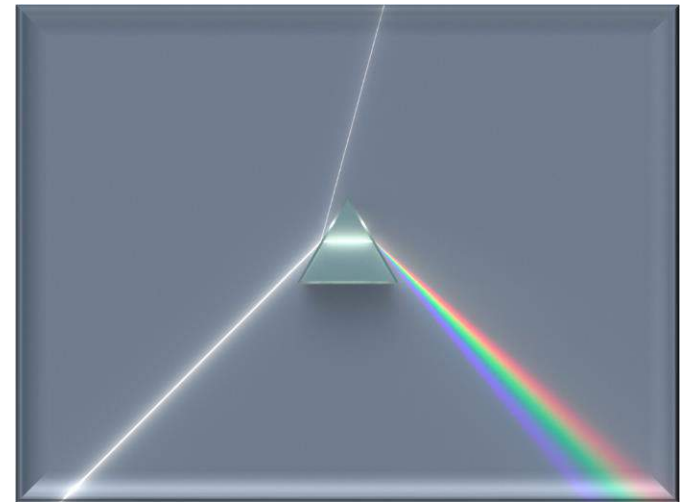
“Forecasting is risky business, especially about the future.”

CONTEXT



This presentation includes the Domestic / Internal condition of the United States as well as International / Transnational conditions and circumstances in its context.

HIGHLIGHTING and underlining are used to provide emphasis...



Future
Conditions

GENERALIZATIONS



The biggest future problem is **complexity.**
There is too much to know and understand.

The second biggest problem...**dynamic change is constant.**

Another big problem is that **there are few – if any simple or direct solutions,** especially when unintended consequences and ancillary effects are factored in.



Future
Conditions

Premise (1)



- The United States **(and our Allies) and our enemies** – and indeed the entire world – are beset by threats, challenges and the **complexities** of the modern age. **This condition will intensify.**
- **It is vital** that our defense, intelligence, and security organizations and capabilities, are supported and sustained at a level commensurate to meet these threats and challenges and to either deter or moderate and respond to...the consequences of untoward acts and unacceptable conditions.
- **At some level...prudent risk compels us to develop and sustain adequate capability.**

Future
Future
Conditions

Premise (2)



- **Data...**

...is now so prevalent, voluminous, rapidly-changing, and complicated -- that it cannot be adequately (or successfully...), dealt with by [humans engaging in cognition alone]. **Instead, humans require the assistance of various aids and assistance to grasp the meaning of data and to act on what it presents to us.**

- As we see the future evolving, we must assume that there is a chance, a risk, a possibility, that an **existential condition** may arise which threatens our way of life and indeed our very existence as we expect it to be.

Complexity is the wave of the future...

Future
Conditions



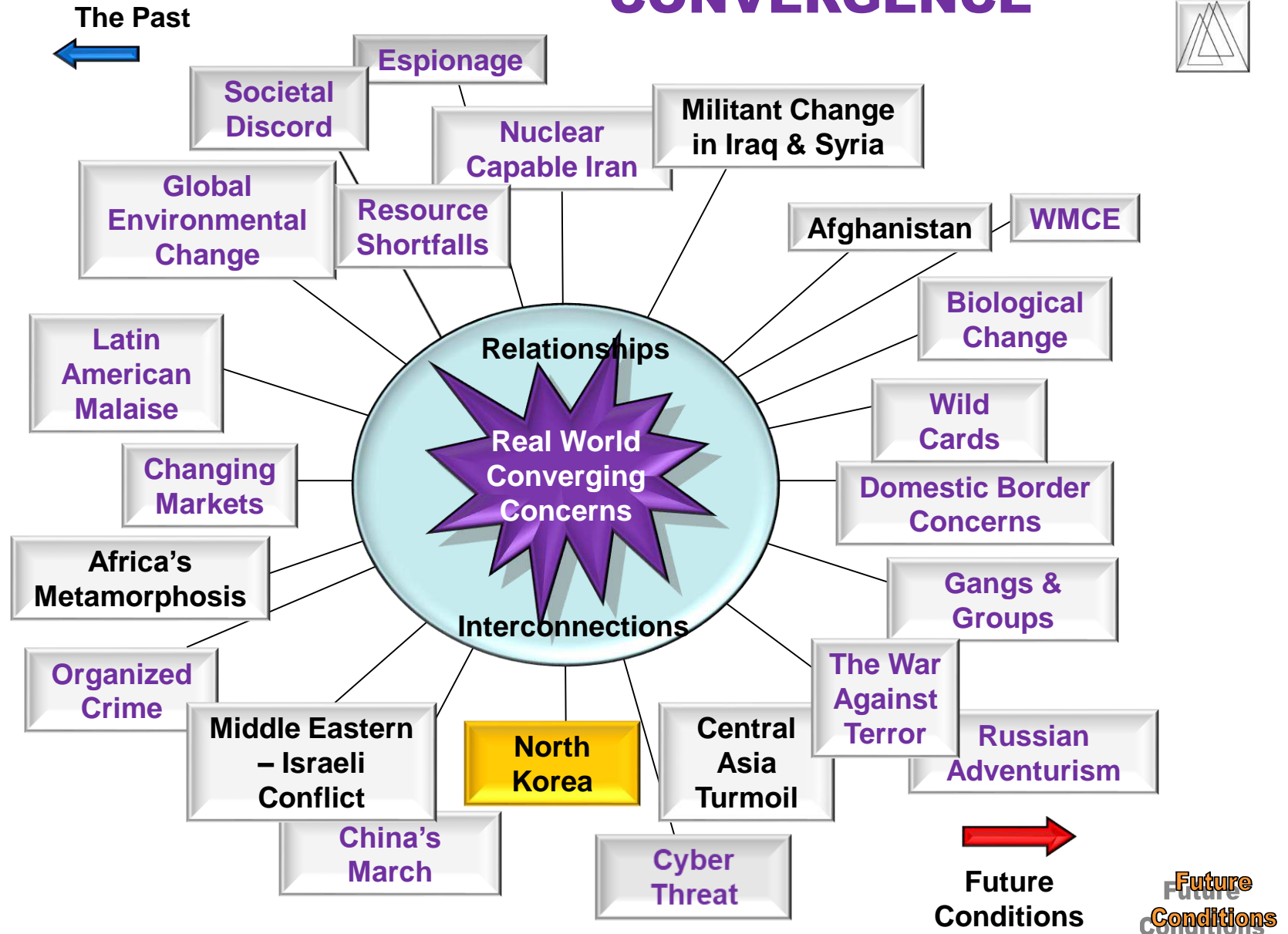
TRENDS AND CONDITIONS

- WE ARE NOW IN AN ERA OF **CONVERGENCE AND EMERGENCE.**
- SEVERAL EVOLVING CONDITIONS ARE NOW **CONVERGING.**
- SOME NEW CONDITIONS ARE **EMERGING** – ESPECIALLY NEW GEOPOLITICAL REALITIES AND NEW TECHNOLOGIES.
- TOGETHER THESE EVENTS ARE **FUNDAMENTALLY CHANGING** OUR CONDITION AND THE CIRCUMSTANCES WE ARE FACED WITH.

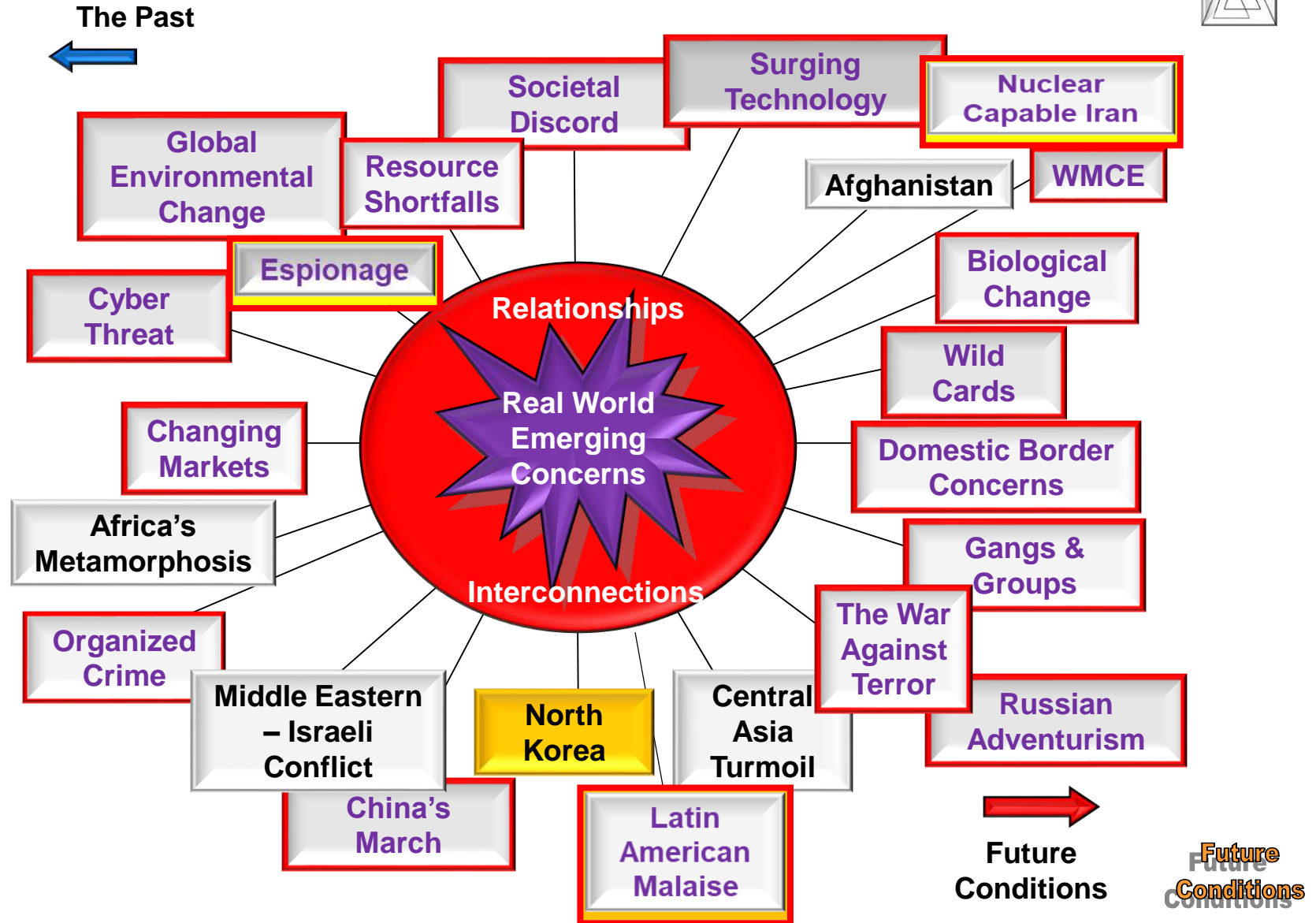
Change is perhaps the only constant...

Future
Conditions

CONVERGENCE



EMERGENCE



Where We Are Now?



- **Small Wars** at the end of the 20th Century and the beginning of the 21st Century arrived at a variety of unclear culminating points and **have fostered uncertain change.**
- **Technology** has affected everything. **Techno-change in techno-time is axiomatic.**
- **Key resources are growing in strategic importance. No resource can be ignored.** Resource shortages take on transnational significance.
- **Global environmental change has compelled resource commitment and some attendant necessary societal response,** while various opinion groups debate the truth of the condition.

Future
Conditions

Key Concerns



- **Instability** – in settled and unsettled cultures and nations (including North America)
- **The Rise of Transnational Crime and Criminal Enterprise** – driven by economic and cultural change and by societal conditions.
- **Violent “Political” Action** Misperception will play a role.
- **Techno-Weapons** – especially the use of weapons with mass and complex effects (WMCE).
- **Environmental Change** -- with devastating effects – may also present “large-War-like conditions.”

Future
Conditions

The Fabric of the Global Condition



The contemporary and future global (and U.S. National) condition can be characterized as a woven and interconnected – interrelated fabric. Inter-dependencies and traditional (historical) associations hold us all together. The thread of the “rule of law” ties the fabric together at its ends.

Caring for this fabric is the challenge we all face...and will be our greatest task in the years ahead.

Future
Conditions



Projected Population in **2030**

2030 rank (projected)	2015 rank	Country	2030 population (projected)	2015 population	Population change
1	2	<u>India</u>	1,527,657,988	1,311,051,000	+16.5%
2	1	<u>China</u>	1,415,545,000	1,376,049,000	+2.9%
3	3	<u>United States</u>	355,765,000	321,774,000	+10.6%
4	4	<u>Indonesia</u>	295,482,000	257,564,000	+14.8%
5	7	<u>Nigeria</u>	252,599,000	182,202,000	+39.2%
6	5	<u>Brazil</u>	228,663,000	207,848,000	+10.1%
7	6	<u>Pakistan</u>	224,916,000	198,925,000	+13.0%
8	8	<u>Bangladesh</u>	186,460,000	160,996,000	+15.9%
9	11	<u>Mexico</u>	148,133,000	127,017,000	+16.7%
10	9	<u>Russia</u>	138,652,000	143,457,000	-3.3%
		<u>World</u>	8,500,766,000	7,349,472,000	+15.7%

Future
Conditions

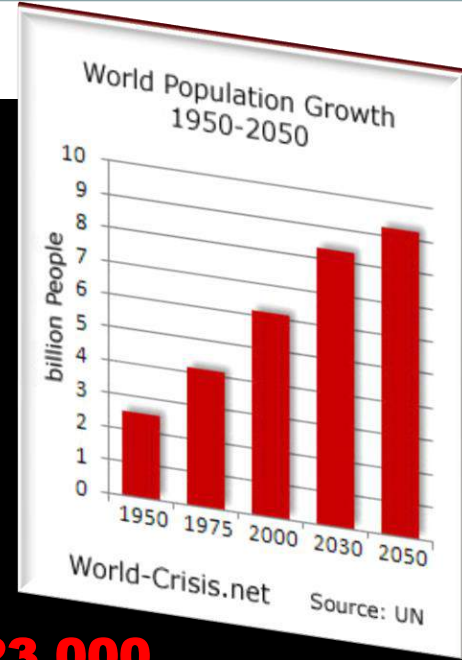
Twenty most populous countries in the year **2050**, presuming no significant changes between now and then.

UN Statistics



7/9/2018

1. India - 1,692,008,000
2. China - 1,295,604,000
3. United States - 403,101,000
4. Nigeria - 389,615,000
5. Indonesia - 293,456,000
6. Pakistan - 274,875,000
7. Brazil - 222,843,000
8. Bangladesh - 194,353,000
9. Philippines - 154,939,000
10. Dem Rep of the Congo - 148,523,000
11. Ethiopia - 145,187,000
12. Mexico - 143,925,000
13. Tanzania - 138,312,000
14. Russia - 126,188,000
15. Egypt - 123,452,000
16. Japan - 108,549,000
17. Vietnam - 103,962,000
18. Kenya - 96,887,000
19. Uganda - 94,259,000
20. Turkey - 91,617,000



2050

Future
Conditions

What Does This Mean For America?



- **Too many people** in needful places and gender imbalance.
- **Too many people dependent on social welfare programs** and other forms of support.
- **Many “people” issues to deal with** – and inadequate systems to deal with them.
- **Rising incidence of extremism** and the effects of that condition.
- **Deterioration of what may be called “traditional values and mores.”**
- **Cultural change** beyond what we have experienced before.
- **Taken collectively** – these conditions communicate a mixture of history and contemporary knowledge that represents a set of dangerous conditions.

Elements of Discord



- **Historical enmity** and inter- and intra-cultural hatred.
- Importance and influence of **ideology**.
- **The rise of harmful fundamentalism and radicalism.**
- **Economic competition** – especially when it involves disputed resources and limited access.
- **Absolute shortages** of required resources (water, rare earth, etc.).
- **Transnational crime** and specific criminal activities.
- **Corruption** especially in governance.
- **Deterioration or absence of the rule of law.**
- **Instability** spiraling into violent failure.
- **Combinations of these elements which can achieve negative synergy.**

Future
Conditions

Critical Shortages



And Distribution Challenges

- **Arable land**
- **Potable and useable water**
- **Critical (strategic) minerals and elements**
- **Skilled labor and technological expertise**
- **Dependable food supply**
- **Electric power**
- **High demand – low density manufactured materials**
- **Inadequate production capacity**
- **Skewed market conditions** which lead to shortages
- **Illicit commerce**
- **Combinations of these factors**

Future
Conditions

Techno-Change



Technology (of all kinds) – seemingly has changed everything, and at the same time has changed very little – in the context of societies and their fundamental beliefs. In some cases the adaptability provided by technology has strengthened the nature of singular ideas or has merely become a tool to further “old” radical ideas or zealotry.

It is likely that “new science” and “new technology” threats will emerge in the next few years...some of these emerging techno-threats are already on the horizon.

Future
Future
Conditions

Key Technology Vectors



- **New Science**
- **New materials**
- **“Printed” finished products**
- **Enhanced energy forms and applications**
- **Directed energy**
- **Non-lethal weapons & control systems**
- **Ubiquitous digital applications**
- **Medical treatment**
- **Agriculture and food production (including access to potable water)**
- **Synthetic Biology**
- **Artificial Intelligence**
- **Robotics**
- **Remote & Off-Set Operations**
- **Nano-technologies & Miniaturization**
- **Big Data exploitation**
- **Advanced computation capabilities (Quantum Computing)**
- **The X-Factor**

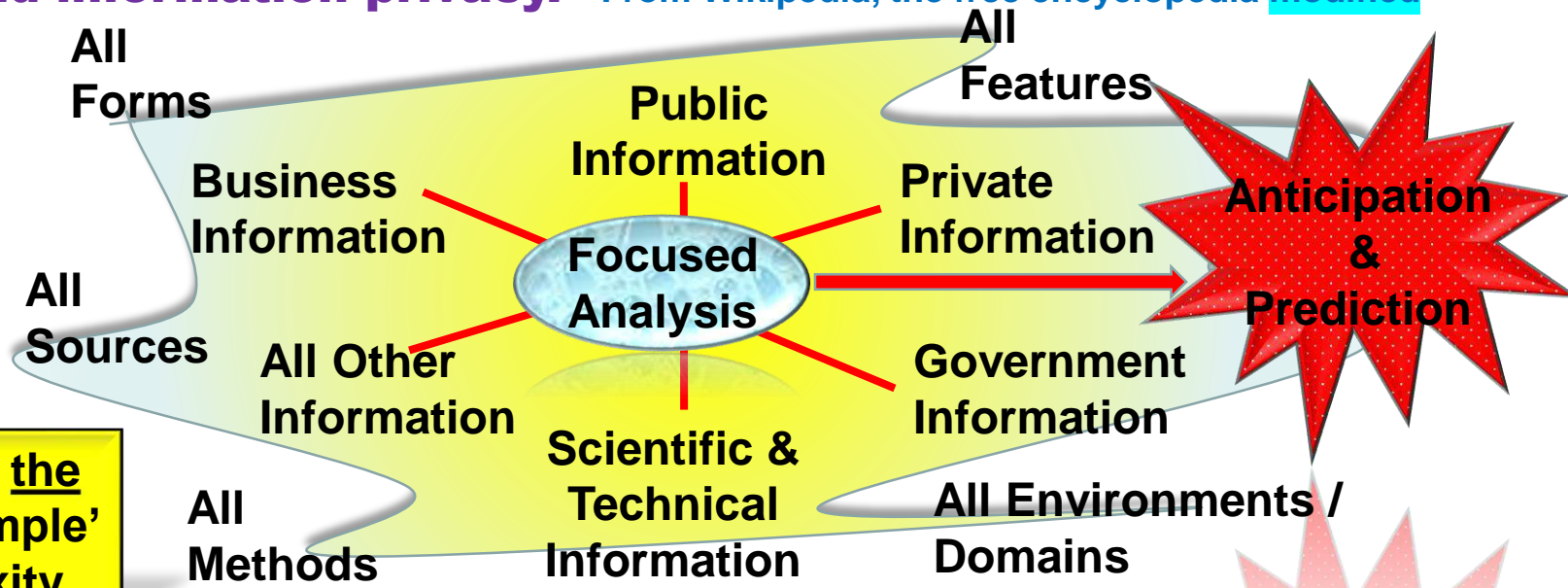
Future
Conditions

Exploitation of BIG DATA



The goal of Big Data mechanisms is to predict future outcomes and to foresee trends and events.

“Big data is a broad term for **data sets** so large or complex that traditional data processing applications are inadequate. Challenges include analysis, capture, data curation, search, sharing, storage, transfer, visualization, and information privacy.” From Wikipedia, the free encyclopedia modified



Big Data is the 'object example' of complexity.

Future Conditions

What Does This Mean For Us?



- **Technology (and its evolution) spark consequential change** that will require adjustment and “new normal” understanding.
- **Techno-change in Techno-time** means that the **pace of technological change is both rapid and imposing** – one can only imagine what may come next – resulting in a marked difference.
- **Some forms of technological change will create ancillary “unintended” effects** that provide opportunities and threats that we will have to contend with.

Future
Conditions



What Might This Mean For Us?

- **The measures of time, distance, speed and tempo, area, and the passage of information have all changed radically in the past 20 years. That change is ongoing.**
- **The global condition is interrelated and interconnected – events there may have important effect here.**
- **Conditions vary between and among nation-states and regions, but there are many “common” variables.**

Future
Conditions

What Else Might This Mean For Us?



- **Cultural control may not be as strong as once perceived**
- **The legal outlines of contemporary conditions may be blurred by emerging “different” technology-driven ethical and cultural constructs.**
- **Taken collectively** – these conditions communicate a mixture of national and regional concern and contemporary knowledge that represents a dangerous set of circumstances.
- **These circumstances are often a matter of perception as much as fact and compel action by the caring and the thoughtful to avoid animus and violence.**

Future
Conditions

BIG THREATS



And Many Concerns...

Future
Conditions

Existential Threats



- The rising potential for the use of **weapons with mass and complex effects (WMCE)** in a future conflict.
- **The hybrid threat** – sometimes referred to as the “multi-dimensional / multi-domain threat.”
- **Internal disruption and destabilization.**
- An additional “threat” concern is: **The contemporary existence and the growing problem of sophisticated crime.**

The Bottom Line



In the future, while we may expect a continuation of the existence of terrorism and limited warfare in all its many forms, similar to what we have been experiencing since the 1990s, we must also now prepare for the advent of larger threats and more perilous conditions which place different demands on our technological, intelligence, military, diplomatic, economic, and virtually all other elements of our national security structure.

Future
Future
Conditions

Operational Threats

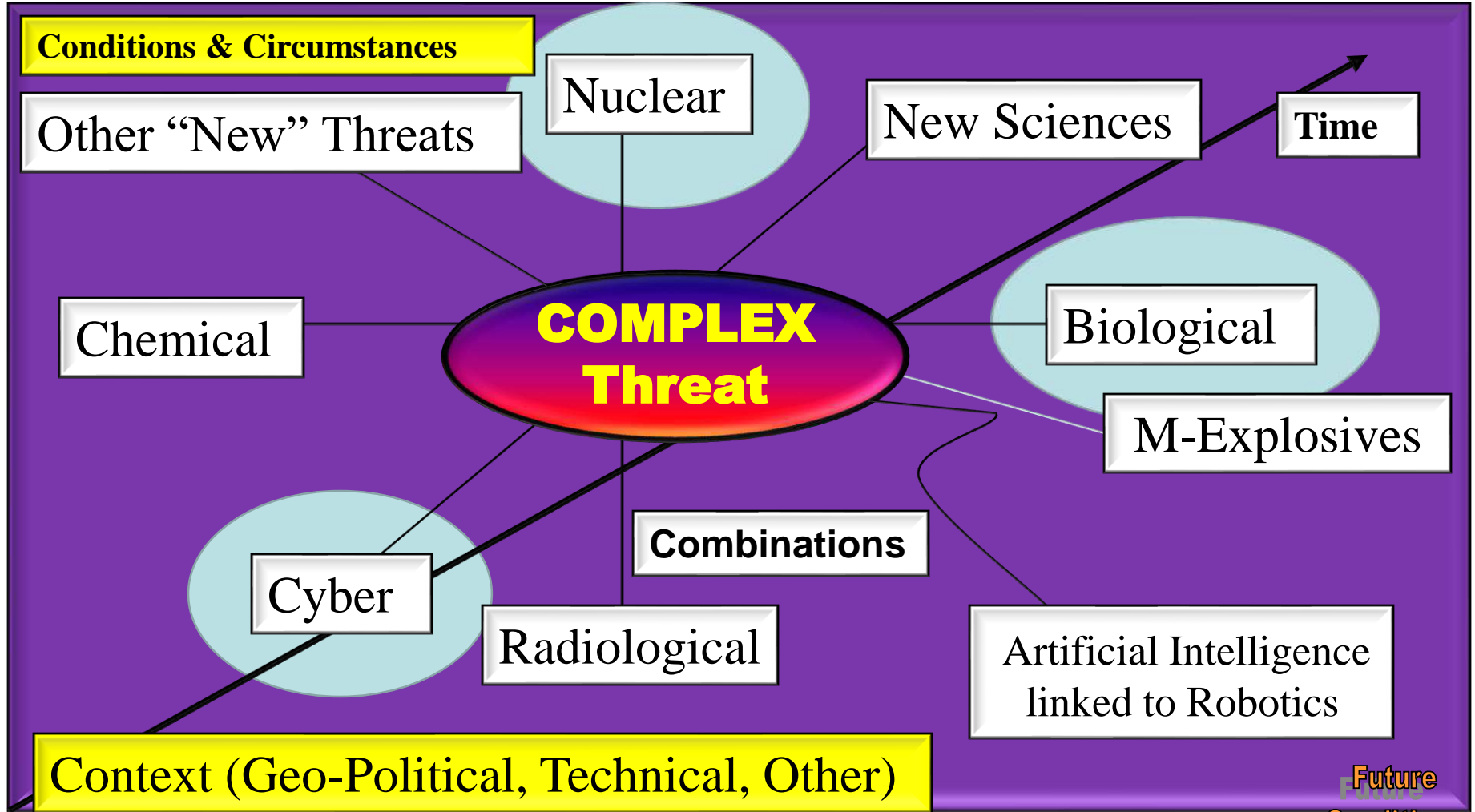


- **Hybrid Warfare / Multi-Dimensional Conflict** (in the zones of potential contemporary conflict)
- **Extremism & Militancy** (supported from the inside and the outside)
- **Crime** (including sophisticated high-cost white collar crime)
- **Developing Cyber Warfare and Cyber Crime capabilities** (a parallel universe of mysterious proportion and portent)
- **Proliferation** (of weapons with mass and complex effects)
- **Advent of “New and Threatening” Technologies** (potential good & bad)
- **Environmental Change** (and its effect on people and places)
- **Changing Global Power Structure** (and its effect on balance and stability)

These global attributes may be interconnected and synergistic, depending on the conditions and circumstances extant...

Future
Future
Conditions

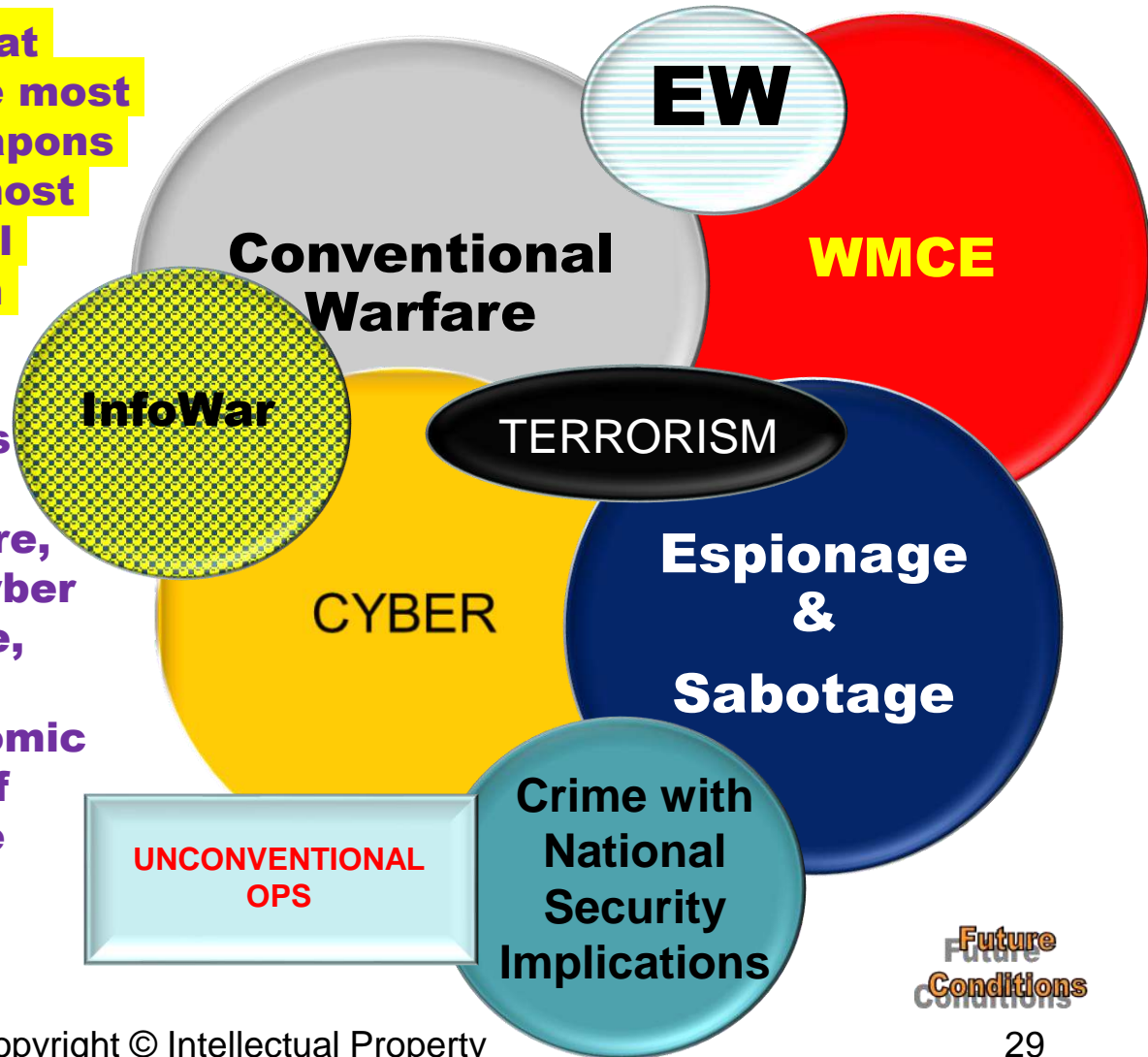
Weapons with Mass & Complex Effects (WMCE)



Heavy-Hybrid Warfare



- **Heavy-Hybrid Warfare** is that warfare which includes the most robust of conventional weapons and capabilities, and the most imposing of unconventional means, brought together in tactical and operational formations tailored for the conflict at hand. It includes technologically advanced conventional kinetic warfare, unconventional warfare, cyber warfare, electronic warfare, psychological warfare, information warfare, economic warfare, and other forms of warfare – carried out in the context of strategic goals. **PMH**



China's Military Direction



China has been embarked for some time on modernizing and improving the quality and capabilities of every element of its military and police. **China** continues to modernize and harden its **nuclear ICBM forces**. These forces are surely defensive but can hardly be thought of without considering their offensive possibilities.

CHINA is perhaps the greatest practitioner of modern espionage in the world

China's cybernetic warfare capabilities are arguably as good or better than any other nation. They continue to put resources and expertise into this capability.

China's careful application of military influence belies what may be thought of as a subtle but definitive move to have both presence and capability – in the form of military and diplomatic personnel – throughout the world – in competition with the U.S.

Future
Conditions

Russian Aggression



Russia exhibits all the signs of a “former Imperial nation,” seeking now to regain some of what was once the Soviet Union, especially in the “near-abroad.”

- Aggression in Georgia, in Ukraine, [in Syria], and its apparent meddling in and challenges to the United States – and elsewhere – are harbingers of what may lie ahead if some form of restraint is not imposed or willingly embraced.
- The apparent willingness of the **Russian** government and much of the citizenry – to back aggressive action – is a key concern. **It's legitimacy is also hard to gauge...**

Future
Conditions



The Sarmat is a heavy ICBM intended to replace **Russia's** aging, Soviet-era missiles that form the basis of its nuclear deterrent. The Sarmat, which NATO named "**Satan 2,**" has been in development since at least 2011 and is believed to be able to carry an increased number of nuclear warheads and has an increased range.

The Sarmat was among the arsenal of new "invincible" nuclear weapons that **Russia's** president Vladimir Putin touted in a speech in March and that included a **nuclear-powered cruise missile and a hypersonic intercontinental missile.**



RUSSIAN DEVELOPMENTS



- **It seems obvious that Russia – for all its many shortcomings and weaknesses – has been developing a new class of weapons systems and capabilities, most of which have not yet been manufactured in large numbers or used in a demanding field condition.**
- **However, the trend is there – similar to China – in that Russia is slowly but deliberately developing credible capabilities to challenge the West.**
- **We should also expect Russia to step forward on the diplomatic and economic stage – to try to wield power and influence into alliances and relationships. It would be a huge mistake to view Russia only through the military capabilities prism.**

IRAN



- **The Iranian leadership has led their nation to or toward the following:**

- **Direct violent confrontation with the West** (and specifically the US).

- **Development of both military and para-military forces** far beyond what might be required for internal security and simple defense.

- **Development or acquisition of weapons capabilities or weapons systems that are inherently offensive** and which threaten regional stability – and perhaps the stability of some parts of Europe.

- **Direct support to terrorist organizations and groups** – including tactical support and participation.

- **Development of precursors and objective weapons with mass and complex effects**, including nuclear, chemical and cyber capabilities.

- **Engaging in rhetoric** that can only be characterized as offensive and threatening to the US and our Allies.

Future
Conditions

North Korea
remains a
volatile and
undependable
nation.

Their avowed
intent is to
undertake
denuclearization.

This is good
news – but so
often in the past
North Korea's
statements have
proven
unreliable.

This time “**may**”
be different...

North Korea



Perhaps the most succinct description of **North Korea** and its leadership is that by remaining apart from the community of nations for so long and in such an intense and confrontational way – they have lost touch with contemporary reality. **But...maybe there really is a way to go forward peacefully...**

BUT – What do we do if they cheat?

Leading Terror Groups in 2018



- **Islamic State of Iraq and the Levant (ISIL, ISIS or simply the Islamic State)**
- **Boko Haram**
- **Al Qaeda**
- **Islamic Revolutionary Guard Corps-Quds Force**
- **Haqqani Network**
- **Kataib Hezbollah**
- **Naxal/Naxalites**
- **An Un-named Group**
- **Tehrik-I-Taliban**
- **Lashkar-E-Toiba**
- **Taliban**
- **Al-Shabaab**

NOTE: These groups can be ordered differently depending on criteria – such as which group is the most lethal or which group is the largest or the richest – but the order of them in a list is really unimportant. They all use savage violence to achieve their goals and they all harken to either a religious foundation and / or political and social grievances. They will persist.



Some lists include the Ku Klux Klan (historically an important terror group in the US), and the Irish Republican Army – but both groups have either diminished to the point of near irrelevancy or have become quiescent. Including them in a contemporary listing seems pointless.

Future
Conditions



Inspire Magazine

Newest issue of al-Qā'idah in the Arabian Peninsula's magazine: "Inspire #17" on August 13, 2017



Out of Step

Out of Step?





网络攻击



Future
Conditions

www.china-defense-mashup.com

CyberCrime



Cybercrime revenues hit \$1.5 trillion a year

[A new] report estimates cyber criminal revenues worldwide of at least \$1.5 trillion -- equal to the GDP of Russia. In fact, if cybercrime was a country it would have the 13th highest GDP in the world. This \$1.5 trillion figure includes: \$860 billion from illicit/illegal online markets, \$500 billion from the theft of trade secrets and intellectual property, \$160 billion from data trading, \$1.6 billion from Crimeware-as-a-Service and \$1 billion from ransomware.

Betanews / Bromium April 2018



Worldwide, there are over 2.20 billion monthly active Facebook users for Q1 2018 (Facebook MAUs) which is a 13 percent increase year over year. (Source: Facebook 04/25/18) What this means for you: In case you had any lingering doubts, statistically, Facebook is too big to ignore.



Growing Like A Weed in Afghanistan



UN Office on Drugs and Crime 2017 Report

Area under opium poppy cultivation increased by 63% since 2016, reaching a new record high.

The total area under opium poppy cultivation in Afghanistan was estimated at 328,000 hectares in 2017, a 63% increase or 127,000 hectares more compared to the previous year.

Total eradication of opium poppy increased by 395 hectares but remained very low.

The 2017 record levels of opium poppy cultivation in Afghanistan create multiple challenges for the country, its neighbors and the many other countries that are transit for or destination of Afghan opiates.

Future
Conditions

Trending Crime



- **Human Trafficking** – including the sale of or exchange of persons for profit.
- **Penetrable Border Crime** – including the U.S. border and the borders of Allied nations – and the attendant exploitation of these borders for criminal enterprise.
- **Cybercrime** – including the stealing and exploitation of digital information for criminal enterprise and the use of Dark Nets for criminal activity.
- **Continuing production of narcotics base materials.**
- **Violence by Disgruntled Persons** – including the so-called “lone wolf” phenomenon of both political and non-political anti-social violence for specific reasons.

These global attributes may be interconnected and synergistic, depending on the conditions and circumstances extant...

Future
Future
Conditions

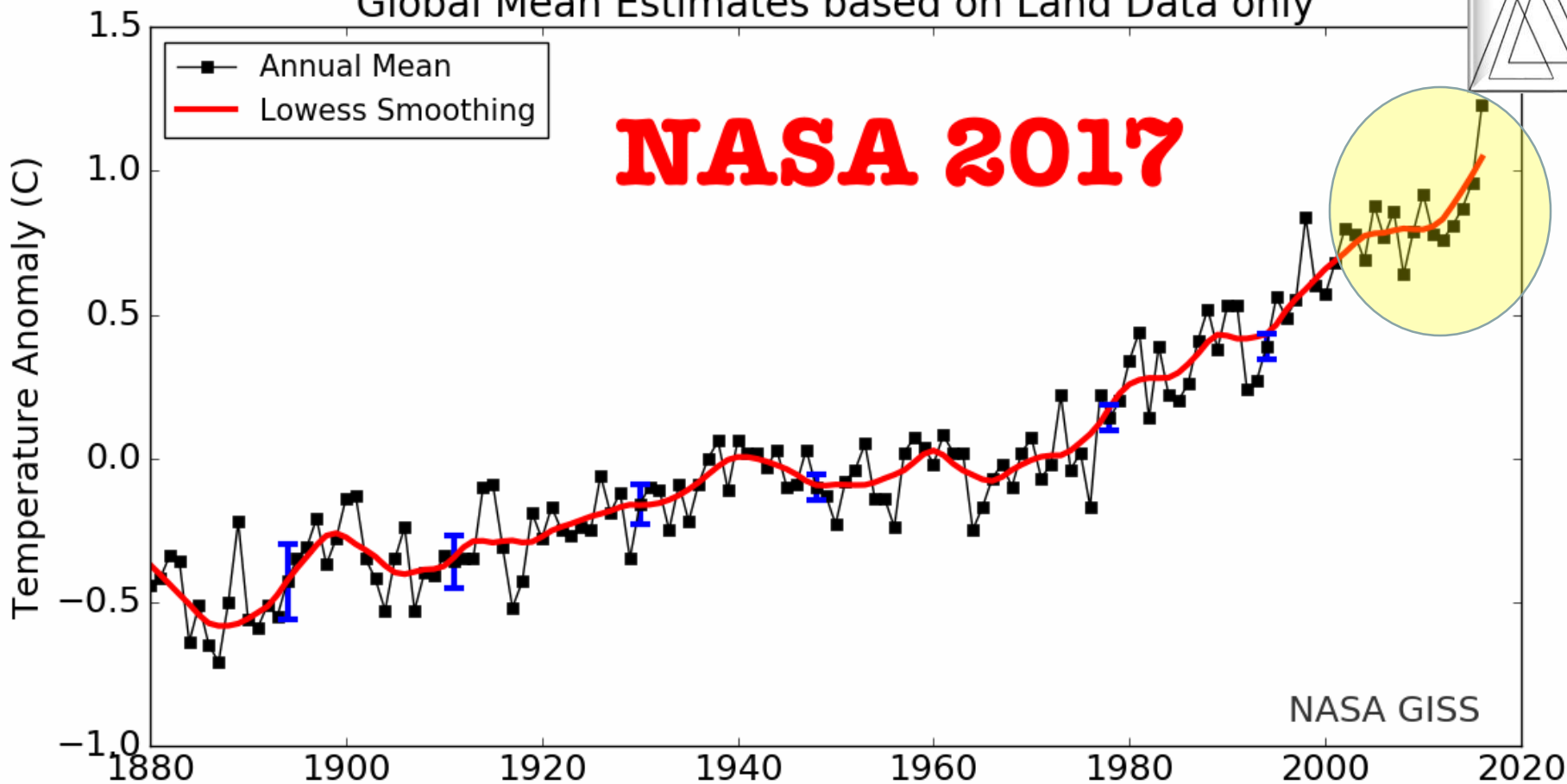
The Potential For Criminal Enterprise is High

- **Transnational criminal organizations and subsidiary organizations, including transnational drug cartels, have spread throughout the Nation, threatening the safety of the United States and its citizens.**
- **These organizations derive revenue through widespread illegal conduct, including acts of violence and abuse that exhibit a wanton disregard for human life.**
- **These groups are drivers of crime, corruption, violence, and misery. In particular, the trafficking by cartels of controlled substances has triggered a resurgence in deadly drug abuse and a corresponding rise in violent crime related to drugs.**
- **Likewise, the trafficking and smuggling of human beings by transnational criminal groups risks creating a humanitarian crisis. These crimes, along with many others, are enriching and empowering these organizations to the detriment of the American people.**

A comprehensive and decisive approach is required to dismantle these organized crime syndicates and restore safety for the American people.

Presidential Executive Order on Enforcing Federal Law with Respect to Transnational Criminal Organizations and Preventing International Trafficking Feb 2017

Global Mean Estimates based on Land Data only



For all of us...there has to be some measure of concern regarding environment change...



Future
Conditions

CONCERNS



- **Rise of New Geopolitical Entities** (potential threats to stability).
- **Continuing Uncertainty** in North Korea (uncertain outcomes).
- **The Apparent Move Toward Strategic Projection Capability** by the Chinese.
- **The Reassertion of “Old Soviet” Goals** by Russia (harbingers?).
- **Instability** in Developing Africa (overwhelming challenges for local governance in some areas).
- **Developing shortages** in the necessities of life (water, food, medical treatment, minerals, fuels, etc.).
- **Corruption** in government and business.
- **Mutation and new diseases forms** and other changes in the biosphere.
- **The potential rise of “new terrorism”** with global implications.
- **Societal instability** (from a wide variety of causes and issues).

These global attributes may be interconnected and synergistic, depending on the conditions and circumstances extant...

Future
Conditions

What Does This Mean For Us?



- **Heavy-Hybrid Warfare** is not only possible but there are some emerging indications of it on the horizon.
- **Limited long-term conflict** is likely especially in the context of disputes that do not require a larger response.
- **Terrorism** (a broadly used term = savagery) is here with us and won't go away. It is represented by many groups and thousands of people.
- **Likelihood** of espionage and information sabotage (and crime and information attack) are growing.
- **Weapons with Mass and Complex Effects** (WMCE) are proliferating – in ways and to degrees that we may not be fully cognizant of.
- **Transnational crime – of all kinds** – pose a “War-like” threat to the US and to our interests elsewhere.
- **New “technologically based weapons and capabilities” may have fundamental “change-agent” effects.**

Future
Conditions



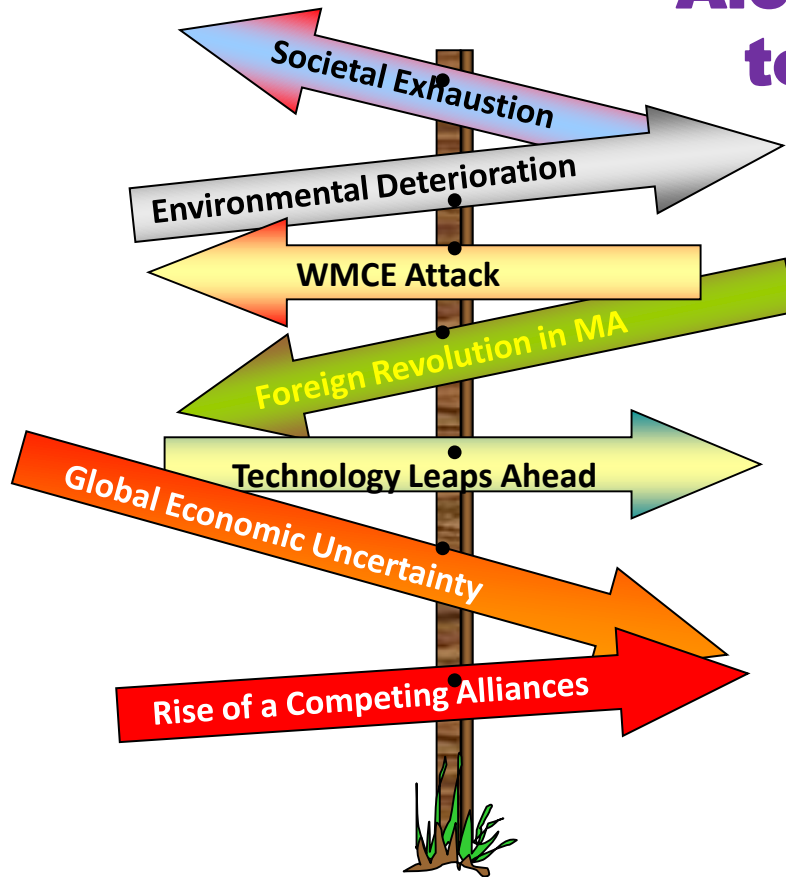
What Else Does This Mean For Us?

- **The “large-scale violence” level in the world is presently at a low to moderate level** – lower than may have been expected in 2018.
- **The potential for large-scale conflict** – on the **Korean Peninsula**, in the near-abroad of **Russia**, in the **Middle East**, on the periphery of **China** – and elsewhere – are current challenges we face.
- **The means of localized warfare and violent crime are present** in some places, including **Latin America** and **Africa**.
- **Long War trends are in place in some conflicts** – which, without dramatic closure, will persist.
- **Extremism and cultural difference and their attendant effects are widespread** and seemingly growing.
- **Uncertainty – as an over-arching condition – is pervasive** – even in some cases when it is merely a **matter of perception** as opposed to a physical or dependable condition.

Future
Conditions



Critical Signs Along the Pathway to the Future...



7/9/2018

Copyright © Intellectual
Property of PMH
Enterprises LLC

Future
Conditions

The Potential For Future Turmoil Is High



- **The meaning of this information is troublesome** but (I think) accurate – it presages the probability that adversaries and enemies will continue to engage in dispute, confrontation, occasional violence, crime, and warfare to seek their ends.
- **It also indicates that some past and present threats are evolving into the future and will be as problematic as ever – if not more so** – since they will include technologies and capabilities we have not yet dealt with and do not fully understand, including weapons with mass and complex effects (WMCE).
- **We need an immediate and clear-eyed assessment of these conditions** – in the context of their conditional and circumstantial complexity.

Future
Conditions



We Need...

...A collective sense of urgency among those charged with understanding and working against whatever may come...

Our tools...in order of practical utility, are:

Science & Technology

Intelligence

Diplomacy

Economic Policy

Military Applications

Other elements of national power...



**Future
Conditions**

Thank you all for your service to the community and the nation...and best wishes for the future. PMH



What's over the horizon?



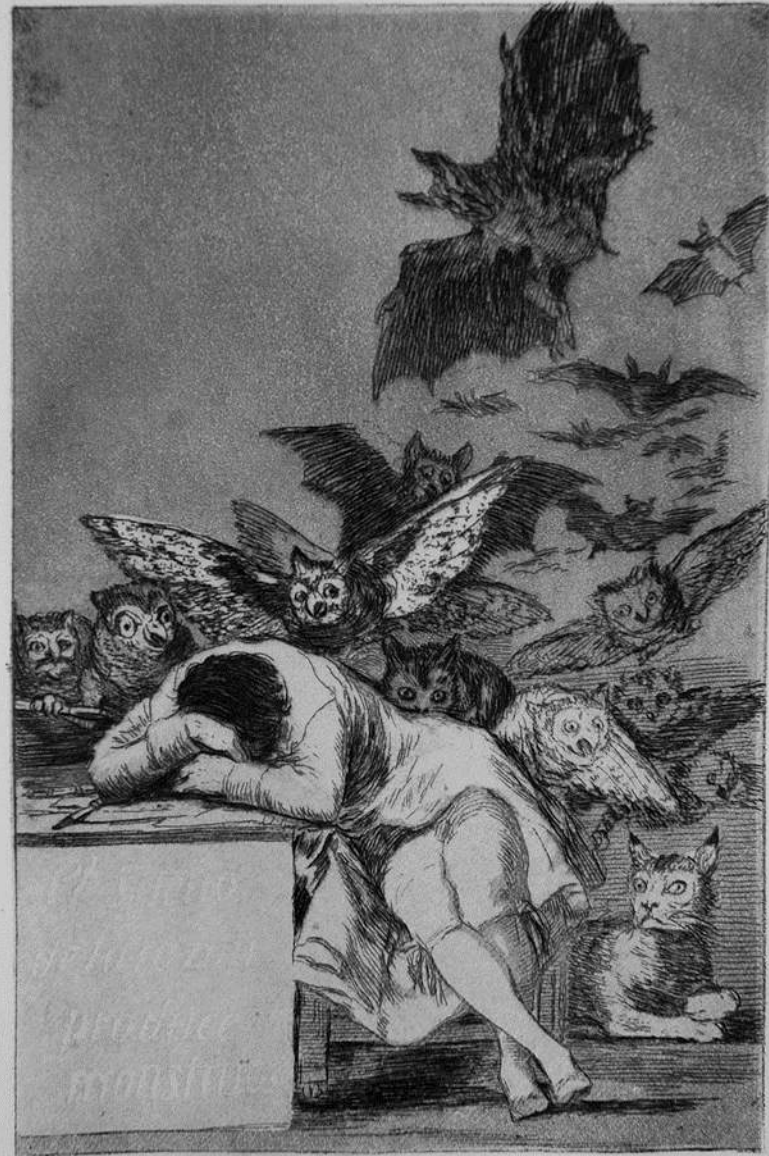
**Future
Conditions**

7/9/2018

Copyright © Intellectual Property
of PMH Enterprises LLC

51

BACKUP



Patrick M. Hughes
Lieutenant General, U.S. Army (Retired)
Email: HPATM@aol.com
Phone: 703-407-5229

2017 Fragile States Index
from Fund For Peace / Wikipedia



1 South Sudan

2 Somalia

3 Central African Republic

4 Yemen

5 Sudan

6 Syria

7 Congo (D.R.)

8 Chad

9 Afghanistan

10 Iraq

7/9/2018

11 Haiti

[https://en.wikipedia.org/
wiki/Fund_for_Peace/](https://en.wikipedia.org/wiki/Fund_for_Peace/)

12 Guinea

13 Nigeria

14 Zimbabwe

15 Ethiopia

16 Guinea-Bissau

17 Burundi

18 Pakistan

19 Eritrea

20 Niger

Future
Conditions

54

Clarke's Three Laws



Three "laws" of prediction formulated by the British writer Arthur C. Clarke. They are:

“When a distinguished but elderly scientist states that something is possible, he is almost certainly right. When he states that something is impossible, he is very probably wrong.

The only way of discovering the limits of the possible is to venture a little way past them into the impossible.

Any sufficiently advanced technology is indistinguishable from magic.”

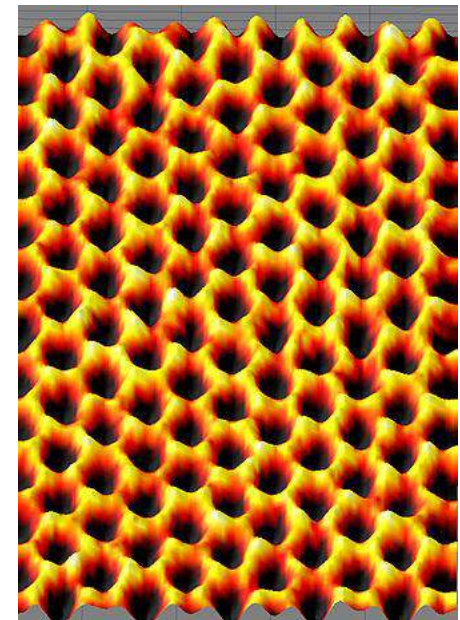
Future
Conditions

Moore's Law



- **Moore's Law turns 50** – dating from 19 April 1965 when first published – asserting that “the number of transistors that can be etched on a given surface area of silicon would double every year – later corrected to every two years.”
- **Some signs of aging of the “Law”** – economics says transistors can be shrunk further but they are getting more expensive – bucking a key element of the original Moore's Law which postulated that they would become less expensive.
- **Current state of the art is to produce transistors that are “only” 14 nanometers (billionths of a meter) wide** – but technologists say they can trim this to about 5nm – “about the thickness of a cell membrane.” Stacking and 3D chip manufacturing are also aiding in keeping the “Law” going.
- **A direct competitor to this trend toward smallness is ‘cloud computing,’** in which there is no particular premium on space and size. Cooling the racks of servers involved in the “cloud” is a key concern – but so far the corollary of Moore's Law – that transistors will follow the same exponential law in regard to energy efficiency – seems to be holding up.
- **Expectations are that the “Law” will hold up for another 10 years.**

Economist Magazine, 18 April 2015 / Wikipedia 2018



Scanning probe microscopy
image of
graphene in its hexagonal lattice structure

Future
Conditions



Complete Presentation

