



# U.S. ARMY COMBAT CAPABILITIES DEVELOPMENT COMMAND – ARMY RESEARCH LABORATORY

ACCURATE TECHNOLOGY FORECASTING TO ENABLE ARMY  
OPERATIONAL OVERMATCH INTO THE DEEP FUTURE

Dr. Troy Alexander  
ARL FUTURES CELL, CHIEF  
ARL FUTURES CELL



# MULTI-DOMAIN OPERATIONS

## DOMAIN-TIME-SPACE EXPANSION



EXPANDED BATTLEFIELD

EXPANDED DIMENSIONS

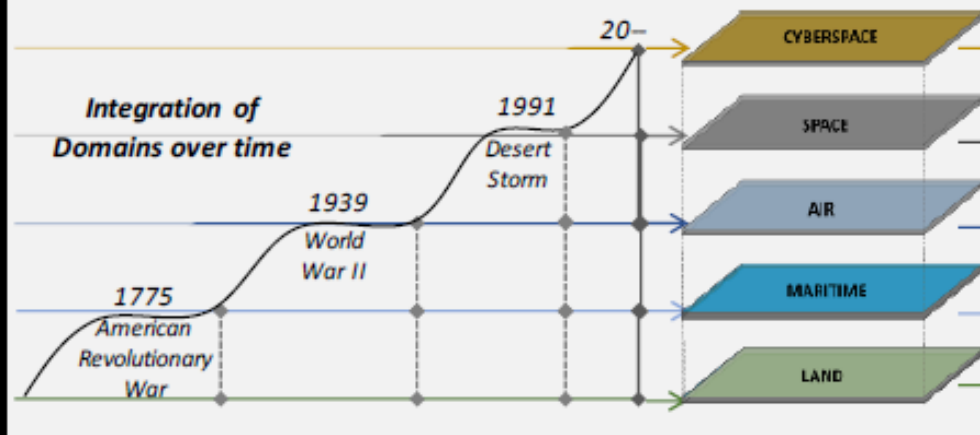
EXPANDED TIME

SMALLER ARMIES

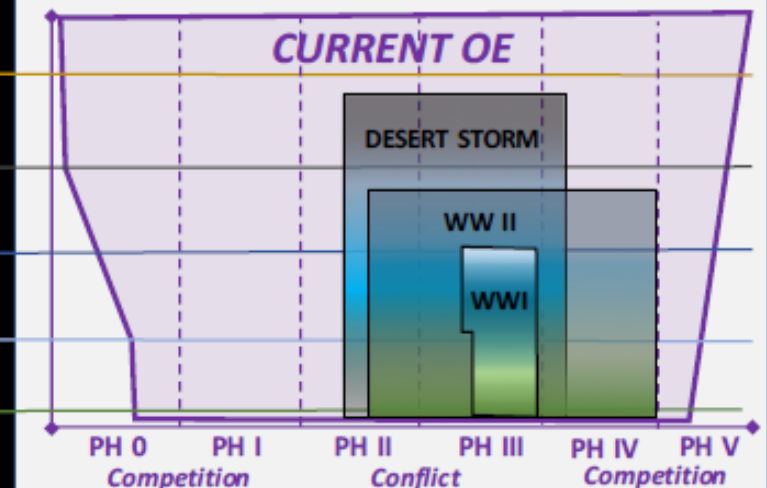
***“...future Joint Forces will leverage better integration to improve cross-domain synergy - the complementary vice merely additive employment of capabilities across domains, time, and space...our ability to project force across domains generates our decisive advantage.”***

*Capstone Concept for Joint Operations: Joint Force 2020, (Washington, DC: U.S. Department of Defense, 2012, page 7).*

### Domain Expansion (Evolution)



### Time-Space Expansion (What is “new”)



***The expansion of time, space, and domains in warfare requires US Forces to operate in a state of competition prior to armed conflict...and remain in competition following conflict.***

Complete

Penetrate

Dis-Integrate

Exploit

Re-Compete



# TECHNOLOGY FORECASTING CONSTELLATION-OF-COLLABORATION



Future Operational  
Environment (FOE) Cell

CDIDs

Directorate of  
Concepts

**Futures and  
Concepts Center**

CCDC  
Centers

ERDC

NGIC

ODNI

MSIC

**Intelligence  
Community**

OSD Strategic  
Intelligence Cell

**Army S&T  
Enterprise**

MRMC

SMDC

ARI



PIAs

**Strategic  
Partners**

National Academies

Open Campus

**Universities**

UARCs

CCDC ARL  
Extended



# ACCURATE TECHNOLOGY FORECASTING



A robust, scientifically-based approach, dedicated to providing forecasts of probable technological developments – from the near-term to the deep future, with a focus on Army and national security implications

- **Scientifically-based projections**
- **Broad Technical Considerations**
- **Long-range timeframe** – grounded, 5 to 40 year estimates
- **Joint Force-focused, Army-centric** – deep consideration of future Multi-Domain Operational (MDO) warfighting capabilities
- **Intelligence-informed ( $I^2$ ) estimates** – begin with consideration of known threats as a foundation to develop S&T estimates
- **Periodic Product Propagation ( $P^3$ )** – periodic dissemination and socialization of S&T estimates on a scheduled basis
- **Forecast Accuracy Assessment**



# FUNDAMENTAL TECHNOLOGY FORECASTING ASSUMPTIONS

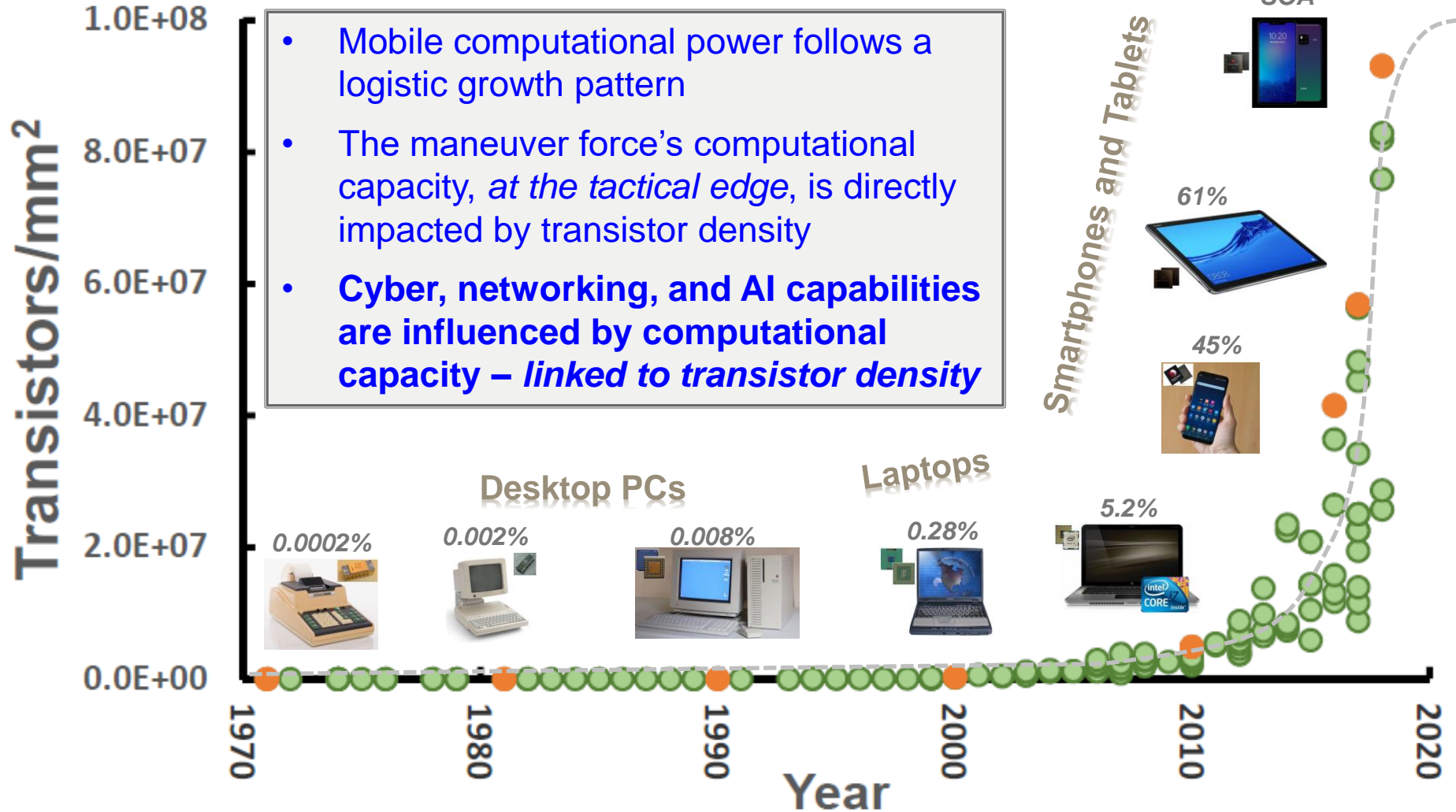


1. The *Nature of War* will not change – it will continue to be primarily a human endeavor
2. Fundamental changes in the *Character of War* will progressively emerge
3. The Army will operate in joint, multi-domain, high-intensity environments to achieve its mission
4. Government investment and S&T activities are critical to continued innovation and invention
5. The nation's land power dominance will continue to rely on significant S&T advances that ensure the maneuver force's competitive advantage
6. Technology will continue to mature through a logistic (sigmoidal) progression
7. Technology performance is proportional to technology adoption



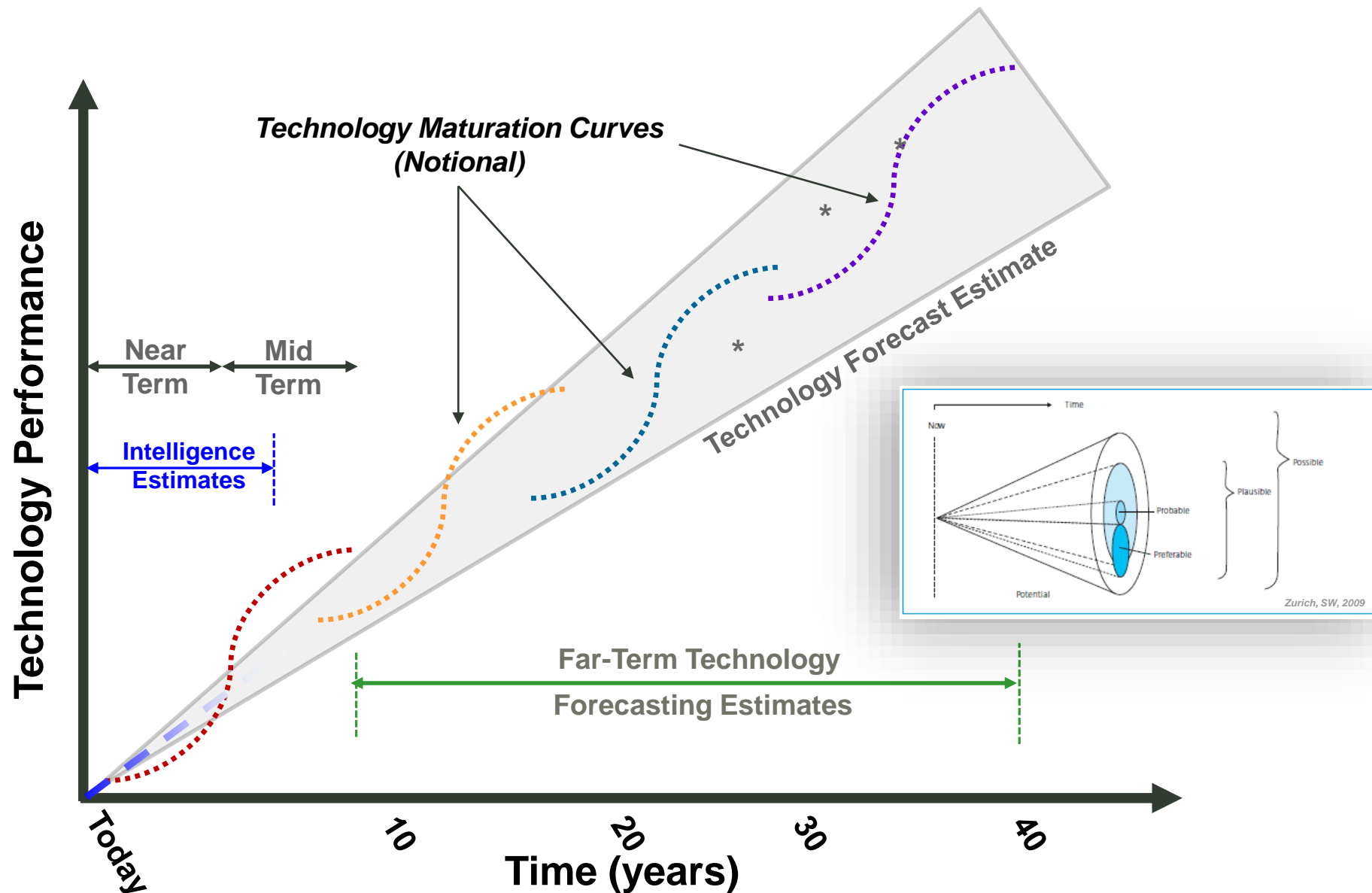


# NON-LINEAR TECHNOLOGY MATURATION





# ACCURATE TECHNOLOGY FORECASTING ACROSS MULTIPLE TIME REGIMES

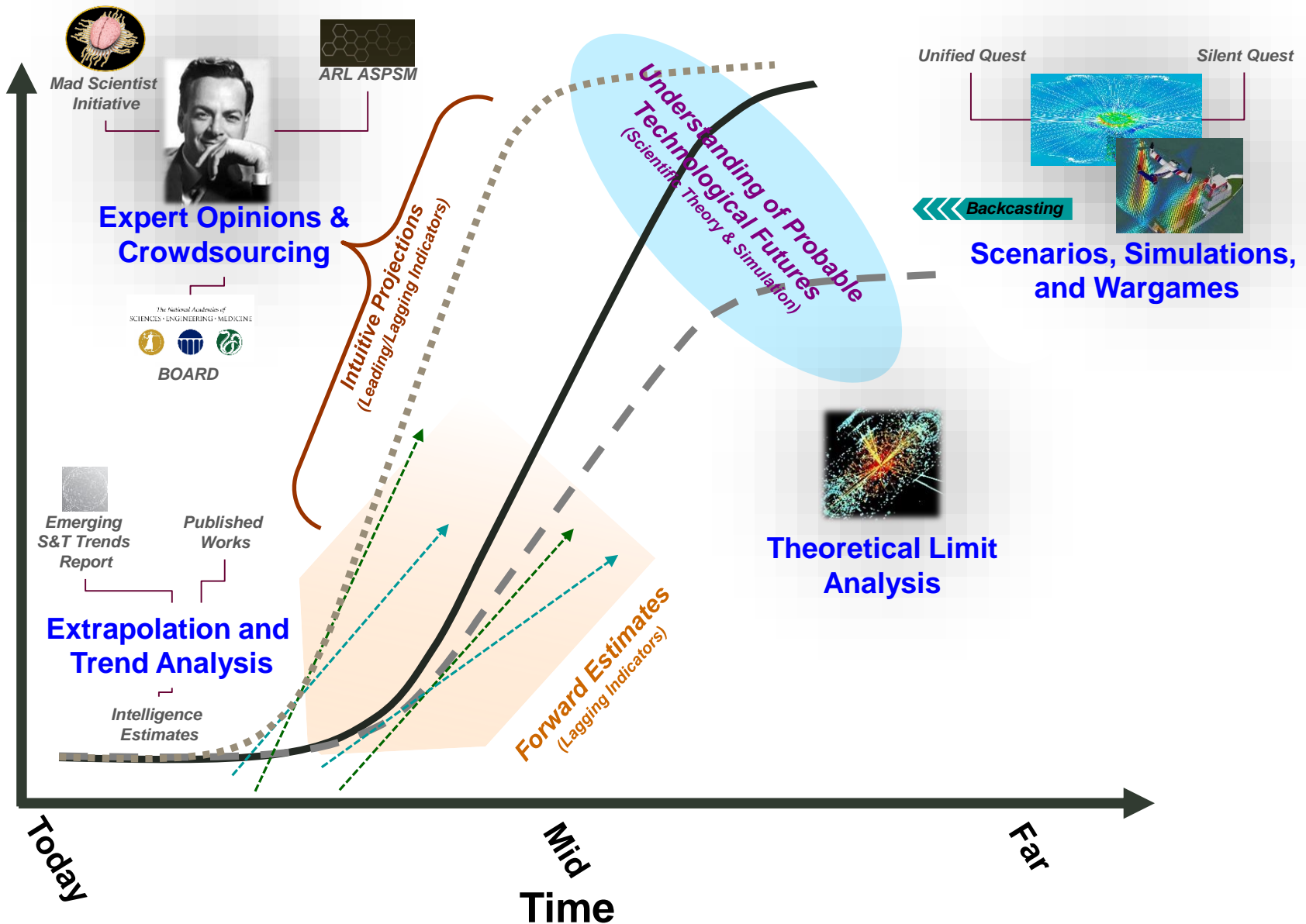




# TECHNOLOGY FORECASTING METHODS



Technology Performance







# NEAR-, MID-, AND FAR-TERM FORECASTING METHODS



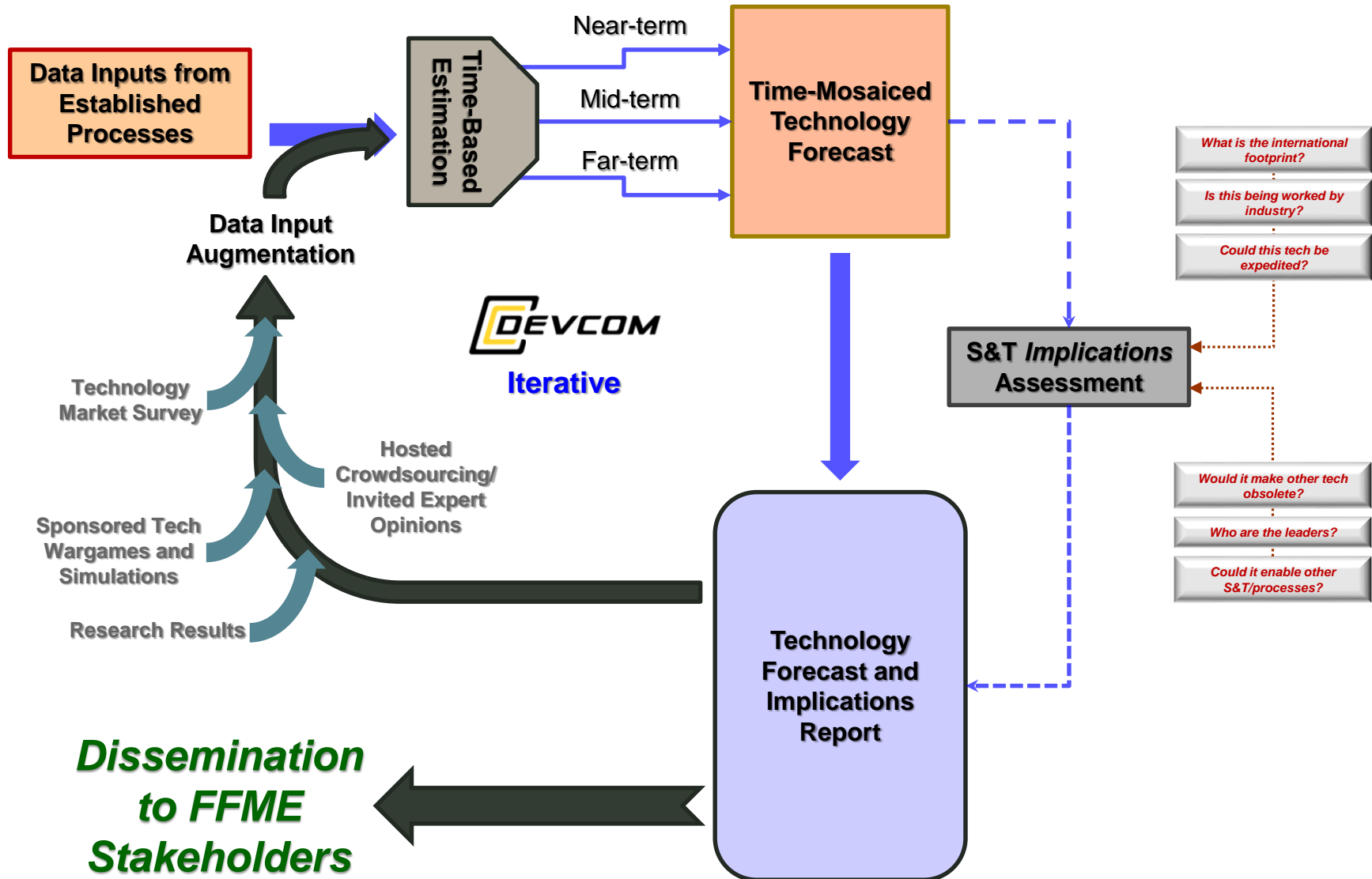
*...multiple methods are simultaneously needed to provided accurate forecasts...*

## Forecasting Method

		Forecasting Method				
		Extrapolation & Trends Analyses	Crowdsourcing	Expert Opinions	Scenarios, Simulations, & Wargames	Theoretical Limit Analyses
Technology Forecast Timeframe	Near-Term (0-5 years)					
	Mid-Term (5-10 years)					
	Long-term (10-20 years)					
	Far-Term Deep Future (20+ years)					

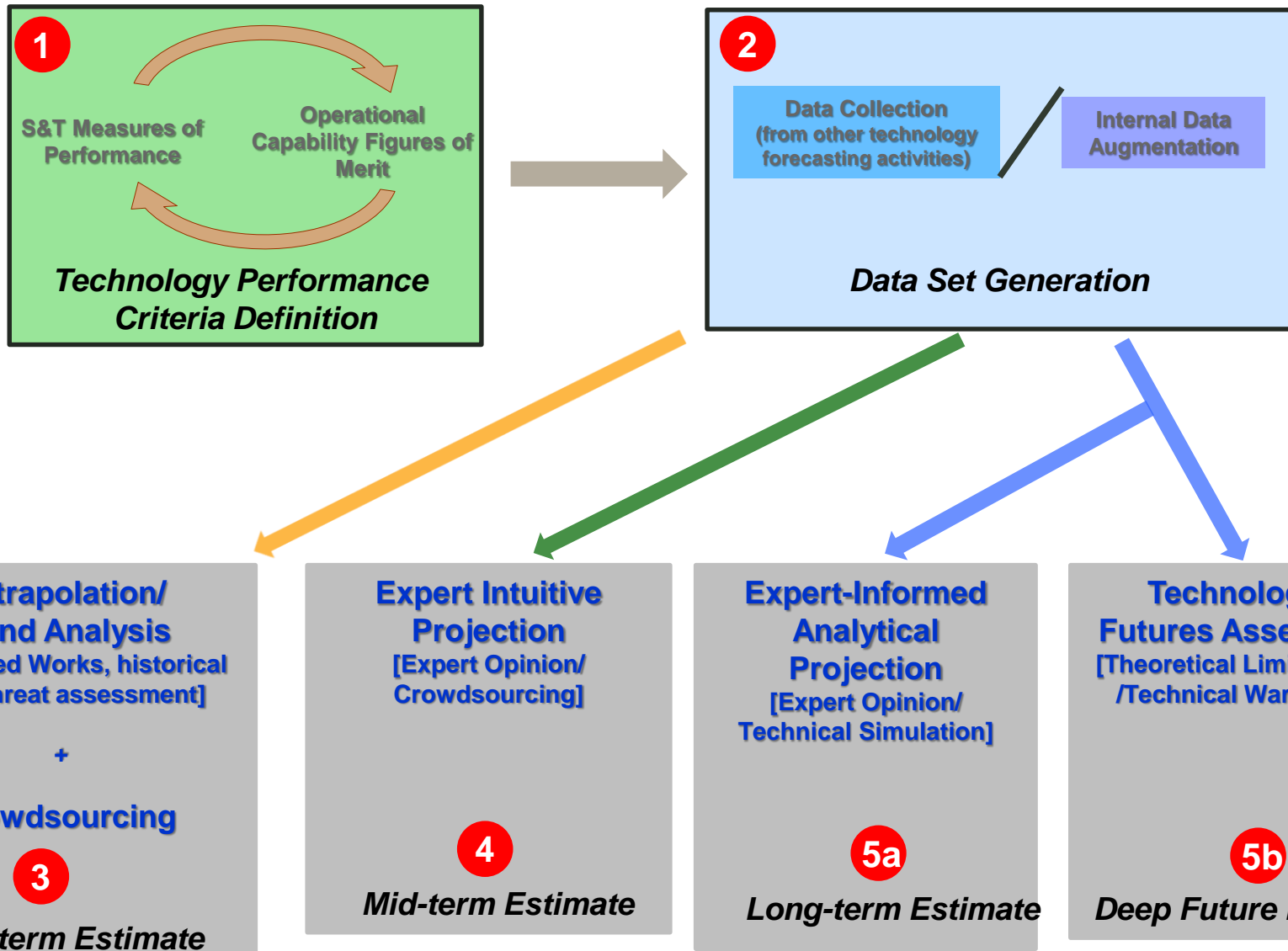


# TECHNOLOGY FORECASTING FRAMEWORK





# TIME-MOSAICED TECHNOLOGY ESTIMATION METHODOLOGY





# DIRECTED ENERGY TECHNOLOGY FORECASTING PILOT



Science



Technology



Capability

**Identification of  
Technology  
Measures of  
Performance**

**5a**

## Directed Energy Long-term Estimate

- Expert-informed simulation
  - Leverage leading-edge modeling and simulation methods, guided with expert opinion, to ascertain probable advances in 10-20 year space
  - Guided theoretical limit analyses
  - DE experts – NAS; UARCs; ARL Extended network; trusted experts
- Partners: National Academies; UARCs; ARLExtended; Army HPC; PIA; FCC/G2

**5b**

## Directed Energy Deep Future Estimate

- Assessment of probable technological futures
  - Host technical wargame
  - Technology backcasting
  - Ascertain most probable advances in 20-40 year space
- Partners: National Academies; UARCs; ARLExtended; Army HPC; PIA; FCC/G2

**4**

## Directed Energy Mid-term Estimate

- Guided, expert intuitive projections
  - Engage diverse communities to ascertain probable advances in 5-10 year space
  - Host expert discussions/selective crowdsourcing
  - Leverage DE expert projections – NAS; Mad Scientists
- Partners: National Academies; Mad Scientists; OSD COIs; DARPA; SMDC; PIA; FCC/G2

**3**

## Directed Energy Near-term Estimate

- Analyze historical data/published works/threat knowledge base
- Establish current SOA and expected near-future progress
- Query authoritative data bases
- Ingest threat assessments
- Leverage “Emerging S&T Trends Report”

Partners: IC/NGIC; ASA(ALT); PIA; FCC/G2

**Time-Mosaiced  
Technology Forecasts**



# PIA SUPPORT TO DIRECTED ENERGY PILOT

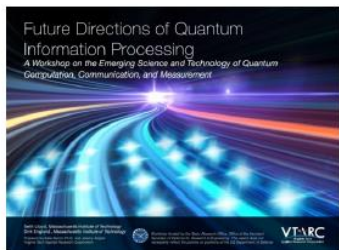


Strategy, Policy, and Planning

4

## Facilitated Technical Workshops

- Expert facilitation, high-quality reporting
- Workshop themes include:
  - Future directions in science and technology
  - Future capability road mapping
  - Red teaming



## Scenarios & Wargames – Mid to Long Term Futures



### 1 Red v. Blue (and White) Wargames

These table-top, turn-taking games begin with a scenario often simulating a real military challenge

### 2 Modeling & Simulation

Modeling and simulation provides a way to exhaustively explore various parameters impacting

### 3 Path Games

This game can be used to consider the long-term journey of technological development. For

### 4 Reverse Path Games

For this game, begin with the long-range technology you want to help enable with your portfolio

### 5 Matrix Games

A collaborative game similar to traditional Red v. Blue table-top games, where the players start of

### 6 Serious Games (e.g., IARPA Sirius Program)

As a wargame is being played out, players may not be able to detect that the decisions they make in a game could potentially be laced with internal cognitive biases that influence what could otherwise be objective thinking. Serious Games involve methods that get players to critically challenge their assumptions and mitigate cognitive biases throughout the course of a game. Such games help mitigate the bias that could creep into the decision making in a traditional war game. As a result, AFOSR Program Officers might benefit their own wargames, by using these techniques to recognize their own cognitive biases and foster more productive and creative thinking.

5b





# MID-TERM AND DEEP FUTURE DIRECTED ENERGY EVENT SCHEDULE

