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Control Research and Technology
Symposium*

**Information Age Transformation
C2 Experimentation
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***“How Much is a Pound of C4ISR
Worth?”***

*An Assessment Methodology to
Evolve Network Centric
Measures and Metrics
For Application to FORCEnet*

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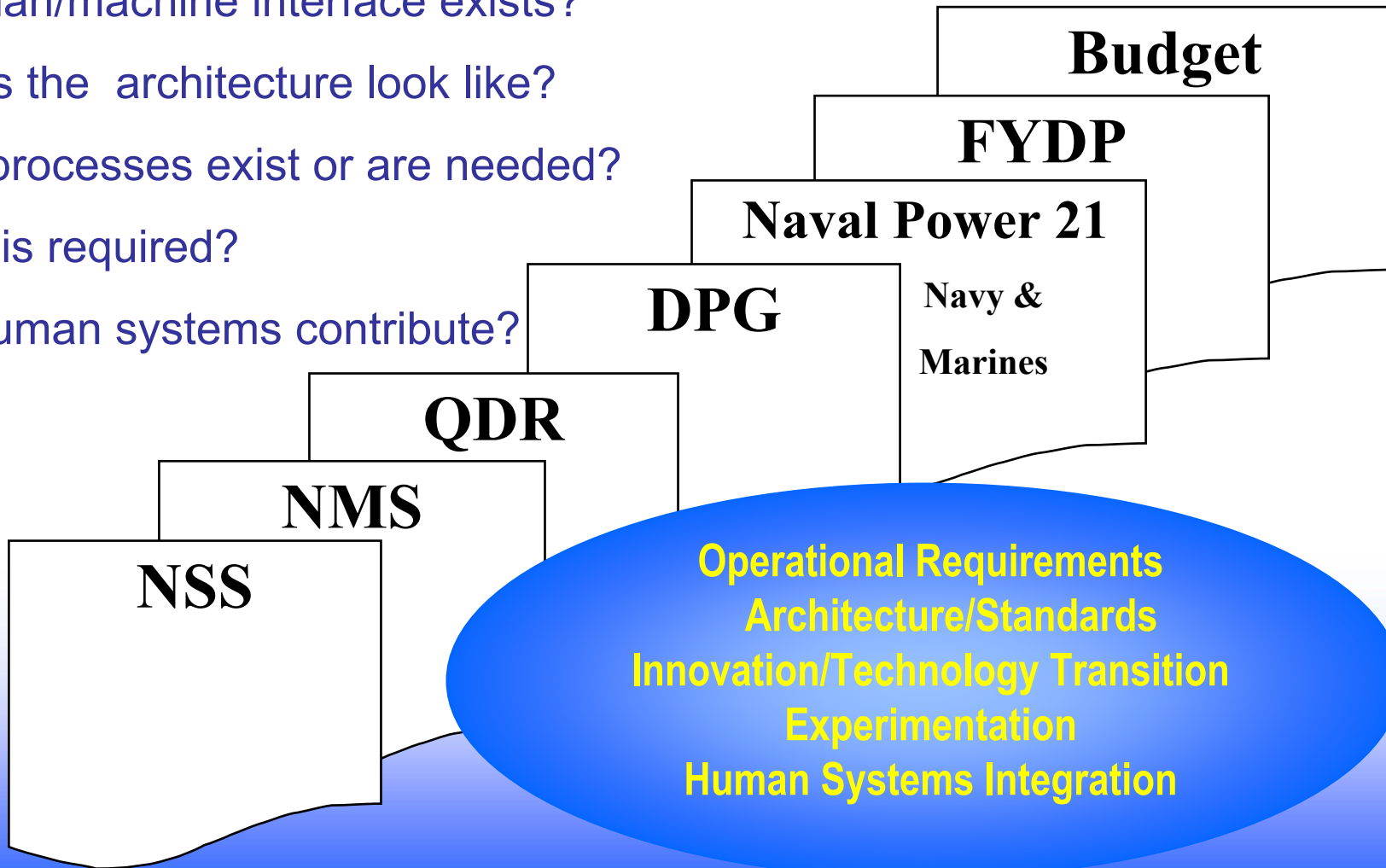
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United States Naval Academy*

Why Measure Value?

Budgeting for C4ISR Operational Effect

- How much weapon system automation exists?
- What human/machine interface exists?
- What does the architecture look like?
- What C2 processes exist or are needed?
- What info is required?
- How do human systems contribute?



Enduring Drivers of C4ISR Value Assessment

- ***Ability to sense***
 - through globally distributed technological-cognitive systems;
- ***Ability to understand***
 - individual perception, shared awareness, and aggregation in organizations to result in knowledge mobilization;
- ***Ability to influence***
 - friend, foe, and others by conditioning of the operational space through behaviors, lines of authority, positioning,
- ***Ability to act rapidly, decisively, and appropriately***
 - as coordinated across tactical, operational, and strategic echelons;
- ***Ability to visualize***
 - the operational space in ways relevant to individual users;
- ***Ability to effect***
 - desired outcomes.

FORCEnet: Vision to Reality

A Holistic Approach*

FORCEnet Vision & Strategy

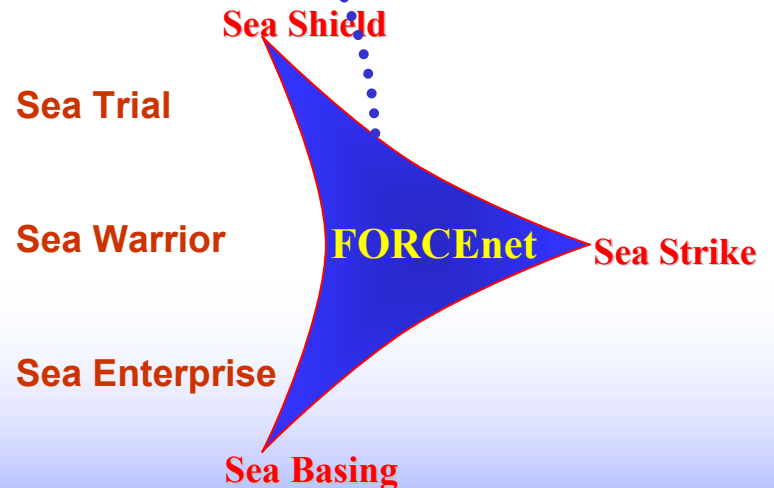
- Enable domination across full spectrum of warfare
- Develop New Operational Concepts out to 2020
- Focus Technologies for Enhanced Capabilities
- Develop Broad Program & Resource Plans

FORCEnet Functional Objectives

- Decision Superiority
- Increased Options
- Increased Agility
- Improved Coordination
- Knowledge Mobilization

FORCEnet Requirements

- Mission Capability Packages / Naval Capability Studies
- Human* Capability Packages



Navy Leaders
make appropriate
course corrections

* Human Capability Packages – a means to achieve mission capability – by equipping the man

*FROM NDIA FORCEnet Study Human Element Group Report.

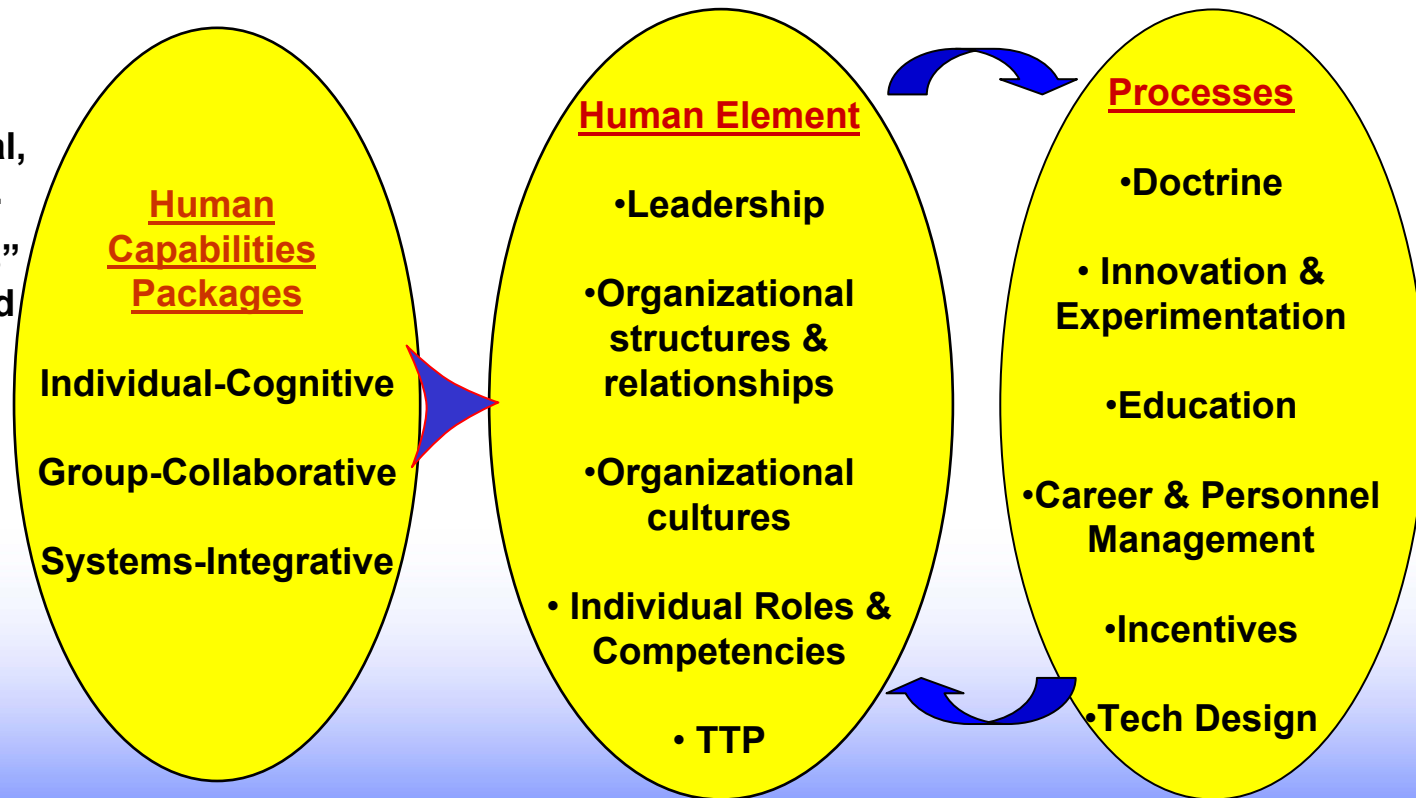
FORCEnet C4ISR “Tradespace” *

Analytical Dimensions

- Perspective (individual, organizational, and systems).
- Knowledge management processes (cognitive, collaborative, and integrative).
- Operational scope (tactical, operational, and strategic).
- Network centric “domains” (cognitive, information, and physical).

FORCEnet Objectives

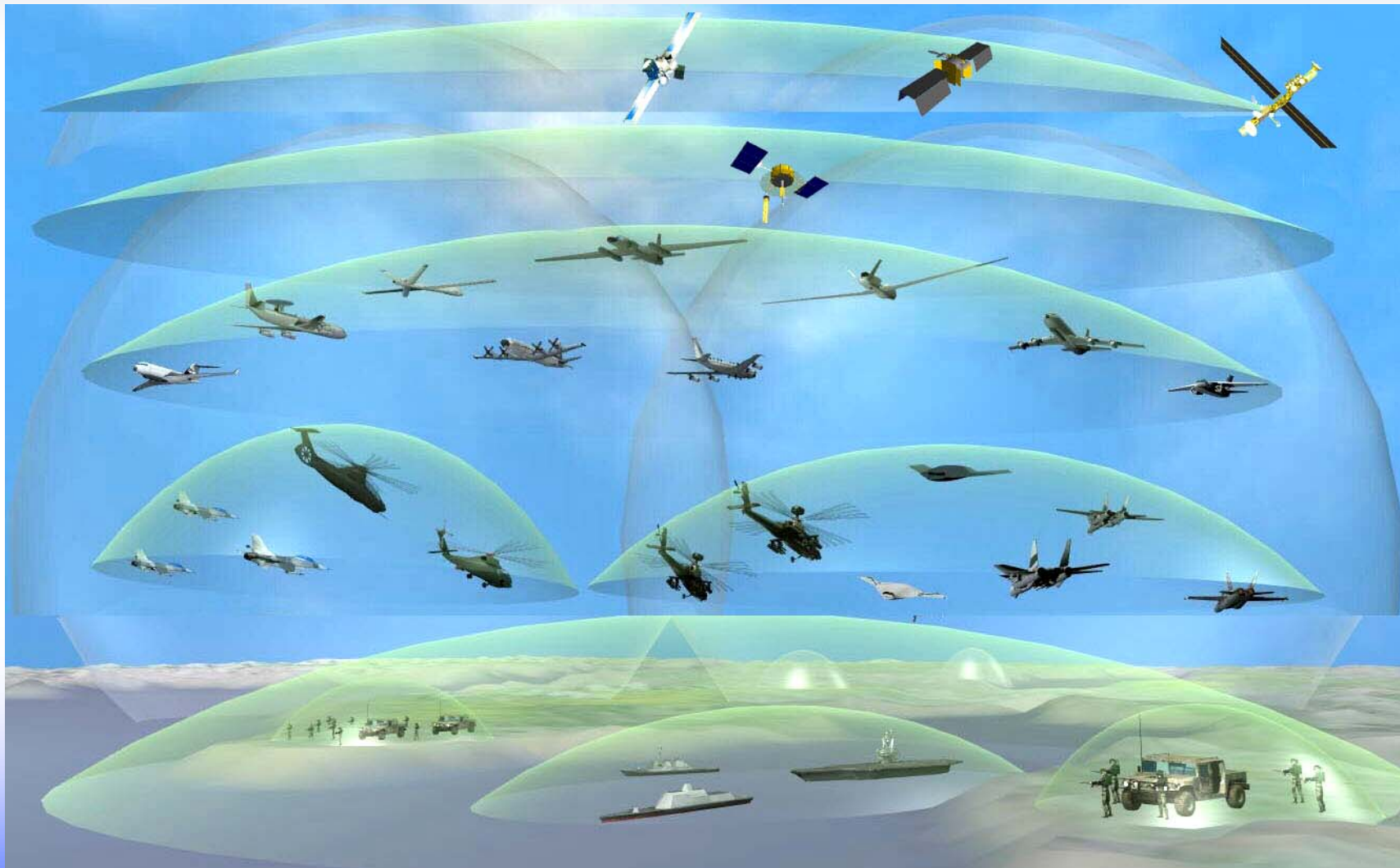
- Decision Superiority
- Increased Options
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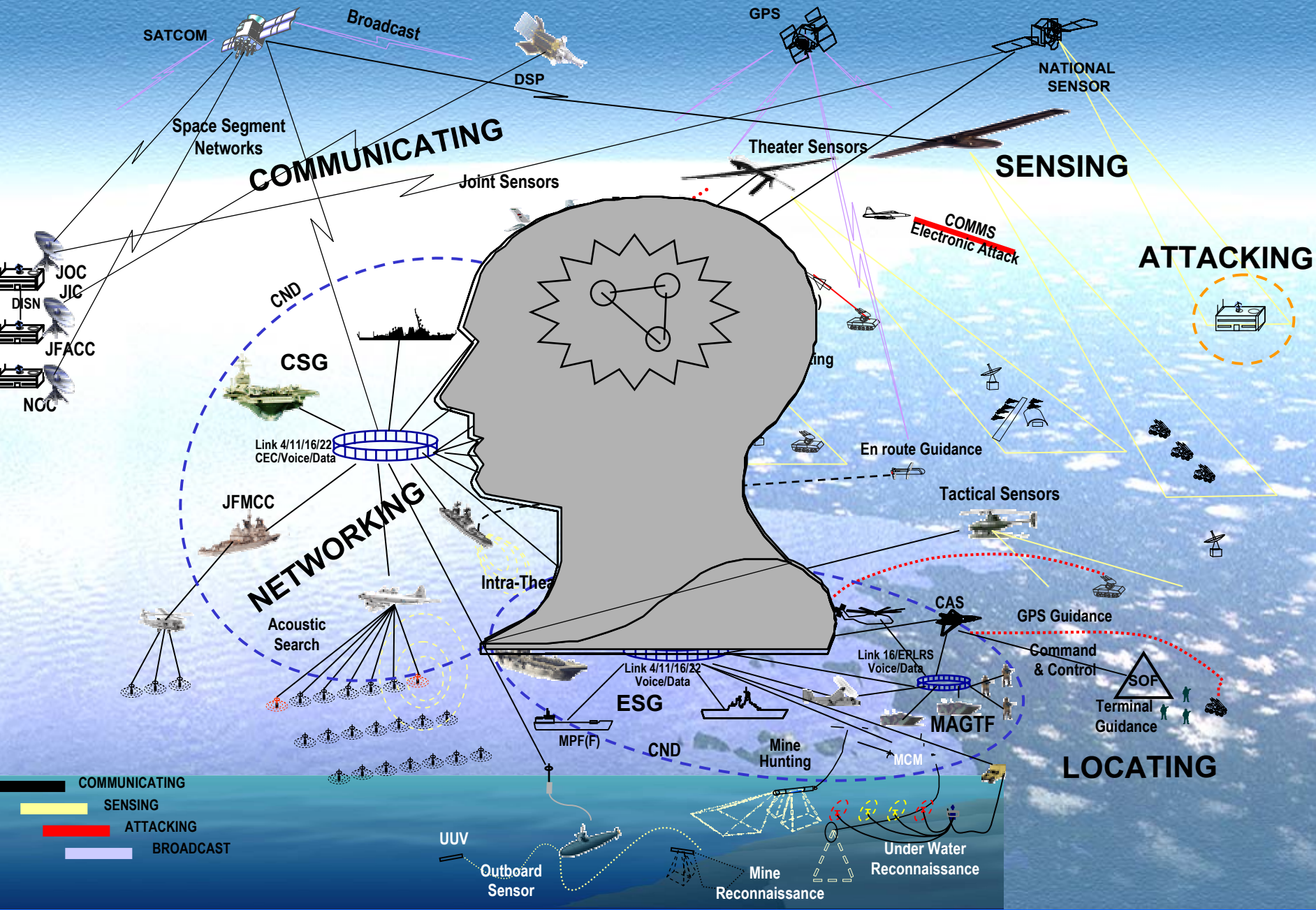
FORCEnet Case Study

- **Framework for Measuring C4ISR**
- **Relationship to the POM Process**
- **Functionally Decomposing Capabilities**
- **Measurements and Attributes**
- **Measuring Shared Situational Awareness**
- **Human Centric Experimentation**

Infosphere Vision



Decomposing the Infosphere



Measured Transformation – A Capabilities Driven Process

- For our purposes, we define a capability as:
 - *that combination of human, technological, organizational, process, and cognitive elements that provides the means to achieve a clearly articulated outcome in a defined context.*
- Implications:
 - Emphasizes ability to link, delink, and relink these elements in ways that are tailored to unique circumstances
 - Embeds the human individually and as part of an organization in a complex system of systems
 - Accepts intangible cognitive processes as a *leveraged* part of the system.
 - Establishes emphasis no longer on the “who” (i.e. traditional threat based approach) but rather on the “how”.

Attributes, Measures, & Metrics

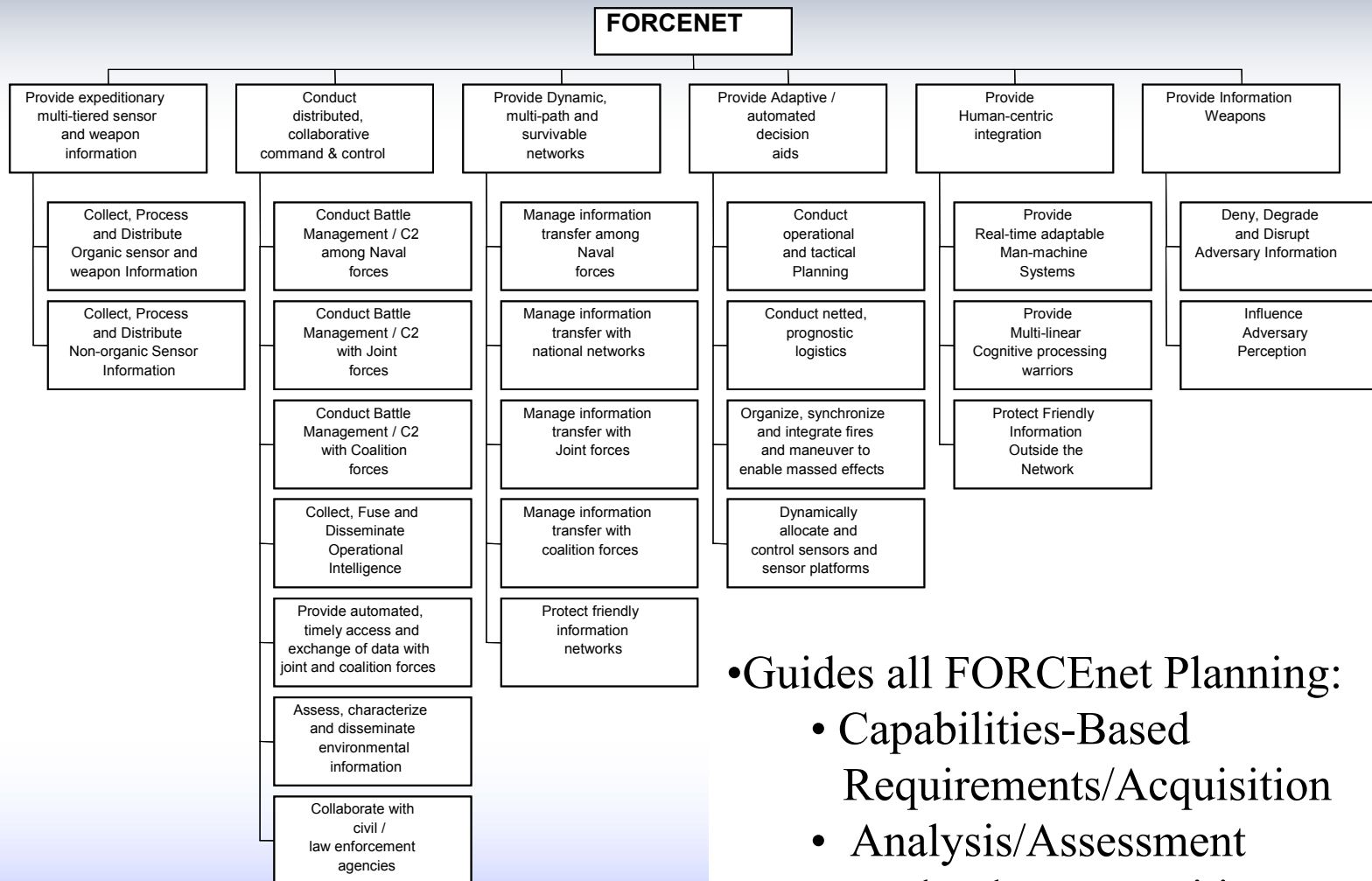
- **Attribute:** some aspect of an event, situation, person, or object considered important to understanding the subject under study
- **Measure:** a vehicle or standard by which some attribute of interest is recorded
- **Metric:** the application of a measure to two or more cases or situations to derive the mathematical dimensions, capacity, and amount of some thing, process, or effect
- Based on
 - ASD(C3I)/OFT Framework for NCW
 - CCRP and NATO Codes of Best Practice (C2 Assessment & Experimentation)
 - Others

A Hierarchical Capability Taxonomy

Defined FORCEnet Capabilities

1. Provide expeditionary, multi-tiered sensor and weapon information
2. Conduct distributed, collaborative command and control
3. Provide dynamic, multi-path and survivable networks
4. Provide adaptive/automated decision aids
5. Provide human-centric integration
6. Provide information effects

Current Top-Level FORCENet Capabilities/Requirements



- Guides all FORCENet Planning:
 - Capabilities-Based Requirements/Acquisition
 - Analysis/Assessment
 - Technology Transition
 - Experimentation/Innovation
- Refined/updated as part of an iterative, lessons-learned process

1. Provide expeditionary, multi-tiered sensor and weapon information

The expeditionary, multi-tiered sensor and weapons grid capability uses a full spectrum of manned and unmanned vehicles, platforms, sensors and weapons to provide the Force Commander with what is needed to locate targets and attack them across the depth and breadth of a theater-sized battlespace. Sensors must determine their position, time and movement at the precise time they are reporting their target or other intelligence information. The time and position information of the track provided by sensors in the grid must be properly attributed (e.g., linked to a standard reference frame with uncertainty (error) and confidence level) for it to be accurately understood, represented and fused with other data / information. Many modern weapons are also dependent on precise time and position (including uncertainty) for effective operation.

Attribute	Notional Measures
Accuracy	Correspondence with ground truth-correlation coefficient (0 = no correspondence with ground truth, 1 = full correspondence with ground truth). Data matrix comprised of relevant information items estimates (for instance: detection, ID, velocity, location, heading, etc.)
Consistency	Degree of lack of ambiguity with previous information
Completeness	Percentage of ground truth relevant and necessary for ongoing task
Precision	Error and confidence level for time and position information compared to a standard reference
Timeliness	Degree to which currency matches what is needed (0 = no match, 1 = high degree of matching between currency level needed and available)

2. Conduct distributed, collaborative command and control

To collaboratively manage land, air, sea, and space operational forces in time, space, and purpose to produce maximum relative combat power and minimize risk to own forces. This activity ensures all elements of the operational force, including supported agencies' and nations' forces, are efficiently and safely employed to maximize their combined effects beyond the sum of their individual capabilities.

Attribute	Notional Measures
Shared Situational Awareness	Degree to which the different individual mental models of the situation are integrated into a common operational picture.
Quantity of Posted Information	Percent of collected information posted
Quantity of Retrievable Information	Percentage of nodes that can retrieve various sets of information.
Understandability	Degree to which information is easy to use (0 = low degree of ease of use, 1 = high degree of ease of use)
Precision	Error and confidence level for time and position information compared to a standard reference
Timeliness	Degree (speed of effect) to which currency matches what is needed (0 = no match, 1 = high degree of matching between currency level needed and available)

3. Provide dynamic, multi-path and survivable networks (2/2)

To provide data and information flow seamlessly and transparently to the warfighter across a fault tolerant, adaptable, self-organizing, holistically engineered continuously available network. The data and information flows across a wide range of transmission paths in an interoperable manner with naval, joint, coalition and civil / law enforcement agencies. Platforms and vehicles communicate freely and autonomously with other elements of the architecture thus the existence and functions of the underlying network are transparent to the warfighter.

Attribute	Notional Measures
Robustness	Number of differing conditions/environments over which network is capable of operating at a given level of effectiveness (baseline level determined by SME, simulation, analysis, empirical analysis, etc.) Effectiveness of network across varying levels of attack/degradation (baseline level determined by SME, simulation, analysis, empirical analysis, etc.) Number of tasks/missions which the network is capable of operating at a given level of effectiveness (baseline level determined by SME, simulation, analysis, empirical analysis, etc.)
Responsiveness	The timeliness of the response to an environmental change (baseline level determined by SME, simulation, analysis, empirical analysis, etc.)
Flexibility	Number of options for responding to an environmental change Compatibility of different responses (0 = not compatible, 1 = fully compatible; determined by SME, simulation, analysis, empirical analysis, etc.)
Innovativeness	Number of novel responses developed and implemented (baseline determined by SME, simulation, analysis, empirical analysis, etc.)
Adaptiveness	Number and timeliness of changes to network structure and processes (baseline determined by SME, simulation, analysis, empirical analysis, etc.)

4. Provide adaptive / automated decision aids (1/2)

To support warfighter decision making by providing recommended courses of action that are adaptive and based upon knowledge of the operational context, commander's intent, rules of engagement, order of battle, etc. and evolution of the battlespace landscape

Attribute	Notional Measures
Robustness	Degree to which decision aids support decision making across a range of situations and degradation conditions
Responsiveness	Degree to which decision aids support decision making which is relevant and timely
Innovativeness	Degree to which decision aids support decision making that reflects novel ways to perform known tasks
Adaptability	Degree to which decision aids support a decision making process with the flexibility to alter decision making in response to the evolution of the battlespace landscape
Consistency	Extent to which decision aids support decision making are internally consistent with prior understanding and decisions

4. Provide adaptive / automated decision aids (2/2)

To support warfighter decision making by providing recommended courses of action that are adaptive and based upon knowledge of the operational context, commander's intent, rules of engagement, order of battle, etc. and evolution of the battlespace landscape

Attribute	Notional Measures
Currency	Extent to which decision aids support decision making that minimizes latency (e.g. Notification - Time of detection = Cueing Time, Time of detection – receipt of refined positional estimate = Update rate, Time of cueing data – time of weapon firing = weapons release time, Firing report received by group commander – weapons firing time = Firing report time)
Precision	Error and confidence level for time and position information compared to a standard reference
Fitness for Use	Relative quality in reference to criteria that are determined by the situation
Appropriate-ness	Extent to which decision aids support decisions that are consistent with existing understanding, command intent and values
Completeness	Extent to which decision aids support relevant decisions that encompass the necessary: <ul style="list-style-type: none">•Depth: range of actions and contingencies included•Breadth: range of force elements included•Time: range of time horizons included

5. Provide human-centric integration (1/2)

Enhance the ability of warriors to multi-task through all phases of warfare while taking advantage of improved Human-Computer Interfaces which leverage the best of humans & computers. This will be possible through improved automation & development of multi-sensory human-computer interfaces.

Attribute	Notional Measures
Competence	Distribution of members knowledge, skills, abilities and attitudes.
Trust	Extent to which members are willing to rely on one another
Confidence	Extent to which members have expectations of the reliability of the organization
Size	Number of team members involved adequate to support mission
Experience	Degree to which team members have interacted in the past on the same task
Diversity	Degree to which team members are heterogeneous or homogeneous across exogenous variables: experience, age, gender, etc.
Autonomy	Extent to which organization is externally or self directed

5. Provide human-centric integration (2/2)

Enhance the ability of warriors to multi-task through all phases of warfare while taking advantage of improved Human-Computer Interfaces which leverage the best of humans & computers. This will be possible through improved automation & development of multi-sensory human-computer interfaces.

Attribute	Notional Measures
Structure	Numbers of layers of authority Functional Differentiation Effectiveness
Interdependence	Extent to which members depend on one another for resources
Cooperation	Extent to which member(s) are willing and able to work together
Efficiency	Extent to which members utilize one another's resources so as to minimize costs and maximize benefits
Synchronization	Extent to which organization is conflicted, deconflicted, or synergistic
Engagement	Extent to which all members actively and continuously participate
Risk Propensity	Extent of risk aversion

6. Provide information weapons:

To integrate the use of military deception, psychological operations, electronic warfare, and physical destruction, mutually supported by intelligence, in order to deny information, influence, degrade, or destroy adversary information, information-based processes, and information systems. (Metrics are under development.)

Attribute	Notional Measures
Lethality	Extent of capability to precisely deliver desired Non-Kinetic (NK) Information Operations (IO) effects.
Coverage	Extent of capability to accomplish IO effects.
Persistence	Extent of capability to sustain IO effects.
Timeliness	Extent of capability to deliver desired NK IO effects at a desired time.
Survivability	Extent of capability to avoid enemy threats, counter ISR, and employ IO techniques to reduce targeting of adversary kinetic systems allowing increased secure maneuvering by ASMD/Deny ISR/SEAD/Networks.

Ontology: Levels of Shared Situational Awareness Defined

Level	SA Focus	SA Process
<p>5 Trans-formational</p>	<p>Agent based communication; establishing a process for adapting processes to support operational contingencies; establishing knowledge delivery mechanisms to provide knowledge to strategic partners; process optimization</p>	<ul style="list-style-type: none"> •Evaluation of performance and effectiveness on a continuous basis •Identifying adjustments and potential improvement to the fusion process •Determining source specific data requirements for processing <p>Recommending allocation and direction of resources in support of the mission</p> <p>Understanding mission, opportunities and risks, adversary's capabilities and limitations, analysis of possible outcomes, and <u>adversary's intent</u></p>
<p>4 Predictable</p>	<p>Concepts embedded in data translated into a common ontology; data mining for patterns and relationships; presentation of knowledge based upon the user's learning profile; network of multiple portals enabling the real-time aggregation of disparate knowledge</p>	<ul style="list-style-type: none"> •Estimating capabilities, i.e. number and location •Predicting enemy intent based on actions, communications and enemy doctrine •Identifying threat opportunities - ID of potential opportunities for enemy threat •Assessment from multi-perspectives •Analyzing predictions of offensive/defensive results of hypothesized engagements <p>Understanding mission, opportunities and risks, adversary's capabilities and limitations, <u>analysis of possible outcomes</u></p>

Ontology: Levels of Shared Situational Awareness Defined

Level	SA Focus	SA Process
3 Defined	Data is aggregated in a central data base; data from multiple operational systems can be extracted on demand; richer artifacts of the process are stored and organized; data presentation includes summaries and analysis; collaborative tools which capture the timeliness, breadth and depth of subject matter experts	<ul style="list-style-type: none"> •Estimating relationships among aggregated objects including events/activities •Interpreting within context weather, terrain and other environmental considerations •Assessment from a multi-perspective (i.e. Blue, Red & White viewpoints) •Understanding mission, opportunities and risks, <u>adversary's capabilities and limitations</u>
2 Repeatable	Data repository mechanism provided to capture individual input and retrieve data; forum provided for distributed collaboration	<p>Focus on individual objects</p> <p>Associating sensor outputs w/specific known objects or initiate new objects</p> <p>Using sensor data to refine the best estimates of current positions for each hypothesized object.</p> <p>Understanding mission, <u>opportunities and risks</u></p>
1 Initial	Limited collaboration, data fusion or correlation	<ul style="list-style-type: none"> •Aligning data with respect to time/space •Relating newly received observations to existing track •Comprehending basic classification of emitters, platforms, etc. •Understanding mission

Case Study: FORCEnet MC02 Data Analysis

- Data was collected in MC02 to determine the impact of values on organizational effectiveness.
- Values for the study included: Centralization, Formalization, Interdependence, Reciprocity and Trust. Organizational effectiveness was based on a Situational Awareness Maturity Assessment.
- Final results are pending detailed and statistical analysis.

Preliminary Conclusions:

- *Traditional cultural values are inconsistent with information sharing and are barriers to Network Centric Warfare.*
- *Based upon the research this has implications for the management of distributed teams.*

Implications for Management

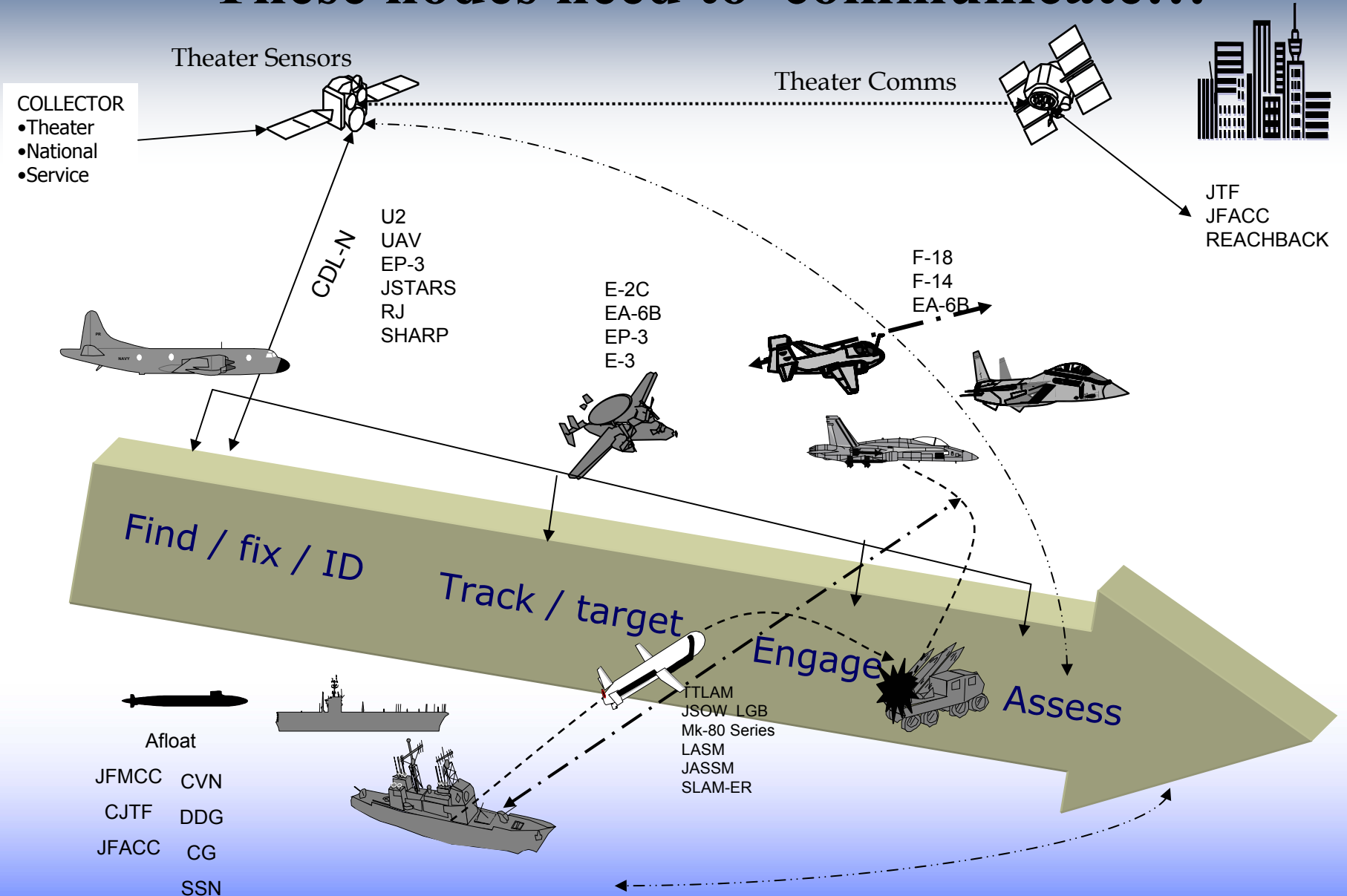
- Collaboration and cooperation become key enablers for organizations to share and utilize the knowledge and expertise of their human capital.
- Motivation and reward systems must be revamped to provide incentives for innovation; sharing and utilizing knowledge.
- Organizations evolve into less hierarchical structures as networked organizations develop that are flexible and able to adapt quickly.
- Group and team working enhance communication and knowledge sharing, and utilize the best skills and experience on every task
- Values of the organization change to reflect the reliance on people, knowledge, and information

Summary

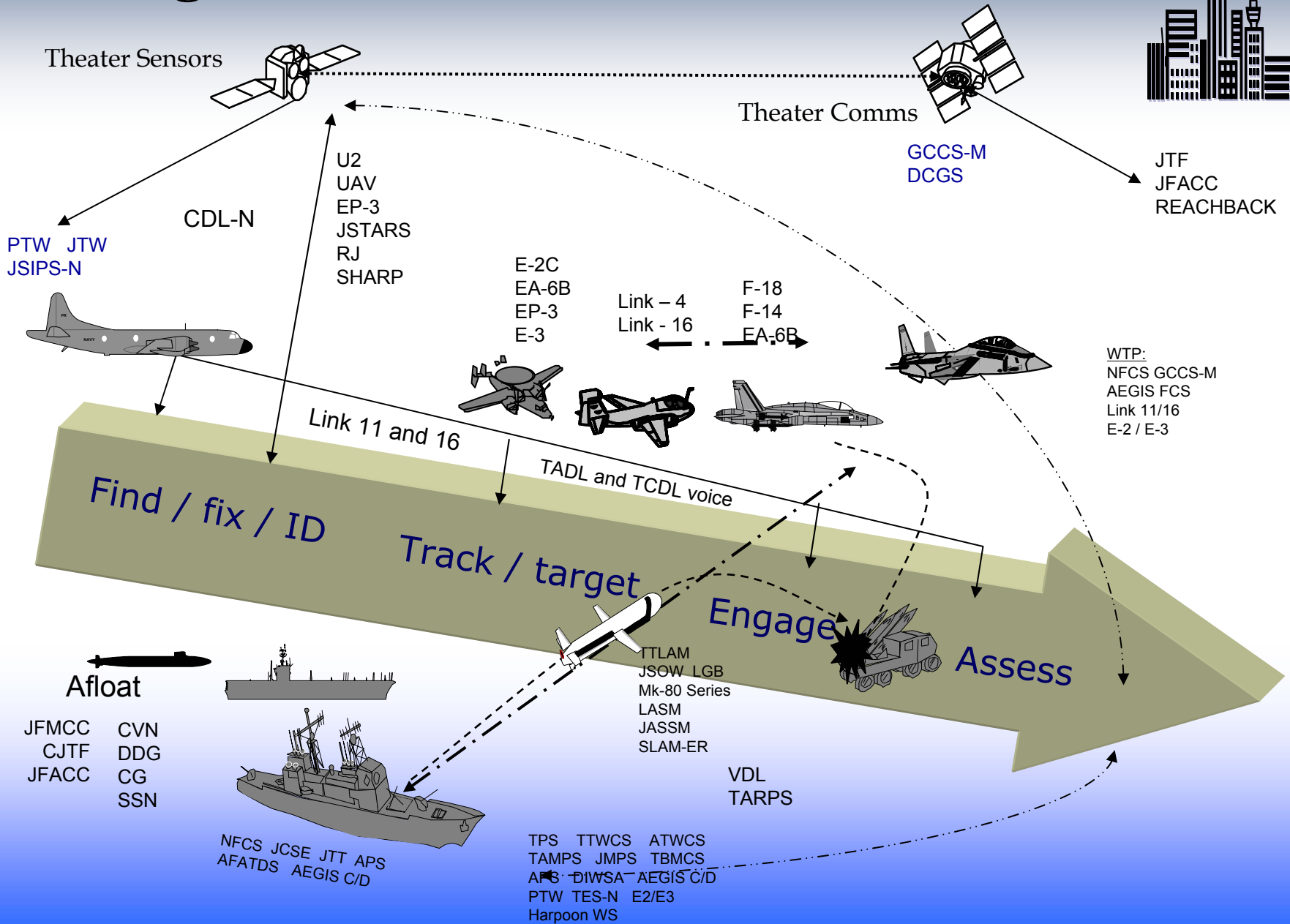
- C4ISR Value assessment depends upon decomposition and contextual definition of the tradespace
- Determining the value of capabilities requires an integrated analytical framework with supporting measures/metrics
- Current FORCEnet capabilities definition provide a solid taxonomic foundation for establishing that framework
- Contextual analysis and trade decisions require situation awareness and methodologies to ensure alignment of perspectives
- A Situation Awareness Capabilities Maturity Model approach provides an ontological resource for assessment using the capabilities taxonomy.

Extras

These nodes need to communicate...



Using These Nets and Decision Processes...



To Pass These IERs ...

Theater Sensors

Theater Comms



JTF
JFACC
REACHBACK

ISR IER's
GEOGRAPHIC COVERAGE
TARGET TYPE
SENSOR ALLOCATION
SIGINT
IMINT
BDI

TACAIR IER's
TACTICAL AIR STATUS
FLIGHT REPORT
AIRCRAFT STATUS
BDI
ID FRIENDLY FORCES
TARGET INTELLIGENCE

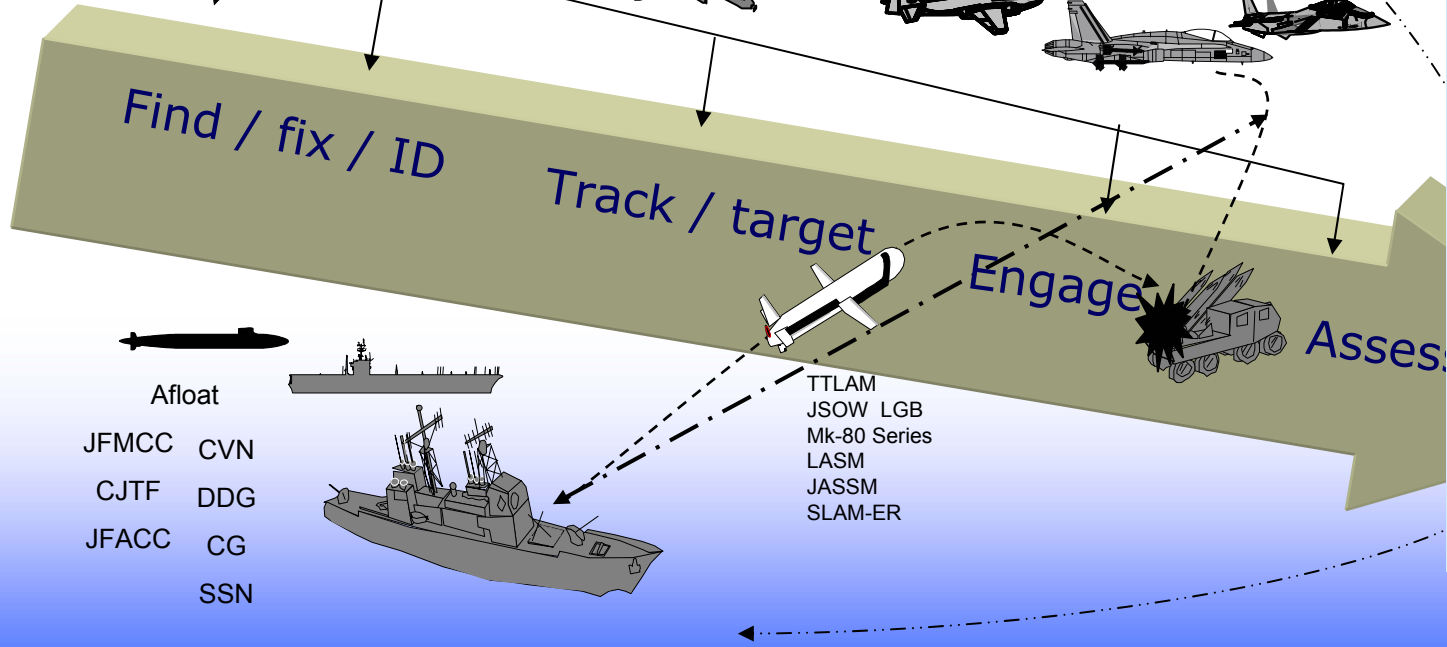
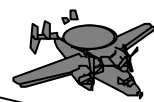
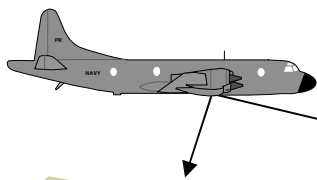
JAOC IERs

- Force Assessment
- Common Operational Picture
- Target Location Error
- Target Dwell Time
- Target Assignment
- BDA
- Mission Information
- Mission Orders
- Collateral Damage Assessment
- Mission Intelligence
- Weapons Control Orders
- Target Cueing
- Target Nomination
- Air Tasking Order
- Tactical Employment
- Strike Mission Coordination
- Weapon Allocation
- Aircraft Mission Status
- Engagement Order
- Tactical Air Control
- Request Attack
- Coordinate Direct Air Support

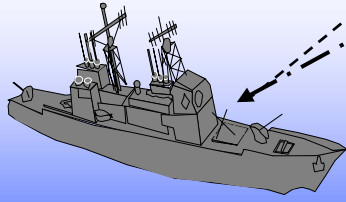
U2
UAV
EP-3
JSTARS
RJ
SHARP

E-2C
EA-6B
EP-3
E-3

F-18
F-14
EA-6B



Afloat

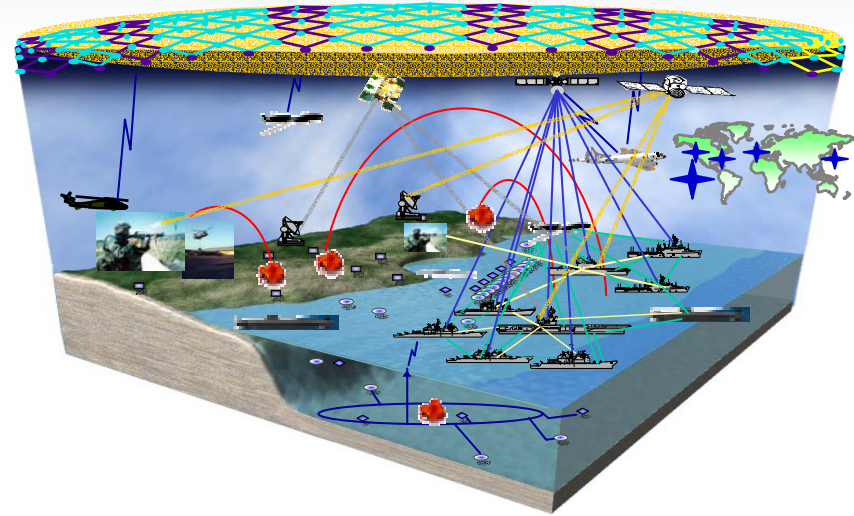


JFMCC CVN
CJTF DDG
JFACC CG
SSN

TTLAM
JSOW LGB
Mk-80 Series
LASM
JASSM
SLAM-ER

FORCEnet Overview

“FORCEnet is the operational construct and architectural framework for Naval Warfare in the Information Age which integrates Warriors, sensors, networks, command and control, platforms and weapons into a networked, distributed combat force, scalable across the spectrum of conflict from seabed to space and sea to land.”



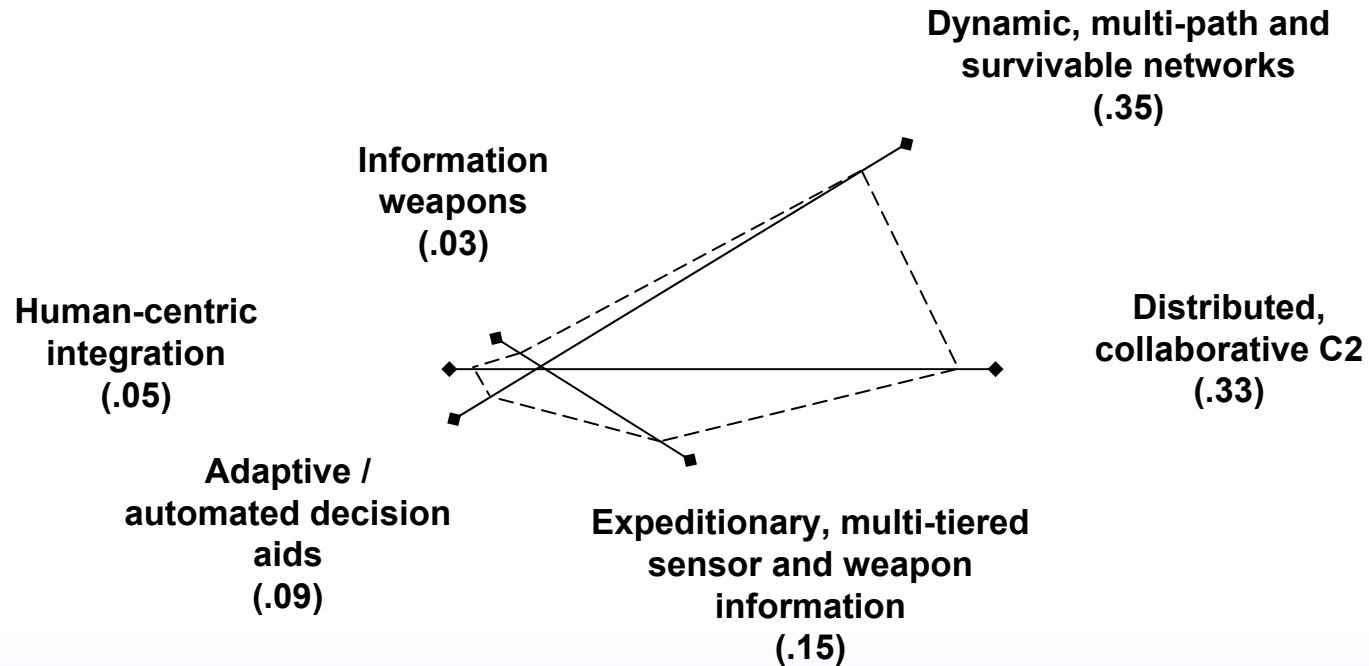
FORCEnet is not:

- A Program
- A System or thing
- An end-state
- “Just a net”

FORCEnet is:

- Mechanism for Naval transformation
- Enterprise alignment and integration effort
- Path to make NCW a reality
- Mechanism for Warrior Enablement
- Capabilities-based approach to requirements and investment, looking across stovepipes

FORCEnet Capability Growth



- ◆ = Desired "end state" for each capability
- (value) = Weight in warfighting outcomes (N6/N7 BCAPP scenarios)
- = notional status of capability