Agenda

• Executive Summary
• Background
  – Terms, objectives, study approach
• Findings
  – Points of leverage in rapid capability life cycle
  – Specific technology areas - engineering, M&S, manufacturing
  – Concept to Capability Engineering
• Conclusion
### Executive Summary

#### Findings

- Significant opportunities exist to develop and deploy technologies to strengthen the Department’s ability to conduct rapid capability fielding
  - However, non-technical challenges (e.g. cultural, budgetary, contracting, etc) must be simultaneously addressed
- Greatest leverage in the “front end” of the life cycle
  - Concept Engineering: Rapidly elucidating the need, exploring solutions, developing CONOPs, and deriving requirements for materiel solutions
    - Virtual environments and rapid physical prototyping are linchpin technologies
- Opportunities exist to increase design, test, and production efficiencies
  - Examples include physics-based M&S to reduce testing and model-based engineering and manufacturing approaches

#### Recommendations

- A concept engineering center should be implemented immediately that leverages the substantial existing capabilities across the Department
- A strategic R&D roadmap should be developed and implemented to mature and transition emerging tools and promising innovative ideas
- A set of potential pilots is recommended to demonstrate the application of today’s toolset to relevant rapid capability challenges
Agenda

• Executive Summary

• Background
  – Terms, objectives, study approach

• Findings
  – Points of leverage in rapid capability life cycle
  – Specific technology areas - engineering, M&S, manufacturing
  – Concept to Capability Engineering

• Conclusion
Terms of Reference

• **Objective**: Provide specific recommendations to DDR&E regarding technological opportunities to significantly **decrease the development time** and **increase the operational effectiveness** of rapidly fielded capabilities.

• **Study Questions**: What are the current technical tools used in both the defense and commercial industries to rapidly design, fabricate, test and validate new systems?
  – Pay particular attention to **modeling and simulation** tools to support rapid design, fabrication, and testing; **system engineering** tools to rapidly design and re-design complex systems; and **manufacturing** processes and tools to speed development.
  – Are there tools that would allow for end to end rapid development, to include such functions as CONOPS development, interoperability, and testing?

• For each of these tools, assess their current capabilities and limitations for DoD rapid fielding needs.

• What are the **emerging technology opportunities**? Identify the technical leaders in these areas and propose approaches to validate the impact of these tools.

• How might these technology opportunities best be developed? **Program scope, scale, and schedule**? Suggestions as to how this might best be done, and by whom are invited.

• Is there any way to **tailor current tools**, techniques, models, methodologies, best practices, etc, to achieve better rapid fielding capability immediately?
Defining Terms

- **Rapid Capability Fielding**: Streamlined projects seeking to field capability in less than 24 months.
  - This could be in response to a stated need of a combatant commander or in anticipation of a potential need

- **Technology Tools**: Software, algorithms, models, simulations, manufacturing hardware/software, and associated processes that support the full life cycle of rapid development
  - In general, organizational, contracting, budgeting, and other non-technical aspects of rapid fielding are off the table
  - To the extent human resources, organizational issues and processes are integral to technical recommendations, they should be addressed
Panel Membership

- **Jim Carlini (Study Lead):** Consultant, former Vice President for Advanced Development, Northrop Grumman Electronic Systems
- **Mark Burgess:** Chief Engineer, Boeing Research and Technology
- **Dennis Roberson:** Vice Provost, Illinois Institute of Technology and former CTO, Motorola
- **Yngvar Tronstad:** Executive Vice President and Chief Scientist, Cogility Software
- **Dinesh Verma:** Dean, School of Systems and Enterprises, Stevens Institute of Technology
- **Bran Ferren:** Co-founder, Applied Minds and former President, Walt Disney Imagineering
- **Study Coordination and Support:** ANSER Corporation, Dr. Mike McGrath and team
Caveats

• Technology tools are not the primary answer to the challenges of rapid fielding
  – Contracting, organizational, cultural, budgeting, and other problems are paramount and must be tackled

• Nevertheless, technology has a role and if integrated into a composite overall solution can have great impact

• Gaining full insight into all relevant Department efforts and technology areas impossible within timeframe
  – Some recommendations require additional research and coordination across the Department
What are we trying to help enable with “technology tools”? 

- Shorten time from need to fielding
  - Reduce time for individual steps in the life-cycle
  - Reduce number of iterations of “design-build-test-produce-field”

- Anticipate and prevent emergence of urgent needs

- Ensure the solution adequately addresses the “need” and has the desired operational longevity

- Move rapid capability fielding from heroic to routine
  - May not decrease the time of an individual project, but enable moving toward a “steady diet” of rapid projects

- Ease transition to a POR
  - Prevent starting from scratch again
Enabling Better Rapid Capability Fielding

DDR&E Rapid Capabilities Technology thrust will develop capabilities to enable more rapid, adaptive, robust, and sustainable solutions to the warfighter.
DDR&E Rapid Capabilities Technology thrust will develop capabilities to enable more rapid, adaptive, robust, and sustainable solutions to the warfighter.
Agenda

• Executive Summary
• Background
  – Terms, objectives, study approach
• Findings
  – Points of leverage in rapid capability life cycle
  – Specific technology areas - engineering, M&S, manufacturing
  – Concept to Capability Engineering
• Conclusion
Extraordinary work is being done across the Department to fulfill warfighter needs, but opportunities abound to strengthen rapid capability fielding.
Where is the Leverage?

Get it right up front: anticipate, properly define the need and technical requirements, assess options/CONOPS, account for sustainment (or obsolescence)…..

*2009 DSB Report
Where is the Leverage?

**Define Need**

60% of “needs” describe a specific solution
(1 year sample of CENTCOM JUONS)

**Concept Design**

**Detailed Design**

Prototyping

**Test**

**Transition to POR**

Too often an afterthought…

Need to “start over” (lack robustness, adaptability, other “ilities”)

**Initial Problem Recognition**

96 days* (Median)

JUONS Prep & Approval

**Field and Sustain**

341 days* (Median)

Time to IOC

Exhaustive field testing is too time consuming

Generally not a problem

60% of “needs” describe a specific solution

...and invest in the tools and training to help speed/automate detailed design, test, and fabrication to compress the development life cycle

*2009 DSB Report
Domain-specific challenges abound – a well-populated toolbox with extremely flexible processes and dedicated, top-notch personnel is essential
Agenda

• Executive Summary
• Background
  – Terms, objectives, study approach
• Findings
  – Points of leverage in rapid capability life cycle
  – Specific technology areas - engineering, M&S, manufacturing
  – Concept to Capability Engineering
• Conclusion
Engineering Findings

- Engineering discipline in rapid capability projects is mixed
  - Ranges from virtually none to “5000-lite”
  - No standard method for determining the appropriate level
- Starting from existing engineering processes is not the best approach:
  - One size fits all systems engineering, focused on comprehensiveness, not agility
  - Process-focused vice outcomes-focused (documenting versus creativity)
  - Front end is particularly lacking in tools leveraging advances in visual modeling, virtual environments, and rapid prototyping
- Cross-cutting challenges
  - Inability to rapidly assess “-ilities” (reliability, producibility, testability, etc.)
  - Accreditation times can limit the ability to field rapidly
  - Reverse engineering tools needed (important for integration with legacy systems)
- Trends
  - Commercial use driving progress in Model Based Engineering
  - Tools and tool interoperability getting better, but ways to go
    - Software: Advances have been made in autogeneration of code, however effective and efficient translation from CONOPS (use cases) to executable models requires more work
    - Hardware: Translation of abstract high level system models (architecture models) to CAD/CAM not there yet (except for microelectronics), but needed….
      - Proposed research in design using hierarchical abstraction (i.e. Eremenko, DARPA) can be a catalyst
  - Increasing use of virtual environments and digital threads (design through manufacturing)
Modeling and Simulation Findings

- Community is vast, with a good deal of excellent work occurring in pockets
- Training community leveraging emerging technologies (e.g. gaming, virtual, mixed, augmented reality)
  - Appears to be little exploitation in acquisition communities
- Ability to easily and rapidly develop gaming scenarios is impressive
  - Work still needed in enhancing realism and physics-based effects
- Physics-based simulation applied to engineering design holds the promise of having a substantive impact on rapid capability fielding
  - Reducing design-build-test cycles (e.g. Goodyear, P-3 sensor integration)
  - Development efforts are expensive and lengthy
- Platform EMI and battlefield communications modeling efforts exist, however a rapid battlefield electromagnetic modeling effort should be explored
- Ability to model human/cultural behavior limited
  - Agent-based modeling coupled to Monte Carlo with real world calibration may hold promise
- There is limited visibility into existing DoD-wide M&S capabilities that might be applied to rapid capability fielding efforts
  - Interoperability also an issue
Manufacturing Findings

• Manufacture of modest quantities is not usually a rapid capability challenge, but:
  – Many examples are “heroic” and not a sustainable business model
  – Quick-reaction production capacity when large numbers are needed may be an issue
• DoD Labs have substantial in-house capabilities
  – Distributed across many sites – need to make visible and accessible
  – Need to keep current with emerging tools and technology
• Focus for rapid prototyping should be:
  – Physical mockups to aid in user-centered design and CONOPS development
  – Functional prototypes to aid in validating engineering concepts
• Focus for limited production should be on total manufacturing time, not just time-on-tool -- leverage is above the shop floor and in supply chain
• Emerging tools:

  **Rapid (Functional) Prototyping**
  • Additive Manufacturing (3-D printing, laser sintering, etc) for mechanical parts
  • Ink-jet printing of circuit boards and solderless circuit card assembly

  **Limited Production**
  • Model Based Enterprise – visualizations and physics based process simulations to generate mfg controls and acceptance test programs
  • Tool-less processes (e.g. composites sans autoclave)
  • Collaborative Mfg Architectures and standards for discovery and integration of mfg services
Agenda

• Executive Summary
• Background
  – Terms, objectives, study approach
• Findings
  – Points of leverage in rapid capability life cycle
  – Specific technology areas - engineering, M&S, manufacturing
  – Concept to Capability Engineering
• Conclusion
Tool-enabled Rapid Capability Development

Near

- Red Teaming
- Needs (Stated and Unstated)
- Tech Opportunities

- Concept Engineering
- Capability Engineering
- Fielded Capabilities

- Conceptual Design
- CONOPS/TTPs
- Input to detailed design and cost/benefit trades
- Prototype(s)

Far

- Red Teaming
- Needs (Stated and Unstated)
- Tech Opportunities

- Concept to Capability Engineering (C2E)
- Fielded Capabilities

- Performance and Materiel Trades
- Prototype(s)
Concept Engineering

Accelerated Concept Engineering

- Conceptual Designs
- CONOPs
- TTPs
- Input to Detailed Design
- Prototype(s)

Iterative Virtual and Real Prototyping; Red Teaming

Warfighter Needs

- Need/mission focused (the right tool(s) to answer the question)
- Warfighter-centric (CONOPS integral, real prototypes where possible, user-centered design and development)
- A persistent environment that favors speed over fidelity
  - Responsive to needs, but also anticipatory
  - Work collaboratively with higher fidelity simulations (e.g. SIMEX), physical exercises, and field experiments

Immerse Users/Developers in a Rapidly-Configured Environment with Real and Virtual Prototypes: Accelerated Concept Engineering
Concept Engineering Tools

**Virtual Environments**
- Persistent, virtual environment
- Gaming, virtual/mixed/augmented reality, 3-D visualization
- Rapidly create relevant environment to explore concepts and CONOPS
- Couple to physical prototyping where user interaction important
- Real-time user feedback
- Bootstrap training
- Remote users

**User-centered Design**
- Create routine user-centered feedback
- Employ selected tools and techniques from “design” community (i.e. IIT, Stanford, Ideo Inc)
- Build upon DARPA TIGR and network of forward-deployed S&T personnel
- Systematically anticipate needs and user-centered design factors
- Iterate with CONOPS

**Rapid Prototyping**
- Where possible, rapidly develop physical prototypes of candidate concepts
  - Physical mockups and functional prototypes as technology permits
- Inform CONOPS development, user interfaces, logistics and maintenance driven changes
- Leverage vast array of capabilities across DoD
- Over time, seamlessly integrate with virtual environment
Capability Engineering

• Rapidly move from concept engineering (conceptual design, CONOPS/TTPs, prototypes) through detailed design, production, and test
• As needed, iterate with concept engineering
• Explicitly account for “ilities”
• Where possible, use physics based models
  – Inform the design and minimize re-work
  – Reduce testing time
• Over time, move to model-based engineering and manufacturing
  – Greatly enhance future system modification speed and efficiency
• Automate the seam between concept engineering and capability engineering (“C2E”)
  – Move from documents to models, virtual environments to CAD
Capability Engineering Tools

**Physics-based Modeling**

- Minimize rework and speed T&E
- Key enablers: physics understanding, reusable models, interoperability, VV&A
- Domain specific: weapons, platforms, electromagnetics

**Model-based Engineering**

- Increase automation, efficiency, CM
- Key enablers: pre-architected modular solution patterns, design libraries and design rules, DFx tools, reverse engineering tools, standards for tool interoperability, increasing abstraction and autogeneration capabilities, CAD-to-VE interface
- Domain specific: mechanical, electronics, software domains

**Model-based Manufacturing**

- Increase automation, efficiency
- Key enablers: physics based process models, auto-generation of manufacturing controls, auto-inspection, robotic assembly, advanced visualization
- Domain specific: flexible processing and fabrication technologies, “tool-less” where possible
Tailored Systems Engineering and Execution Strategy

- Early, small execution strategy workshop
  - < 10 very seasoned people; < 4 hrs
- Qualitatively assess risk (technical, execution, acceptance)
- Consciously impose desired operational longevity
- Start from zero process and work up (not 5000 and work back)
- Hybrid of a la carte and “packaged strategies”
  - Review gates, personnel requirements
- Depend on judgment, not process
- Capture “packaged strategies” over time with honest assessment of utility/outcome
Agenda

• Executive Summary
• Background
  – Terms, objectives, study approach
• Findings
  – Points of leverage in rapid capability life cycle
  – Specific technology areas - engineering, M&S, manufacturing
  – Concept to Capability Engineering
• Conclusion
## Conclusion

**Findings**

- Significant opportunities exist to develop and deploy technologies to strengthen the Department’s ability to conduct rapid capability fielding
  - However, non-technical challenges (e.g. cultural, budgetary, contracting, etc) must be simultaneously addressed
- Greatest leverage in the “front end” of the life cycle
  - Concept Engineering: Rapidly elucidating the need, exploring solutions, developing CONOPs, and deriving requirements for materiel solutions
    - Virtual environments and rapid physical prototyping are linchpin technologies
- Opportunities exist to increase design, test, and production efficiencies
  - Examples include physics-based M&S to reduce testing and model-based engineering and manufacturing approaches

**Recommendations**

- A concept engineering center should be implemented immediately that leverages the substantial existing capabilities across the Department
- A strategic R&D roadmap should be developed and implemented to mature and transition emerging tools and promising innovative ideas
- A set of potential pilots is recommended to demonstrate the application of today’s toolset to relevant rapid capability challenges