Strategic Implications of Cloud Computing for Modeling and Simulation

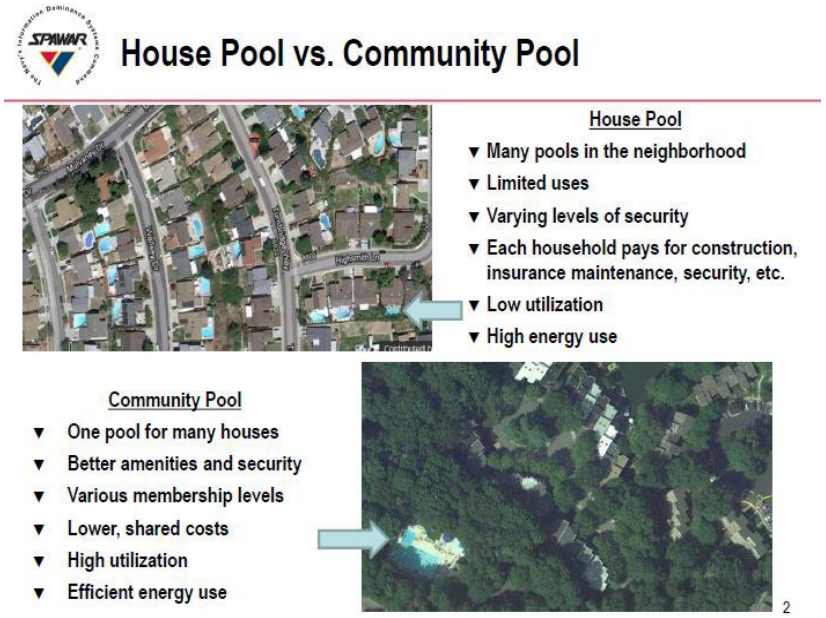
NDIA SE Division M&S Committee
April 19, 2016

Outline

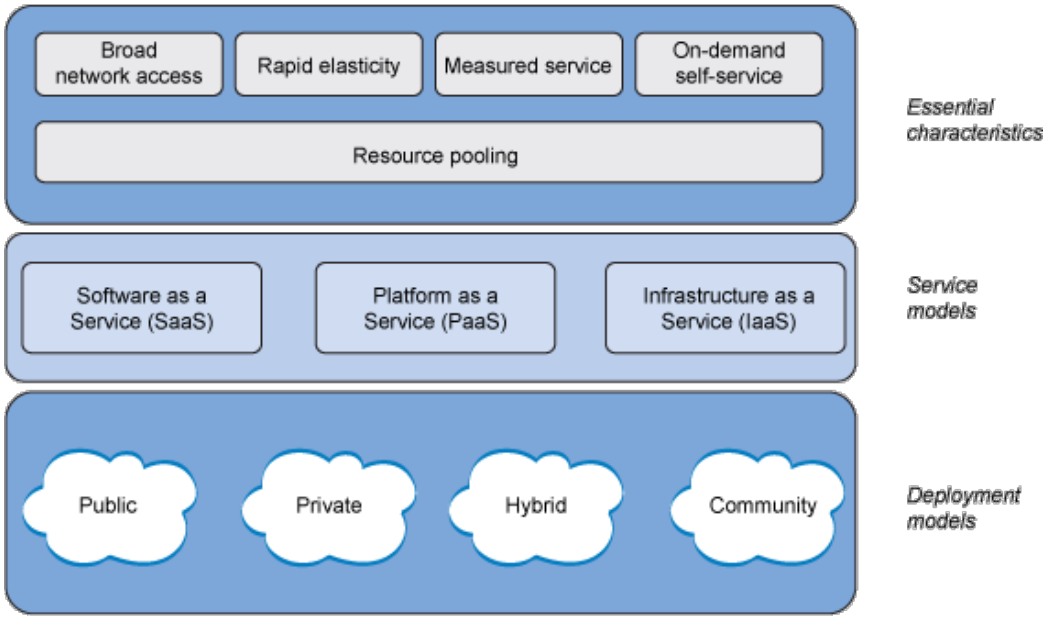
- Framework
- Benefits and Barriers
- Summary and Highlights
- Insights
- Recommendations

Sponsor's Question: What are strategic implications Cloud Computing for Modeling and Simulation (CCMS) in the Defense enterprise

Cloud Computing and Modeling & Simulation



- Models and Simulations
- Distributed / Constructive
- Time Managed / Real time
- Composability
- Pre / Runtime / Post



Framework

Post-Runtime	AAR, Post-hoc Analyses						
Runtime (Real Time)	M&S Execution – LVC						
	M&S Constructive - Distributed					JTE	
	M&S Constructive						
Runtime (non-real time)	M&S Constructive (robust to response latency)			OneSAF			
	M&S Constructive (NOT robust to response latency)						
Pre-Runtime	Exercise Preparation						
	Models						
	M&S Data						
	M&S Catalog						
		Business Model Only	Virtualization Only	Within a Data Center	Across Data Centers	Composed / SOA Within a Data Center	Composed / SOA Across Data Centers

Benefits and Barriers

Lots of Promises!!!

- Cost efficiency
- Unlimited storage
- Backup and recovery
- Automatic software integration
- Easy access to information
- Quick deployment
- Easier scale of services
- Scalability
- Rapid development, deployments, and change management
- Agility
- Efficiency
- High reliability / availability
- Flexibility
- Better performance
- Greater mobility
- Green IT data center
- Improved security
- Improved automation, support and management
- …

Study Framework

Potential Benefits

- On Demand Self Service
- Broad Network Access
- Rapid Elasticity
- Resource Pooling
- Business Model / Measured Service
- Exercises (heavy interactions)

Potential Barriers

- Performance
- Architecting for Cloud
- Service Composition
- Trust/Risk/Accountability
- Security and Privacy

On Demand Self-Service

- Potential of "anytime, anywhere", on-demand simulation capabilities
- On-demand self-service and multi-tenancy provides M&S users with availability of the simulation as needed and accessible even while other users might be using the same application

Broad Network Access

- Provides an environment that is device and location independent, expanding accessibility and resources
- (M&S already does but cloud will) continue to support remote access, utilizing the same network infrastructure already in use.
- It offers the potential to make parallel and distributed capabilities much more widely accessible to users who are not experts in this technology and who do not already have access to HPC platforms.
- Distributed sims do not, generally, support the use of handheld mobile devices. Therefore Commanders cannot run intense sims on their future C2 devices.
- Lowers barrier to entry because it eliminates the need to purchase and operate HPC equip at local site.

Rapid Elasticity

- As-is, the alternative is to either overprovision the infrastructure within the users organizations to meet the peak expected workload, leaving the facility underutilized during periods of less intense usage, or to create a lower cost facility that is unable to meet the demands offered at times of peak usage.
- The "pay as you go" cost structure of cloud computing is attractive if the computational requirements of users vary greatly over time. Cloud allows the amount of computational power that is used, and the cost, to expand and shrink according to the users needs.

Resource Pooling

- Handheld devices and terminal cheaper than full up workstations
- Place facilities in locations with lower cost electricity, power, cooling, labor, property costs and/or taxes
- Provides computing services remotely, freeing users of the burden associated with managing computing resources and facilities
- Outsources computing infrastructure, reducing or eliminating the need for organizations to offer extensive IT services
- Decreases cost of ownership by reducing licensing requirements, hardware and software maintenance/upgrades, and facility resources.
- Cloud provider may be able to apply computing infrastructure more affordably than locally operated facility (economies of scale)
- May provide an alternative to cluster, grid and parallel environments.
- May improve fair fight, due to common content and standards
- Reduces need specific hardware, utilization of hardware goes up, remote hardware cheaper, hardware only provided for 1 or few sites, hardware upgrades only needed centrally, better utilization, ease of technical administration
- Utilization of software improves, software upgrades only needed centrally, licenses shared across users, ease in licensing.

Business Model (Measured Service)

- Long sought after visions where computing is provided to consumers as a utility, like electricity, water or natural gas. In contrast to the norm today, where organizations potentially incur large capital expenditure costs to build and operate the own computing infrastructure and it.
- Pay per use / new business models

Exercise Specific

- Set up can take months in coordination and weeks on the ground (e.g., costs to travel for exercise support, integration, test).
- Staff sits idle if exercise goes down.
- Reduces initial investment and O&M costs
- Will only have to upgrade servers at relatively small set of data centers. S/W upgrades/patches much easier.
- Simplifies testing and deploying new hardware.
- Increased collaboration and common access to the same resources, reducing fair fight issues and helping with CM
- Ramping up exercise environments is quicker, resulting in faster implementation times and "time to value", allowing for quick and inexpensive "try out" new ideas / concept exploration
- Pre-exercise scenario development, analysis and dry runs can take place in cloud
- From perspective of simulation vendor, compatibility is a much less daunting task
- Parallel batch processing
- Exercise system footprint is reduced, including hardware, space and power.
- Resources can be reallocated for other applications and exercise configurations without the need to wipe and reinstall the o/s and app every time.

Challenges – Performance/Latency

- Parallel scientific codes executed over EC2 ran significantly slower compared to execution on dedicated cluster nodes.
- Services hosted within the cloud can incur significant performance degradations
- Cloud environments are shared among many users, and individual users are not guaranteed exclusive access to the processors assigned to that user's virtual cluster. In principle, GANT scheduling techniques can be used to ensure an individual user is allocated a set of physical nodes at the same time instance, however, this property may hot be guaranteed by the cloud provider. This can lead to difficulties for parallel sim apps, especially those that utilize optimistic synchronization techniques.
- Distribute sim with inter-clouds can introduce challenges with interoperability, and other constraints related to performance.
- Cloud environments tend to be better at providing high bandwidth communications among applications than in providing low latency. Many sims are accustomed to sending many small messages requiring quick delivery rather than fewer large messages requiring high bandwidth.
- M&S tends to use the underlying virtualized hardware more extensively for prolonged periods of time. The applications have higher memory requirements, intensive central processing unit usage, minimum CPU counts per node, multiple distributed nodes, and a low latency/high bandwidth network. During execution, the demand on the virtualized hardware will be at a sustained high load for significant portions of the simulation exercise.

Challenges – Architecting

- Not all M&S applications will reside in the cloud. The integration of LVC and C2 and other operational equipment (UAVs) will require M&S cloud implementations to allow for a mix of cloud and non-cloud resident applications.
- Simulations need to be architected for virtualization
- Inter-cloud will require further standardization (syntactic, semantic, and pragmatic) and standardized definitions of functionality (to support service composition)
- Front end user interfaces – *real* user friendly interfaces, common tools and C2 consoles should be available as SaaS on the front end
- Other inter-cloud challenges include federation creation and initiation; joining and retiring federates to and from federations; migrating federates from one cloud to another; platform migration from one cloud to another; management of entity ownership among federates in different clouds; registration and subscription for the entities simulated by the federates; perception management.

Challenges – Service Composition

- In a SOA-based inter-data center configuration, the attribute of an entity could be updated based on the computations of many federates. In DIS/HLA, an attribute of an entity is normally owned by a single federate, so DIS and HLA would not suffice for integrating the federates in this type of federation.
- Due to self configuration, optimization, and healing mechanisms, services may migrate during execution. Therefore, new dynamic routing schemes, jitter resilient algorithms for real-time simulations, congestion control schemes, etc. are required in SOA/inter-data center configurations.
- Inter-datacenter federation configuration (i.e., determining the federates interoperable with each other and selecting the set that fits best to the constraints and performance expectations) is a new challenge, proved as an NP Complete problem. That is, if the number of alternative service modules is high, it is not possible to find the optimum solution in a reasonable time.

Challenges – Trust/Risk/Accountability

- Users must be assured that proprietary and confidential data will be secure in a cloud environment.
- Trust is stated as the main barrier for potential subscribers before they embrace cloud services. Trust must be established between M&S and CSP. This requires an in depth understanding of risk and accountability of a CSP. MSaaS federations, which are basically cloud service mash-ups, exacerbates the complexity of accountability, risk and trust relations.
- The risk that a cloud user has to accept is higher than the risk a CSP accepts. CSP usually keep the locations of their server farms and data centers abstracted away from users. CSPs can use services from other CSPs, and even private clouds may be linked to partner clouds. The transfer of accountability may end up at an unfamiliar CSP, increasing risk for the users.
- Risks get higher and more difficult to analyze in nested cloud architectures (i.e., inter-cloud, service mash-ups, and partner clouds). Composing an MSaaS from services provided by multiple clouds is a challenging task. The risk and trust relations among the clouds and services contributing to a composite MSaaS are complex.

Challenges – Security & Privacy

- Risks that have specific dynamics related to M&S include: self-configuring, self-optimizing, self-monitoring, self-healing. May create opportunities to exploit because of implementation bugs OR using these processes to degrade services.
- Large databases with high number of clients – create new opportunities for DoS attacks.
- DoS attacks in Medium Access Control (MAC) and higher layers of networking protocols, more sensitive because of central compute
- Malicious insider
- Insecure interfaces and APIs
- Data loss or leakage, increased in cloud
- Not easy for users to estimate risks since most of the underlying architecture, infrastructure and platform details are abstracted away.
- Vulnerabilities introduced by virtualization, to include VM Hopping, Mobility, Sprawl, Escape, Hijack
- Unauthorized users performing analysis of network traffic to derive information about the results of a simulation-based study.
- Although the centralization of services increases security by reducing size of the infrastructure to protect, that also creates points of gravitation for cyber and physical attacks. When a system does get hacked, the impact is much bigger compared to a distributed architecture.
- Multi-level security.

Heavy Hitters - Benefits

- On Demand: Potential of “anytime, anywhere”, on-demand simulation capabilities.
- Broad Network Access: Support the use of handheld mobile devices.
- Resource Pooling: Outsources computing infrastructure, reducing or eliminating the need for organizations to offer extensive IT services.
- Measured Service: Pay per use / new business models
- Exercise Specific:
  - Set up costs
  - Ramping up time

Increased capability

Cheaper

???

Cheaper

Increased capability

Heavy Hitters – Risks/Challenges

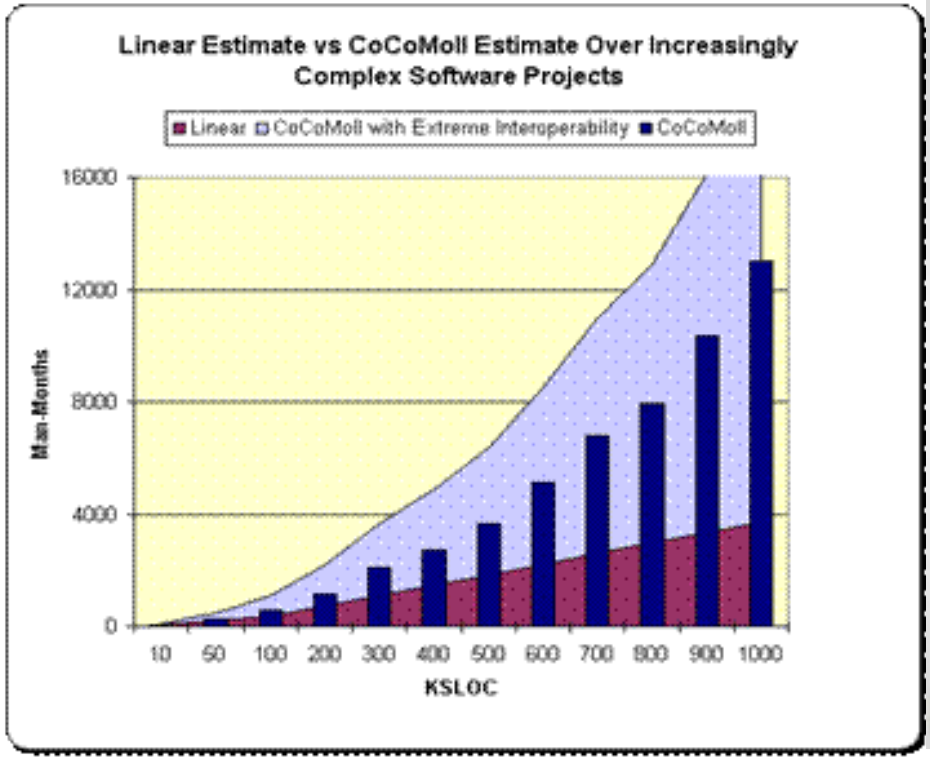
- Cloud environments tend to be better at providing high bandwidth communications among applications than in providing low latency.
- M&S tends to use the underlying virtualized hardware more extensively for prolonged periods of time.
- Not all M&S applications will reside in the cloud.
- Simulations need to be architected for virtualization
- Inter-cloud will require further standardization (syntactic, semantic, and pragmatic) and standardized definitions of functionality (to support service composition).
- Unauthorized users performing analysis of network traffic

Observations / Insights

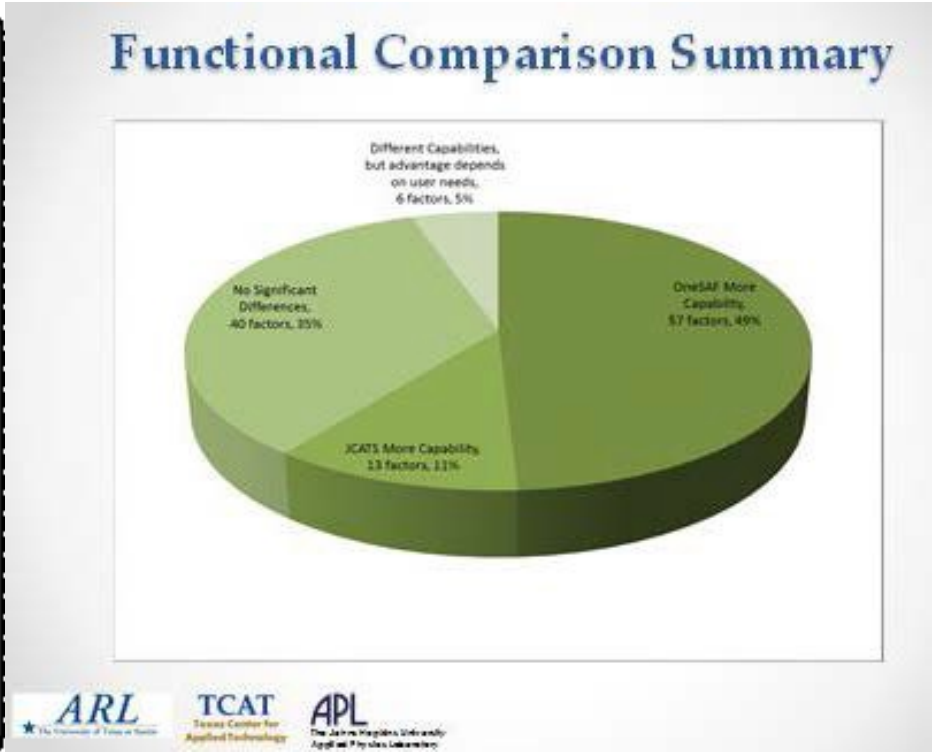
- The biggest new thing that will be strongly, if not completely, enabled by the Cloud is M&S support in Battle Command (Course of Action Analysis)
- M&S Community Myth Busters
  - It is possible to leverage a cloud without employing SOA, and to leverage SOA without employing cloud computing. Some M&S Community literature discusses them as though they must co-exist.
  - It is possible to leverage cloud without employing Virtualization. Some M&S Community literature discusses them as though virtualization is a necessary but not sufficient pre-condition for Cloud.
- We have not discovered, at an abstract level, any advantage or disadvantage to M&S employed in a cloud infrastructure, that would not be true of any typical IT Application or System employed in a cloud infrastructure.
- In support of Data Center Consolidation and Cloud Migration, many Services' CIOs are embarking on Application Rationalization efforts.
- Cloudy Crystal Ball (no pun intended!): It will be important, in near future, to determine whether M&S is an IT function or an S&T function.

Potential Cost Savings in Pictures

leveraging SOA to achieve composable M&S has great potential to reduce overall M&S costs



savings by defining common simulation architecture infrastructure



savings by reducing the development of redundant models in simulations

New Capability in Pictures

“COMPUTER!” -

- Plot three routes from my current location (point A) to my new assembly area/linkup (point B) where I will link up with local friendly forces. I want four routes, fastest, shortest, best concealment, and best coverage given current threat intel.
- In the point B assembly area, plot recommended location of my comms devices for the best coverage within the assembly area.
- I have three sensors with me, two EO/IR and one thermal. Plot recommended locations for these sensors to cover expected avenues of approach into the assembly area.
- I have two machine guns and six rifles, plot recommended locations and range cards to provide the best 360 protection for these weapons.
- I see a group of people on cell phones moving to my location. Who are these people and what do you know about the cell phones?

Recommendations (1 of 2)

Type of Enabler	Policy Action	Investment	Sponsor/RO
Business	Establish managerial baseline.	Follow lead of the CIO community by applying application rationalization-like methods to the DoD's M&S portfolio to facilitate the introduction of new solutions and retire old solutions and to provide the strategic management data required for making sound decisions and investments.	DMSCO – internal
	Investigate business model implications.	A number of new constructs (e.g., measured service, composability, outsourcing computing infrastructure, etc.) have implications for new and powerful business models for M&S users, sponsors and industry developers. Define the business model implications across all of the M&S stakeholders, government, industry and academia.	$ over 1 year
Cultural	Lead by example.	Move DMSCO enterprise capabilities to a cloud-based infrastructure. In particular, moving assets like the M&S catalog to a public cloud theoretically improves the accessibility and availability of the capability (i.e., catalog) to other agencies and coalition partners.	DMSCO - inter
	Take steps to promote trust.	Develop primer expanding on the differences between requirements for the successful operation of IT versus M&S in cloud-based infrastructures. Use primer to inform Defense Information Systems Agency (DISA) and eventually broker the development of service-level agreements between cloud providers (i.e., DISA's Mil Cloud) and potential M&S customers.	$ in year SLA in out yea
Technical & Cultural	Establish experimental framework, to include cloud resources.	Broker deals (see Appendix A) on behalf of the M&S community with cloud providers (i.e., Mil Cloud, EC2, etc.) for free time and resources to test cloud capabilities. Develop a campaign plan for series of experiments per the framework offered in **Error! Reference source not found.** and barriers presented in Section 5.B. What questions need to be addressed, in what order, and by whom? Offer these free resources to M&S users in return for performance data and lessons learned in accordance with the campaign plan.	DMSCO & DIS $ for cooperative effort over 2 years

Recommendations (2 of 2)

Technical & Cultural	Educate community on potential cyber threats.	Develop a primer for community on potential cyber vulnerabilities of M&S in a cloud-based infrastructure (e.g., exploitation of bugs in the implementation of M&S; degradation of services through processes related to self-configuring, self-optimizing, self-monitoring, and self- healing; potential for denial of service due to the interactions of very high numbers of users with very large databases; reverse engineering the simulation study results through analysis of network traffic; etc.). Include preventive measures in the form of best practices.	$ over 1 year
	Advance state of M&S to best enable these cloud processes.	Continue research in composability and SOA, but especially in the context of cloud processes including but not limited to self-configuration, -optimization, and -healing mechanisms. Examine new mechanisms required for efficient load-balancing across distributed exercise in a cloud based infrastructure.	LOE TBD by th Experimentatio Campaign Plan
Technical	Advance research bridging current methods with future computing paradigms.	Examine research in federation creation and initiation; joining and retiring federates to and from federations; migrating federates from one cloud to another; platform migration from one cloud to another; management of entity ownership among federates in different clouds; registration and subscription for the entities simulated by federates; and perception management.	LOE TBD by th Experimentatio Campaign Plan
	Issue new VV&A guidelines to support requirements for SOA and composability.	Commission report drawing upon community knowledge to recommend new VV&A methodologies and guidelines focused on regression-based methods suitable for requirements of SOA-based implementations.	$ over 2 years
	Establish new architecture(s) for cloud-based M&S.	Commission the competitive design, development, test and transition of a framework for SOA and mobile M&S. DoD M&S efforts focused on mobile computing should be tightly coupled with DISA's and the Services' approaches and infrastructure for cloud computing and mobility. A concerted effort, as opposed to a series of small exploratory projects is necessary to establish a robust infrastructure that enables greater accessibility to models and simulations via cloud computing, SOA, and mobility.	DMSCO & DIS for a cooperative effort over 3 years but with net savings over time

Final Thoughts on Way Ahead

- Two biggest(?) mistakes DMSO made in implementing the HLA:
  - Interoperating at too high of a level (i.e., simulations instead of models)
  - Forcing HLA on **everybody** in the DoD, even when not required by a community's use case.