



Millennium Challenge 02 ***The good, bad, & ugly.***

VV&A in Practice

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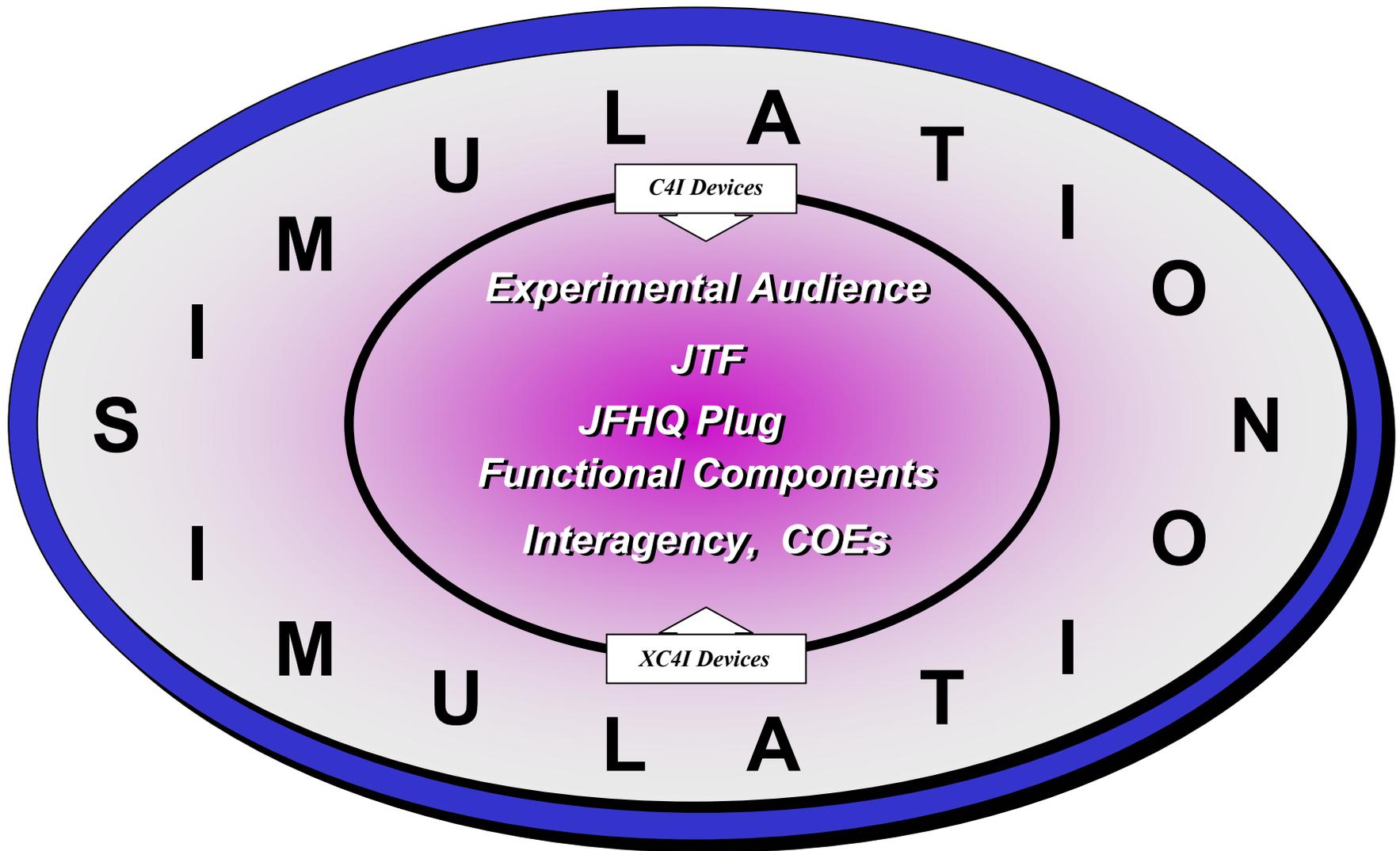


Millennium Challenge 02:

A Case Study of VV&A in Practice



13,500+ soldiers, sailors, airmen, marines, and contractors had to press the I BELIEVE button.



4 - 5 sims max. Do it all the time. No big deal.

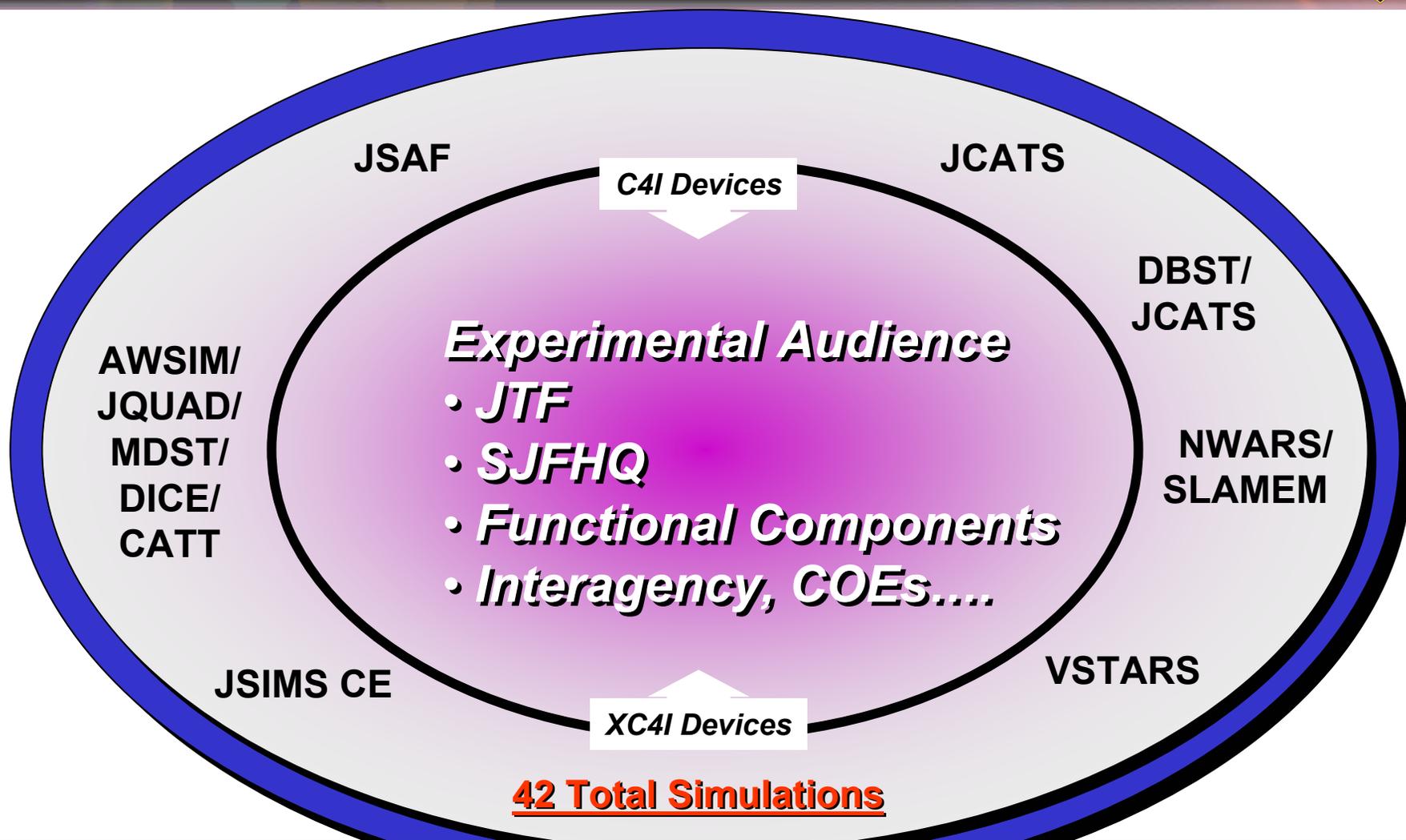


And Congress said:

- Services will play
- Integrate live and sim

*If your requirements don't change,
nobody is watching.*

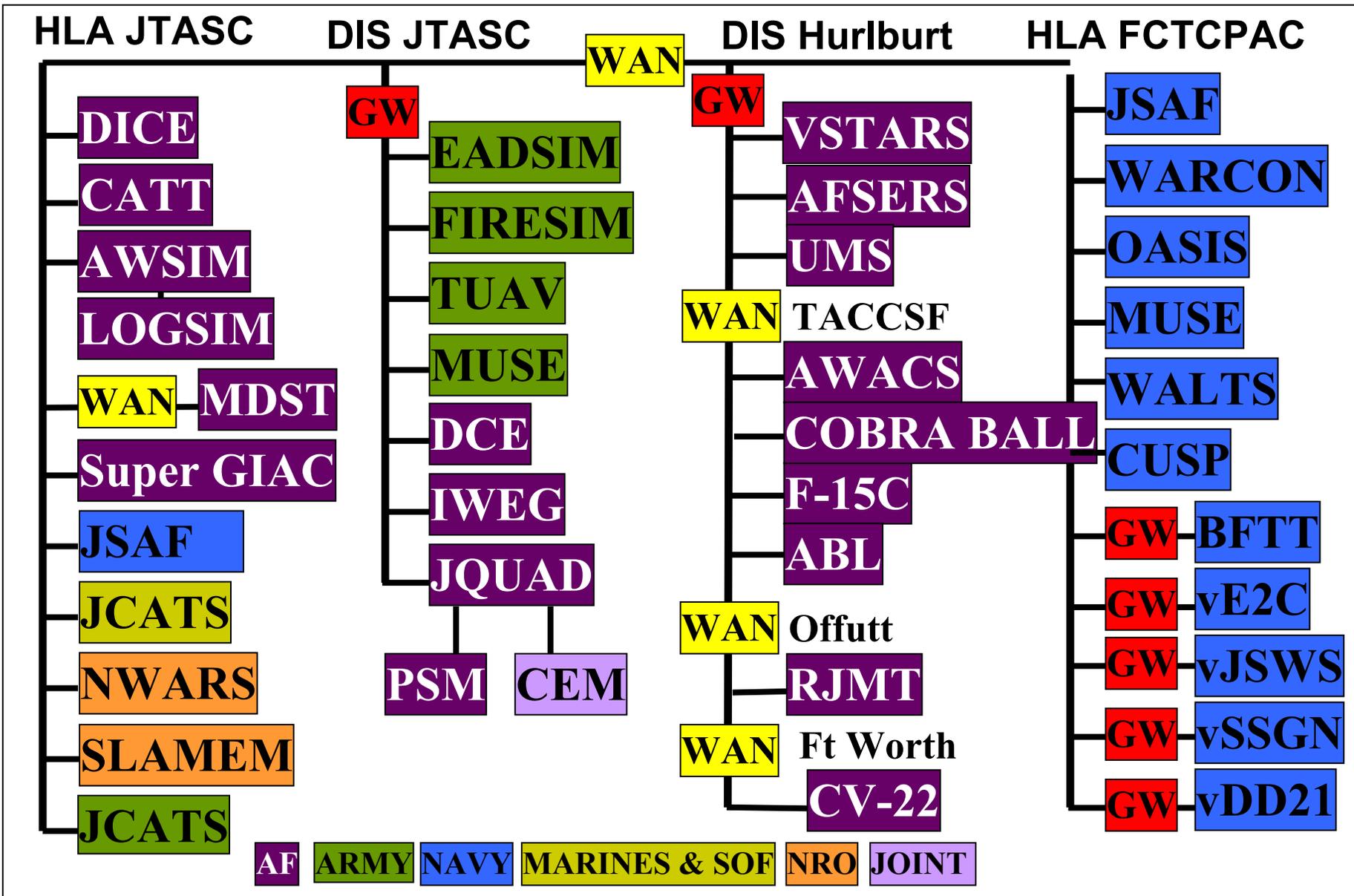
Ceranowicz, 2002



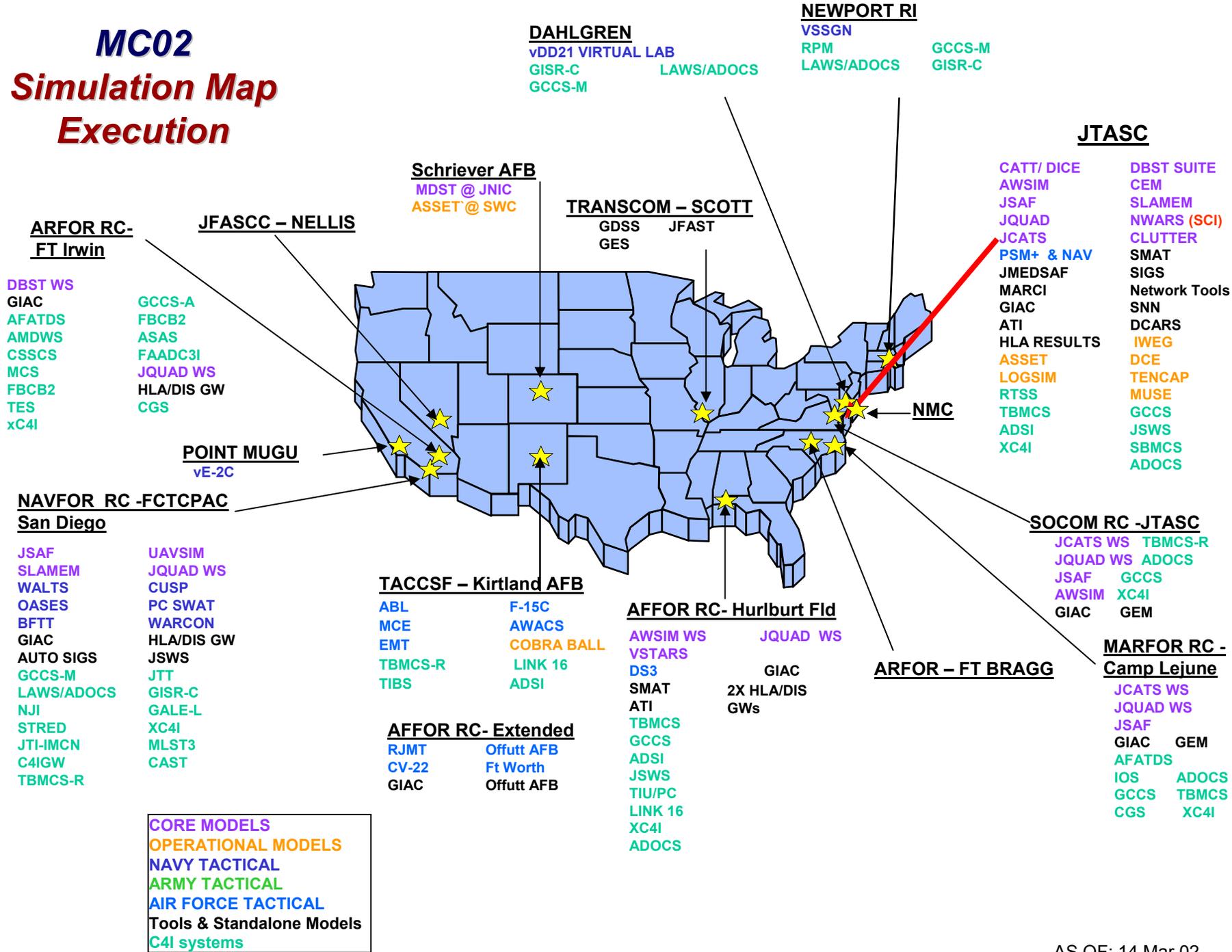
Simulations from Service Analysis, Training, & Experimentation Communities with Live forces creating a requirements-driven, Joint synthetic battle space.

Simplified MC02 Sim Architecture

VV&A in Practice



MC02 Simulation Map Execution

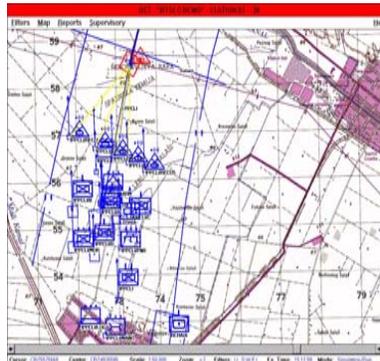


- Core Simulations – 19
- Operational Simulations – 5
- Tactical Simulations – 18
- TOTAL = 42 in MC02 Federation (+ 9 Standalone)

- 3,000+ multicast groups
- 90+ HLA federates
- Live/sim integration



LIVE – 13,500



Simulation – 32,000+ platforms



Virtual Simulators – 6

**Largest simulation federation in history.
And it n-e-v-e-r went 'down' – 408 hours of continuous operations.**



- **Total budget over 2 years: \$250M**
- **Total R&D budget to build the federation: \$13M**
- **Code bending complete in 1 year**
 - **9 integration events (technical tests)**
 - **4 spirals (operational tests)**
- **Number of people participating: 13,500 M&S: ~450**
- **Number of computers & workstations: 2950**
- **Simulated battle space: ~1,00,000 sq. miles**
- **Different types of entities modeled by all federates: 675 and 434 munitions: ~110,000 possible and interesting interactions.**



- **Basic V&V philosophy**
 - Each service provided V&V'd models.
 - USJFCOM focused V&V efforts on inter-federate interactions and C4I stimulation.

- **There was no “V&V Testing” per se**
 - V&V was integral part of A-L-L functional tests, critical event tests, thread tests, and vignettes.
 - There was NO V&V day or period!
 - Continuous process. Dedicated V&V was present from very first IM through the last day of execution. VV&A personnel earned team membership.

- **Service SMEs were present every step of the way**
 - Not all SMEs are created equal



- **V&V of simulation infrastructure - Was data distributed to federates as necessary?**
 - **Way cool use of HLA Results to verify PDUs were reaching all sites; recording instances at multiple sites – compare results. Elegant and definitive.**
- **Terrain – Was the virtual world correct?**
 - **Synthetic Environment Evaluation - Inspection Tool (See-It) used for automated checking and correction. See-It now checks the intermediate S1000 and the final CTDB products.**
- **Technical Integration Database (TIDB) created for MC**
 - **O-N-E, global, and continuously accessible source of information: systems, platforms, bugs, workarounds, etc. etc. THE recording and management tool; V&V, developers, C4I, Sim, etc.**



- **Enumerations: 600+ platforms & 400+ weapons**
 - **At least 4 attempts at self-adjusting processes.**
 - **Finally appointed a Czar, built management tools into the TIDB and monitoring tools into the federation. Wonderful end to a LONG story.**
- **Interaction documentation: 110,000+ possible ...sigh**
 - **Took a lot of team wrangling to pick a course ahead**
 - **Interactive matrices for class interactions built into TIDB. This is absolutely a way to go for future.**
 - **Face validity remained preeminent tool due to sheer size of problem set. (KUDOS to testing team)**
 - **We missed ONE interaction: boundary condition. Obviously, the ONE that everyone noticed...!**



- **Requirements were like hen's teeth**
 - **“Kulp's 100” were life saver; sim initiated but early!**
 - **If it wasn't a requirement – we didn't build it.**
 - **V&V would have ground to halt without requirement focused foundation.**

- **Setting the experiment in 2007 left some data threads hanging in the wind – no experience and no data.**



- **We did not force or protect certification of the simulation “operational” environment.**
 - **Some few, but influential, people were playing with different rules and expectations.**
 - **24 hour operations were widely interpreted differently.**
 - **Uninformed people are making good livings with M&S assumptions.**

- **The federation fidelity was something to be reckoned with**
 - **Processes: those who did not do homework blamed sims**
 - **Results: “That would never happen in the real world.” Ahh....**
 - **It is MUCH easier to script an answer.**
 - **Entities don’t lie.**

- **Only played with ~35,000 entities.**



Questions?



- **There is no detailed scenario defined for the MC02 event, the accreditation will be solely based on tests involving “a similar class of situations”.**
- **Presumption will be made that proper model performance in testing implies proper results will be produced during execution.**
- **Situations will be systematically tested and the results validated by SMEs. Caveats will document situations where performance is invalid, and propose possible work around schemes.**



The federation is a 90% solution, it is not all things to all people.

JECG-01 Live Target BDA Process

Problem/BACKGROUND: Targets which will be attacked by live forces are dislocated from targets on the Hybrid Terrain and in the scenario that they will represent.

DISCUSSION:

1. When these targets are attacked by live forces, the attack and the BDA that occurs must be reported against an existing BE numbered target on the Hybrid Terrain so that damage can be assessed against assets in the simulations and reported to the JTF.
2. Live ranges and their associated targets are not located on the same terrain that they are intended to represent in the scenario. Therefore, live targets will not correspond to targets on the Hybrid Terrain and in the scenario for which BE numbers have been assigned. As live forces respond to operational plans or direction from higher headquarters, they will prepare plans and assign targets to support the plans of the JTF and Components. These plans should reflect targets on the Hybrid Terrain and in the scenario from the Prioritized Effects List for which BE numbers have been assigned.
3. For live OPFOR attack against Blue live targets, the procedures for Blue attack of targets without BE numbers, outlined in C. 3 below, will be used.



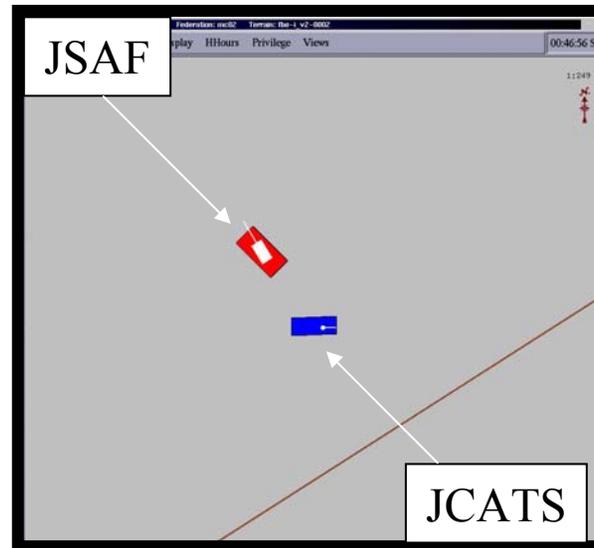
ACCREDITATION CRITERION	V&V TEST
1. Measures of Performance / Measures of Effectiveness	Technical Testing
2. Situational Awareness Data	SME Reviews during Spirals
3. Joint Intelligence Surveillance Reconnaissance (JISR) inputs	SME Reviews during Spirals
4. Entity Motion	Federate V&V by federate owners
5. Maintain real-time operation	Technical Testing
6. Fault Tolerance	Technical Testing
7. Terrain Data	Terrain verification testing at Spirals
8. Warfighting Actions	SME Reviews during Spirals
9. Representation of specific systems or forces	Technical Testing (enumeration checking)
10. JEF Execution	Verification
11. Logistics	SME Reviews during Spirals



- **Exercise Directive #4 provides a list of the forces that will be available for use in MC 02, at an operational level.**
- **Federates will simulate these forces at a lower level, typically individual platform entities.**
- **SMEs will work with JFCOM to identify their Service's force at the individual entity level used by the Service model.**
- **The resulting force will be realized in the Service federates via initialization file/database/etc. and provided for future reference.**



- ✓ Provided by Service sims
- ✓ Described by Service SMEs
- ✓ 4 services and SOCOM
- ✓ **30K platforms** for play
- ✓ Interactions are sim to sim
- ✓ Real time
- ✓ Controlled by HITL
- ✓ 2007 capabilities
- ✓ Tested or RWA activated
- ✓ Medium logistics play
- ✓ “Box of Rocks” unit menu

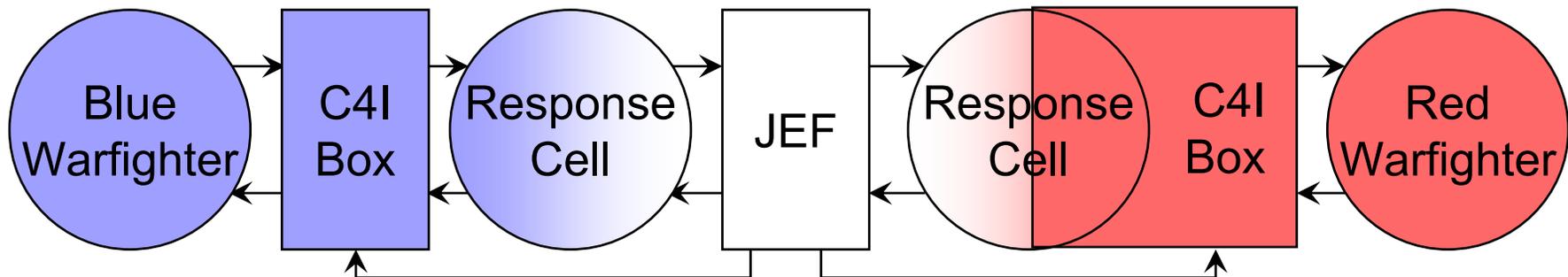


- ✓ Ground to ground
- ✓ Air to ground
- ✓ Ground to air
- ✓ Surface to surface
- ✓ Subsurface to surface
- ✓ Subsurface to ground
- ✓ Surface to air
- ✓ Air to surface
- ✓ Air to air
- ✓ Space
- ✓ Sensors

- Technical Federation Agreements detail ‘how’ the sims interact.
- Service SMEs and JFCOM testers define/approve functionality.
- Requirement driven within technical bounds.
- Shooter determines detection and hit, target determines damage.
 - ~ **400** different platforms with ~**600** munitions.
 - ~ **110,000** possible weapon-target pairings.



- The goal of the Joint Experiment Federation (JEF) is to simulate the Joint battle space for the purposes of presenting a realistic operational picture to stimulate the experimental audience, via their C4I devices, and the white cell players.





- **Predictive experiments, MC 02 is set in 2007, can't always be tied to real data.**
 - **Several emerging systems were key elements of service experiments.**
- **Overall MC 02 experiment outcomes are a mixture of simulation results and operator actions.**
 - **Many rules and work arounds were used to offset simulation weaknesses.**
- **Subjective, SME based, validation focuses on areas of greatest perceived military significance.**
 - **Actual experiment might play out differently.**



- **Two layers of testing were conducted**
 - **Technical tests tied to Federation Agreements Doc.**
 - **SME evaluation of functional tests by subject area.**
 - **1000 updates/sec is far more than SMEs can look at.**
- **No “V&V Testing” was done, all integration and functional tests contributed V&V evidence.**

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- **Testing Considerations:**

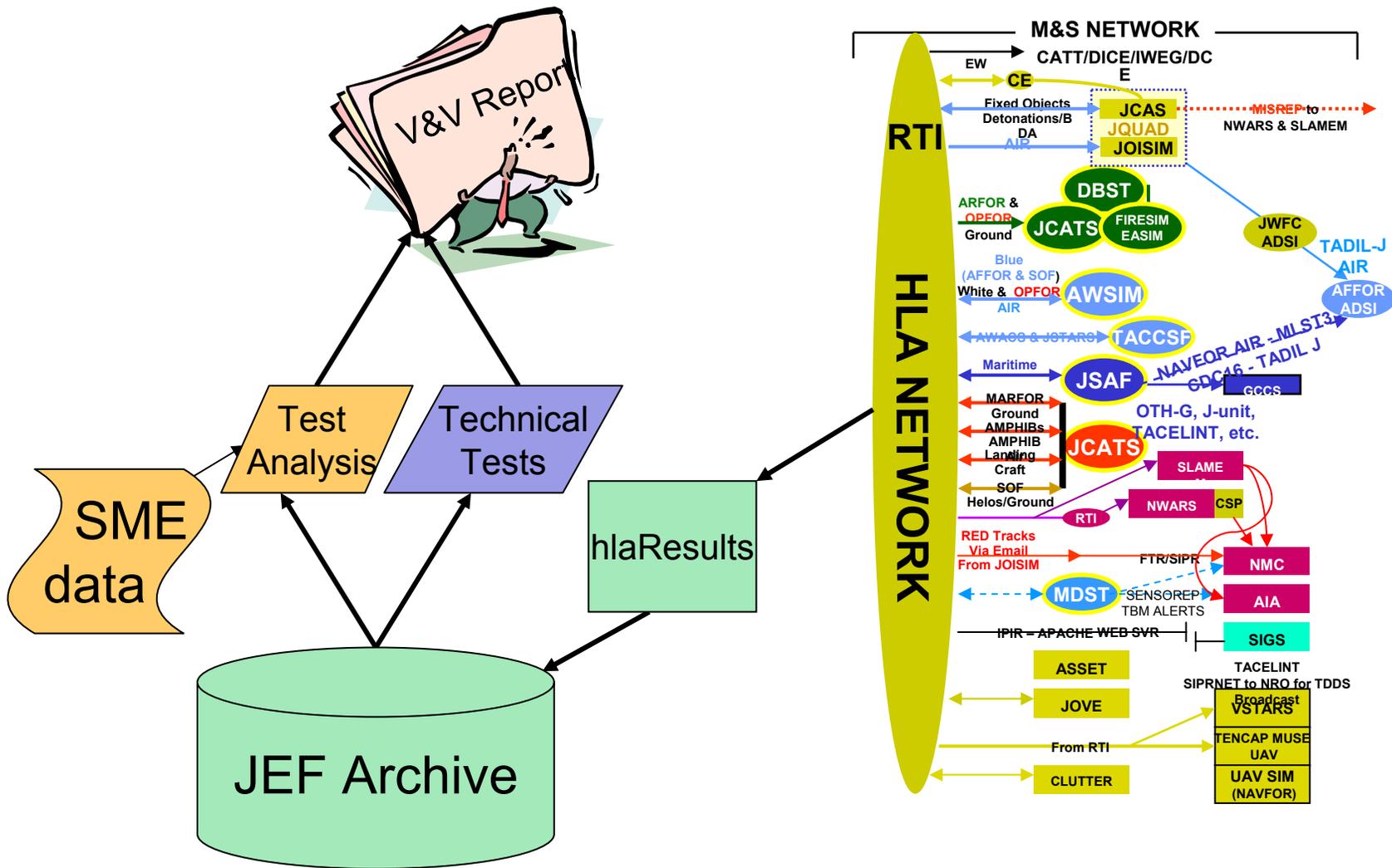
- **Infrastructure - Is data distributed to federates as necessary?**
- **Terrain - Does the virtual world match between federates?**
- **Representation (enumerations) - Do federates agree on what they are representing, including platforms, sensors, and munitions?**
- **Detection - Do federates perceive the situation realistically?**
- **Engagement - Do weapons cause realistic effects?**



- **There is no detailed scenario defined for the MC02 event, the accreditation will be solely based on tests involving “a similar class of situations”.**
- **Situations will be systematically tested and the results validated by SMEs. Caveats will document situations where performance is invalid, and propose possible work around schemes.**
- **Routine federation execution produces 1,000 data updates per second, much more data than SMEs can evaluate manually.**

Test Consolidation

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V&V Technical Testing

Sample

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Key

G
Y
R
N/A

No anomalies observed during V&V

Anomalies observed in unusual or unlikely situations only.

Capability not reliable, controller intervention necessary.

Not applicable to this federate.

TEST AREA	AWSIM	JCATS-A	JCATS-M	JSAF	CATT
Join Federation	G	G	G	G	G
Resign and Rejoin	G	G	G	G	G
Initial Object Update	G	G	G	G	G
Air	G	G	G	G	N/A
Ground	N/A	G	G	G	G
Sea	N/A	N/A	G	G	N/A
Other	G	N/A	G	G	N/A
Heartbeat Object Update	G	G	G	G	G
Air	G	G	G	G	N/A
Ground	N/A	G	G	G	G
Sea	N/A	N/A	G	G	N/A
Other	G	N/A	G	G	N/A
Object Update (State Change)	G	G	G	G	G
Air	G	G	G	G	N/A
Ground	N/A	G	G	G	G
Sea	N/A	N/A	G	G	N/A
Other	N/A	N/A	N/A	G	N/A
Object Reflection	G	Y	G	G	G
Air	G	G	G	G	G
Ground	N/A	G	G	G	G
Sea	G	G	G	G	N/A
Other	N/A	R	G	G	N/A
Owned Object Delete	G	N/A	N/A	N/A	N/A
Normal Delete Reflected Obj	N/A	N/A	G	G	G
Time-Out Delete Reflected Obj	G	G	G	G	G
Save State	G	G	G	G	G
Crash Recovery	G	G	G	G	G
MunitionDetonation Interaction	G	G	G	G	N/A
WeaponFire Interaction	G	G	G	G	N/A
DamageAssessment	N/A	G	G	G	N/A



- **Key Data Validation Activities:**
 - **Forces - Exercise Directive provides a list of the forces that will be available for use in MC 02, at an operational level.**
 - ◆ **Federates will simulate these forces at a lower level, typically individual platform entities.**
 - ◆ **SMEs work with JFCOM to identify their Service's force at the individual entity level used by the Service model.**
 - ◆ **The resulting force is realized in the Service federates via initialization file/database/etc.**



- **Key Data Validation Activities:**
 - **Terrain - Custom data products were built for a large scale (24° x 24°) virtual battle field.**
 - ◆ **Analytic investigation of the databases identified problems where different formats of the terrain data needed repair to correlate.**
 - ◆ **Functional Tests confirm that federates use terrain data correctly.**
 - ◆ **Rules and work arounds are written for known problem locales.**
 - **Target Data - Target specifics must be aligned beyond just the federates; this data is also used by the C4I and XC4I systems.**



- **Key Data Validation Activities:**
 - **Enumerations - Federates were examined and tested to make sure all enumerations matched, or were mapped reasonably.**
 - ◆ Platform entities were organized by battlefield function and compared.
 - ◆ Weapon fire enumeration lists were built for each function and consolidated.
 - ◆ Target entities validated weapon damage effects on an enumeration by enumeration basis (>50,000 individual cases).



- **MC 02 approaches to integration, testing, and V&V could be applied to any other large federation.**
- **Continuous V&V involvement and shared testing allowed a very large problem to be broken into manageable pieces.**
- **The PEOPLE involved have accomplished a lot, with the technology.**

V&V is a PROCESS, not an event!



Synthetic Environment Evaluation - Inspection Tool (SEE-IT)

A Prototype Automated VV&A Tool



SEE-IT has been designed to evaluate and inspect environmental data provided in SEDRIS transmittal format (STF).

Verification and Validation of Environmental Data

- **Allows environmental database users to assess content and quality, at any time during the database lifecycle**
 - **“Is this the correct product for my application?”**
- **Allows environmental database producers to identify and repair unintended constructions before product delivery**
 - **“Have we built this product correctly?”**

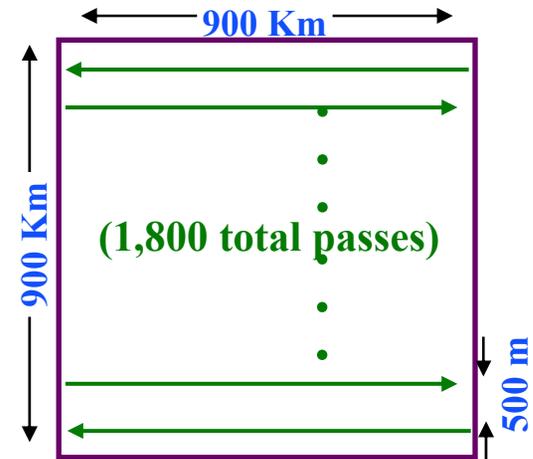


- **Typical environment inspection practices are manual operations.**
 - **visual inspection.** However, the visual database is
 - ◆ not necessarily the same as that used for simulation calculations
 - ◆ may not even focus on the most appropriate data.
 - **semi-automatic approach,** moving simulation entities repetitively across the database,
 - ◆ may not examine all relevant data,
 - ◆ cannot be used in areas where specific simulation entity movement is prohibited,
 - ◆ cannot describe problem cause,
 - ◆ only locates general areas that may contain environment errors,
 - ◆ may be influenced by errors in the simulation control software
 - ◆ does not provide any guide to appropriate corrective actions.
- It can also be **very time consuming**

Time Analysis & Comparison



Concept: Send a simulation entity back and forth across a database and visually observe its performance to locate anomalies. Assume a pass is made each 500 meters, the database is 900km square, and the simulated entity travels at ‘S’ KMPH. Then, the time (hours) required to examine the entire database is:
 $(1,800 \text{ passes} * 900\text{KM/pass}) / \text{“S” KMPH}.$



Entity Speed (KMPH)	20	40	60	80	100	200
Time - hours	81,000	40,500	26,973	20,250	16,200	8,100
Time - days	3,375	1,688	1,124	844	675	338
Time - <u>years</u>	9.25	4.6	3.1	2.3	1.8	0.92

(Using multiple simulation vehicles reduces time requirements linearly, but all the other problems still remain....)

SEE-IT required less than an hour to examine a 900 x 900Km simulation database (about 2.4 million polygons inspected)*

* 270 Mhz SGI



- **Physical Anomalies**

- **Vertical Tears**
- **Anti-Gravity Areas**
- **Road Disconnects**

- **Feature Interactions**
- **Black Holes**
- **plus other checks...**

- **Terrain and Man-Made Feature:**

- **Counts**
- **Indexing**

- **Other Capabilities**

- **Terrain views, shaded relief, wire frame, cross-section line of sight.**



- In addition to condition identification and location, **SEE-IT has the ability to automatically correct some conditions that do not require adjudication by human editors**
- **These kinds of conditions include:**
 - Repair of “T” vertex surface polygon topologies
 - Removal of duplicate objects
 - Repair of nearby linear features that are not coincident
 - Repair of vertical tears in polygonal surface topology
 - Adjustment of outlier elevations
 - And others to come...
- **Current SEE-IT implementation relies on SEDRIS format as both input and output for corrections**



- **Articulating the requirements for terrain builds**
- **Establishing parameter ranges for anomaly acceptance/rejection**
- **Assessing the urban jungle**
- **Addressing the SPP “size” terrain analysis**
- **Working through the (un)Fair Fight**



- **The V&V effort is limited to inter-federate considerations.**
- **The primary method of validation is “face validation”. To the extent possible data will be collected during the Spiral tests and used to validate the federation performance using Service SMEs to provide assessment.**
- **Federate owners provide documentation that the federates have been through a V&V process (including the federate and input data) and any limitations or caveats associated with their federate.**
- **MC02 M&S Requirements charts provided by the Analysis Team define the data which are important to MC02.**