

Modeling and Predicting HLA Federation Performance

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**MIT Lincoln Laboratory
Distributed Systems Performance Modeling Office
(DSPMO)**

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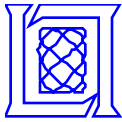
Overview

- **The Federation Performance Modeling Consortium**
- **What are We Trying to Accomplish?**
- **Modeling Approach**
- **Tools Required**
- **Progress to Date**



What Federations Do

- **HLA Federations can have different performance goals**
 - Time-managed, fast-as-possible Time-managed, human-in-the-loop
 - Wall clock time (time “happens”) Minimum latency, hardware-in-the-loop
- **Federation divvies up the virtual world, considering**
 - **Functionality**: types of simulated objects, sources, granularity, etc.
 - **Modularity**: decomposition, reusability, potential extensions
 - **host performance**: computation throughput, available memory
 - **network performance**: bandwidth and latency between federates
- **Federates exchange object attributes, interactions via RTI**
 - (Some) RTIs attempt to minimize traffic over the network with data distribution management, message aggregation, etc.
 - RTIs may offer other services such as time management, reliable transport



Predicting Federation Performance

- **Goals**
 - Reduce cost of Federation development and debugging
 - Prediction by extrapolation on observables using models
- **Deliverables**
 - Predictive modeling tools and user guides
 - Initial predictive models for a specific RTI (1.3NG)
 - Catalog of observable features and metrics
 - Developed during model prototyping; useful for predicting performance of similar Federations
 - Tools to extend the catalog



An Iterative Process

- **Goals**
- **Research**
 - **Conceptualize models, define observables**
 - For some specific Federates and specific RTIs
 - **Statistical nature of models and observables**
 - Can't hope to know all details
 - Model salient behaviors and their variability
- **Modeling**
 - **Build prototype predictive models**
- **Measurement and Analysis**
 - **Are measured observables sufficient, efficient, etc?**
 - **How accurate, reliable are predictive models?**
- **Deliverables**



How Is This Effort Different?

- **Benefits HLA Community at Large**
 - Relies on input from Consortium members
 - Models and tools must be relevant, useful, and cost effective to broad constituency
- **Focused on Boundary Behavior**
 - Exchanges between the Federates and the RTI
 - Not dependent on detailed internal models of Federates
 - Modeling effects of Federate activity
- **Quantitative Models for Performance Prediction**
 - Getting beyond performance of two or three test Federates with “evenly” balanced work loads
 - Tools to aid Federation development
 - Is my Federation working as predicted at this stage?

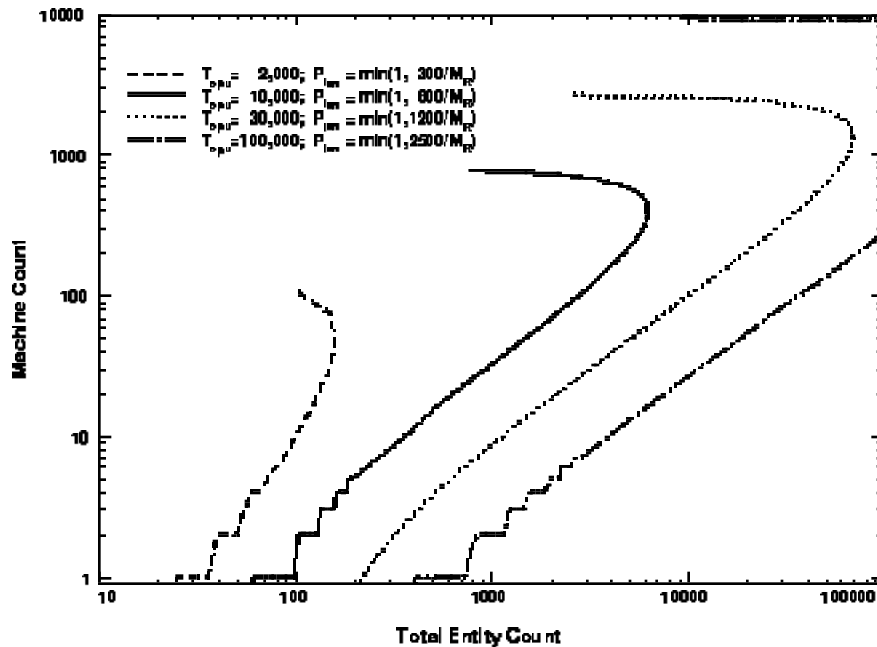


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 - Performance Feasibility Limits
 - Nominal Performance
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Task 1: Feasibility Limits



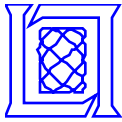
- More federates, more objects, demand more processing resources
- Limited resources per host requires greater distribution of processing
- Greater distribution of processing requires more communication processing
- At some point, all resources end up being consumed by communication processing!

Predict whether a proposed Federation will overwhelm available resources.



Host Resource Constraints

- **Each host has resource limits**
 - CPU cycles/sec
 - Random Access Memory (RAM)
- **Per-host resource costs include**
 - OS overhead to maintain Federate, RTI, other apps
 - Cost of simulating objects
 - Cost of processing updates and interactions via the RTI
- **Available RAM affects CPU load**
 - Less RAM necessitates more swapping to/from disk
- **Violation of resource limits is catastrophic**
 - Dropped messages, unacceptable latency, time stalls, etc.



Feasibility Limit Model

Each host must satisfy

$$\left(\begin{array}{c} \text{Simulation} \\ \text{Overhead} \end{array} \right) + \left(\begin{array}{c} \text{Simulation} \\ \text{Processing} \end{array} \right) + \left(\begin{array}{c} \text{Message} \\ \text{Processing} \end{array} \right) \leq T_{\text{CPU}}$$

Intrinsic costs of application, RTI, OS support

RTI management services costs per Federation layout

Maintenance costs of objects and attributes

Task assignment costs for local objects

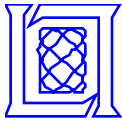
Task execution costs for local objects

Response to Interactions

Generation of Interactions

Per Message Costs of RTI Services

Limit Model is a set of constraint relationships that must be satisfied for the most stressing activity distribution.

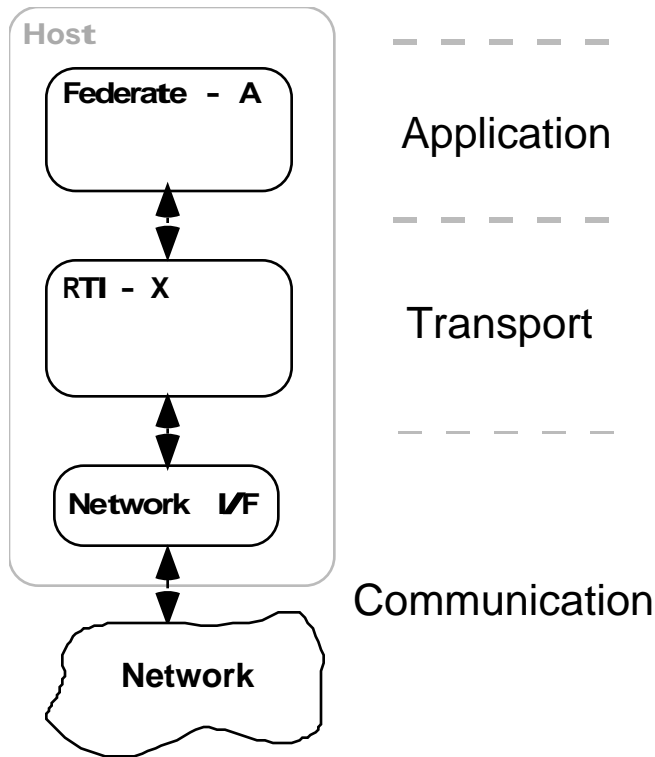


Task 2: Nominal Behavior Modeling

- **Predict how well the Federation will satisfy performance requirements**
 - Minimum latency, hardware-in-the-loop
 - Time-managed, human-in-the-loop
 - Time-managed, fast-as-possible
 - Wall clock time (time “happens”, 3 hours or 3 days)
- **Requires models of message statistics**
 - Message **source statistics**
 - **Effects of RTI and network** on messages



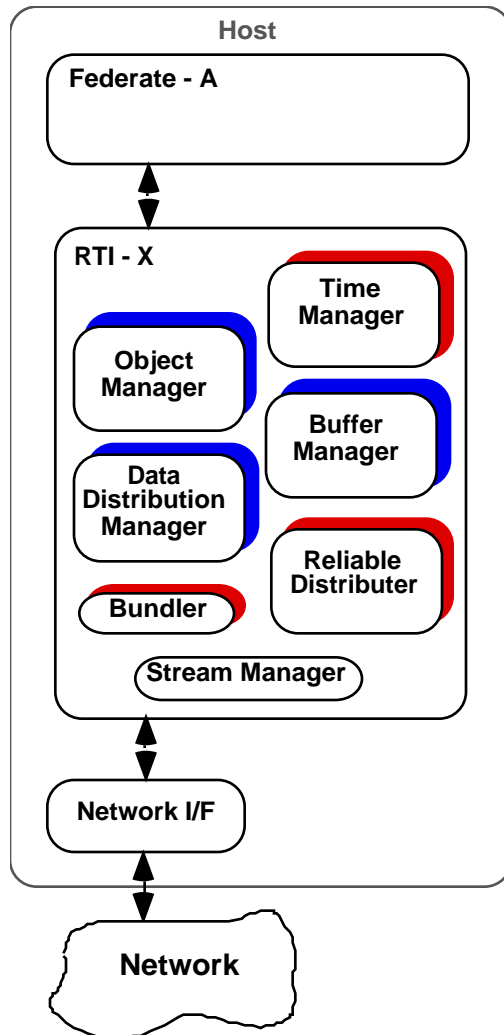
Predictive Model Components



- **Each Federate emits and collects messages**
 - messages are statistically distributed in size, time of emission, destination
- **Transport model (RTI-specific)**
 - Forwards messages based on subscriptions
 - Alters message distributions
 - Time managers, bundlers, and reliable transport alter time distributions
 - DDM alter destination distributions
- **Network model**



RTI Behavior Model



- RTI's "message relevance filtering" saves Federate CPU cycles, but costs **message delay** and **memory consumption**
 - Time Manager delays messages
 - Buffer Manager consumes memory to store pending messages
- **Some of these effects have been modeled by others**
- **This study will tie together existing models and create new models as needed**

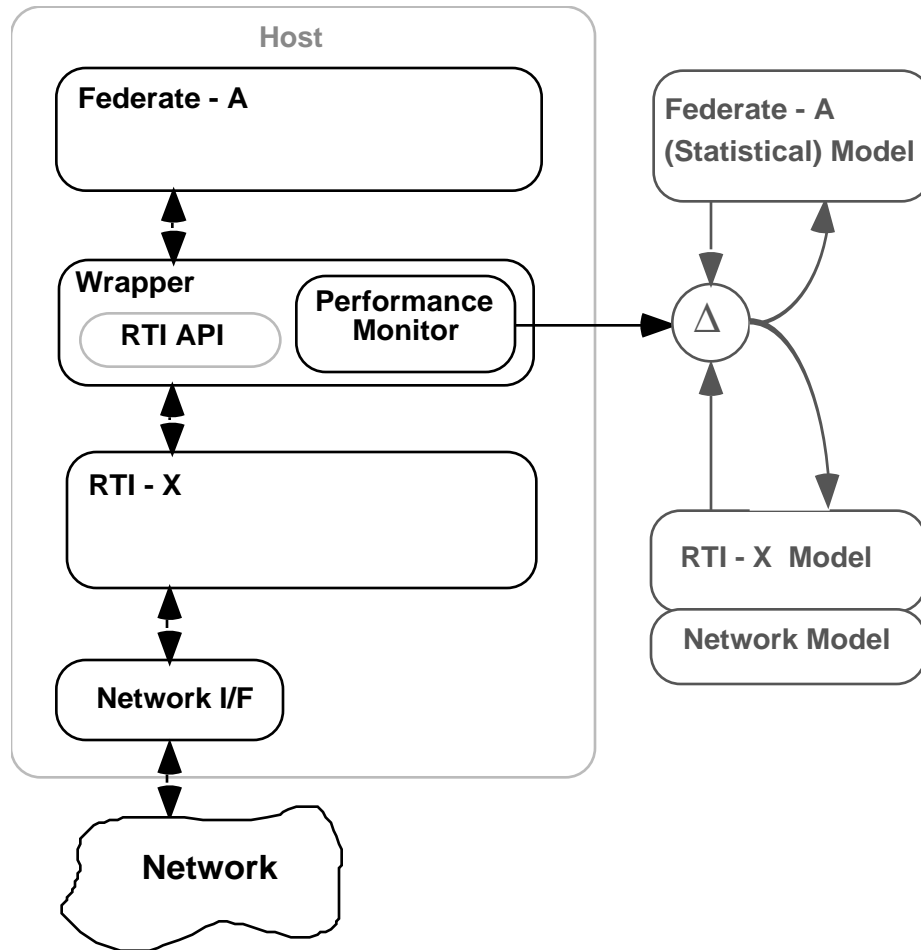


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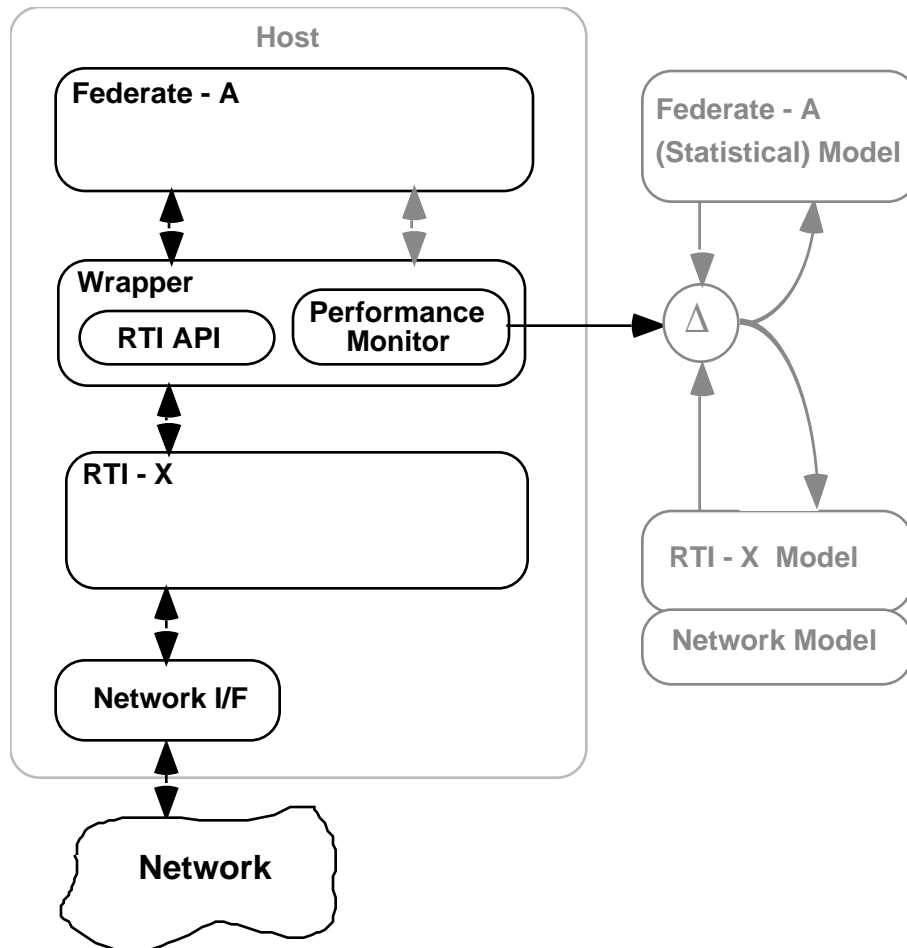
RTI Wrapper



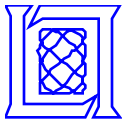
- **Generic interface layer between any Federate and any RTI**
- **Produces statistical snapshots**
 - Federate and RTI exchanges
 - Federate and RTI resource consumption (memory, CPU)
- **Supports real-time performance monitor**
- **Provides “ground truth” data for development and verification of performance models**



RTI Wrapper

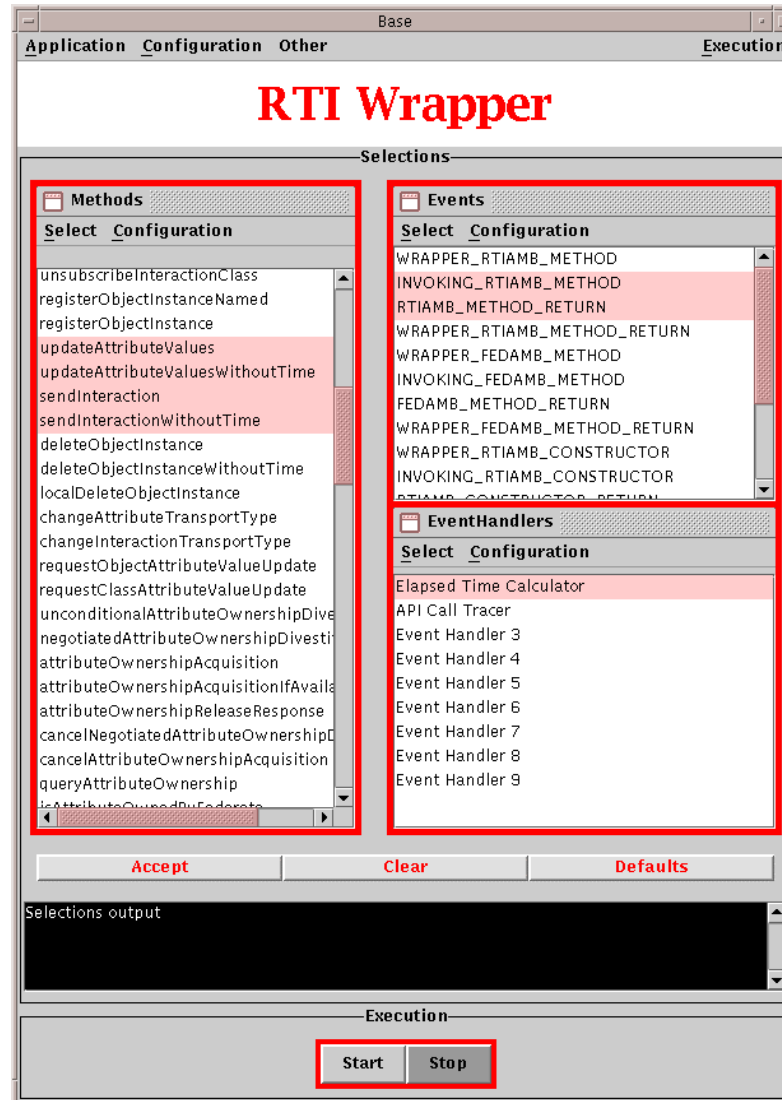


- **Federate calls the Wrapper just like the RTI (API is identical)**
- **Instrumentation capabilities are open-ended:**
 - extensible catalog of measurables
 - a Federate can plug in customized measurement functions
- **Run-time configurable (what is measured, when, and how)**



Run-Time Configuration Control

Which API methods



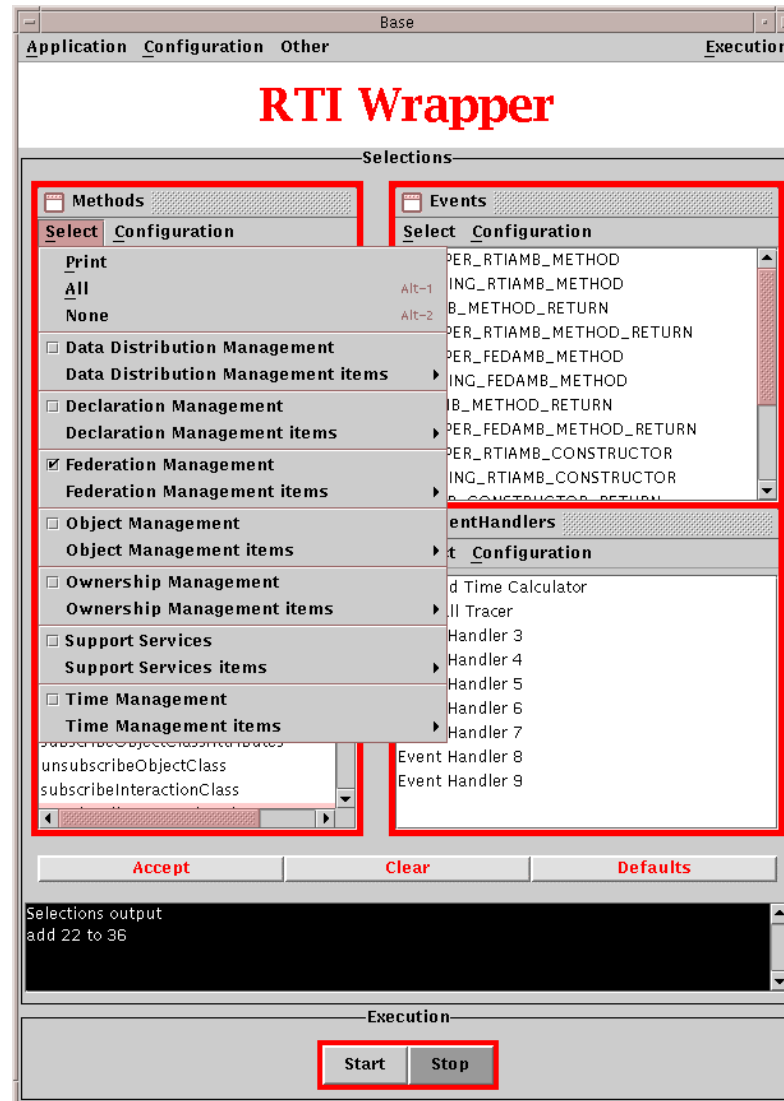
Which points in execution flow

Which performance measurements



Configuration Panel: Shortcuts

Quick-keys
Save run-time configurations



Note:

- **GUI requires no Federate code**
- **API controls also available to Federate**



Wrapper: Progress to Date

- **Built a framework in which instrumentation can be developed**
- **Supplied a few native instrumentation functions**
- **Framework allows Federation developers to customize and control instrumentation capabilities**
- **Framework is usable with virtually no Federate code changes**
- **Adapted example applications to demonstrate use of the Wrapper (HelloWorld, Benchmarks)**
- **Initial release anticipated 15 October**

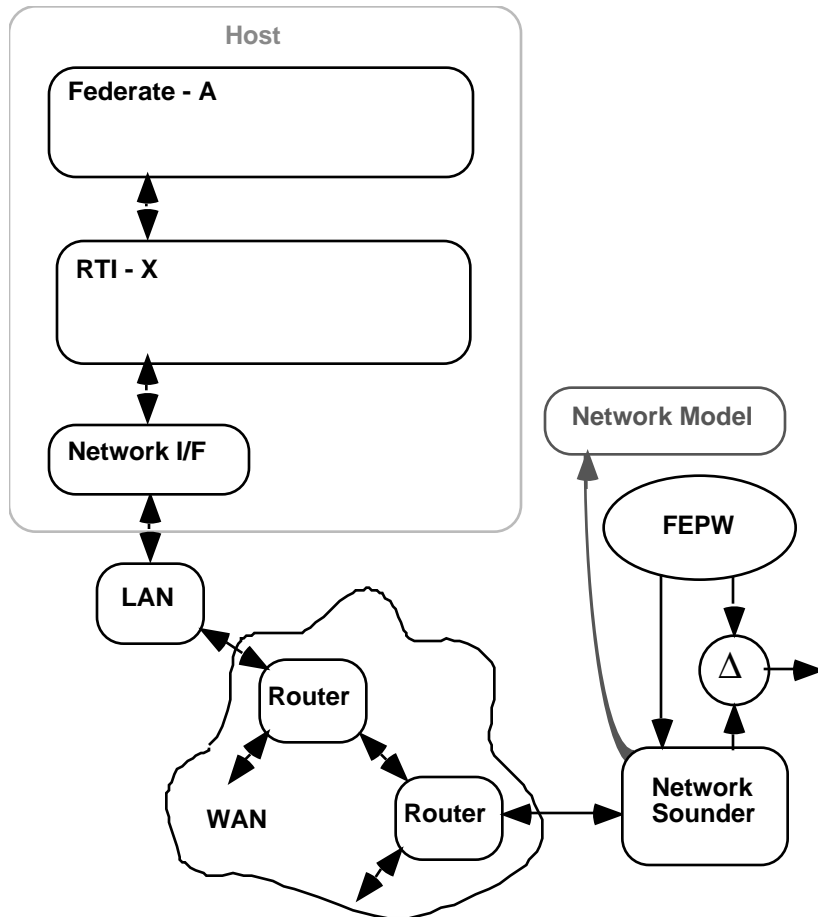


Wrapper: Future (with Consortium)

- **Extend maturity and breadth of instrumentation functions**
- **Port to additional platforms**
- **Additional testing**
- **Develop protocols for formatting and reporting output**
- **Develop mechanisms for collaboration, control, and information sharing across a Federation execution**



Network Sounder



- **Builds Federation connectivity model**
 - Initialized by Federation host table (from FEPW, etc.)
- **Capabilities**
 - Verify required host connectivity
 - Measure and quantify network performance
 - Discover (unanticipated?) non-Federation related traffic
 - Aid debugging
- **Assertion**
 - IP networks will require the most complex sounder



NetSounder: Near Term Capability

- **Verify basic network connectivity**
 - **Import Federate host IP info from FEPW DIF file, or alternate source**
 - **Stand Alone Application (RTI generic)**
 - DNS lookup
 - ICMP / TCP Ping
 - Traceroute
 - Telnet (useful to aid in debugging)
 - **Distributed / Coordinated Application (OS / RTI specific)**
 - TCP / UDP connections
 - Multicast verification
 - Reliable and Best Effort transport
- **Initial Release anticipated 15 Oct 2000**



NetSounder: Future Capability

- **Measure network performance**
 - Identify network topology (routers, etc)
 - Intrinsic latency between Federate host platforms
 - Sustainable throughput (bandwidth)
- **Identify network loads**
 - Verify that Federate generates anticipated levels of network traffic
 - Identify excessive network traffic not associated with Federation
- • **Network performance statistics used to develop Federation predictive models**



NetSounder: Host Table

- **Federate host table read from FEPW or alternate source**

Host name	IP addr
gerenuk	155.34.130.130
addax	155.34.130.56
oryx	155.34.130.63
oribi	155.34.130.11
nyala	155.34.130.128
imp	155.34.130.14
macwolfson	155.34.160.59
rhebok	155.34.130.51



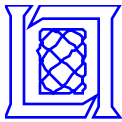
NetSounder: Network Tests

- **Verify basic network connectivity**

Host/IP from file: "host_ip.txt"
Federation name: "dummy_fed"
Network Connectivity tests run from host: "gerenuk"

Host name	IP addr	DNS Lookup	OS ICMP ping	Perl TCP ping	Traceroute	Telnet Probe
gerenuk	155.34.130.130	pass	n/a	n/a	n/a	pass
addax	155.34.130.56	pass	n/a	n/a	n/a	pass
oryx	155.34.130.63	pass	n/a	n/a	n/a	pass
oribi	155.34.130.11	pass	n/a	n/a	n/a	pass
nyala	155.34.130.128	pass	n/a	n/a	n/a	pass
imp	155.34.130.14	FAIL	n/a	n/a	n/a	FAIL
macwolfson	155.34.160.59	pass	n/a	n/a	n/a	FAIL
rhebok	155.34.130.51	pass	n/a	n/a	n/a	pass

Close



NetSounder: Diagnose Errors

- Diagnose host connectivity problems

Network Connectivity Tests

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Federation name: "dummy_fed"
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Host name	IP addr	DNS Lookup	OS ICMP ping	F	probe
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oryx	155.34.130.63	pass	n/a	n/a	
oribi	155.34.130.11	pass	n/a	n/a	
nyala	155.34.130.128	pass	n/a	n/a	
imp	155.34.130.14	FAIL	n/a	n/a	pass
macwolfson	155.34.160.59	pass	n/a	n/a	FAIL
rhebok	155.34.130.51	pass	n/a	n/a	pass

Test Result Info

macwolfson: problem connecting to "macwolfson", port 23: Connection refused

OK

Close



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Progress to Date

- ✓ • **Solicit consortium feedback on concepts**
- ✓ • **Search for existing tools and models**
- ✓ • **Develop initial suite of tools**
- ✓ • **Solicit SIW community feedback on concepts**
- ✓ • **Establish mechanism for tool distribution**

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DSPMO Web Site

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Location: <http://dspmo.ll.mit.edu/> What's Related

 **Welcome to DSPMO !**
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from our IEEE Simulation Interoperability Workshop (SIW) Fall 2000 paper: 00F-SIW-085

**"Toward Predictive Models of Federation Performance:
Essential Instrumentation"**

ABSTRACT. With support from DMSO, MIT Lincoln Laboratory is developing tools and techniques for measuring and characterizing the performance of HLA federations operating with various RTIs. These tools and techniques are intended for use by federation developers to study, understand, and enhance the performance of their federations. They are intended for application across many types of federations, from time-managed, analysis-oriented federations interested in maximizing the number of executions possible within a fixed time interval to hardware-in-the-loop federations interested in minimizing end-to-end latency.

An essential initial step in this effort is the development of instrumentation to capture interactions between the federates and the RTI, as well as data flows among the federates. This paper will describe a generic RTI "wrapper" that can capture call patterns (federate-to-RTI and RTI-to-federate) to generate statistical descriptions of service invocations, including histograms of time patterns in these invocations, etc. This instrumentation software will begin to address performance measures and concepts discussed in previous SIW papers by various members of the M&S community with distinctly different concepts of which aspects of overall federation performance are most critical.

In subsequent phases of this effort, data from federations who agree to use these tools and to share their collected performance data will be used to develop predictive models of federation performance. As they mature, these models can be used in conjunction with other tools and test federates for federation planning, development, testing, diagnosis, troubleshooting, and optimization.

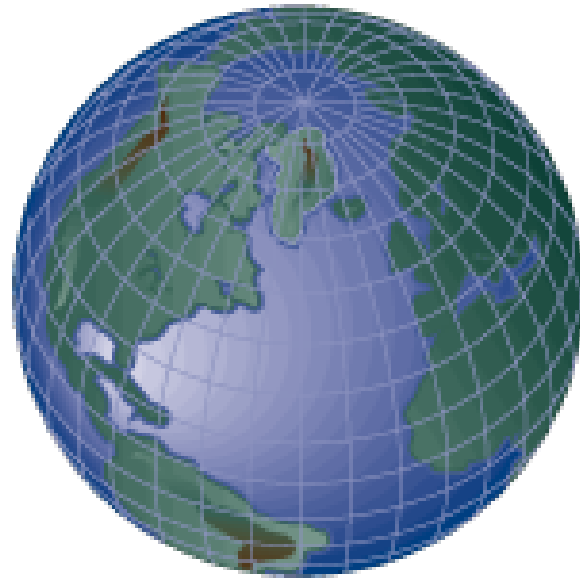
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--> *More detailed info on the RTI Wrapper will be available soon*

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NetSounder builds a connectivity model of the entire federation. It may be initialized from the host table in the FEPW or some other source. The near-term utility of NetSounder is to provide basic connectivity verification tests for all host computers used by federates in the federation.
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DSPMO Consortium
Membership in the DSPMO new tools consortium is extended to developers and users throughout the HLA community who are willing to participate and share in tool development, data collection, and model development.
--> If you are interested in joining the consortium, please fill out the [Consortium Request Form](#).

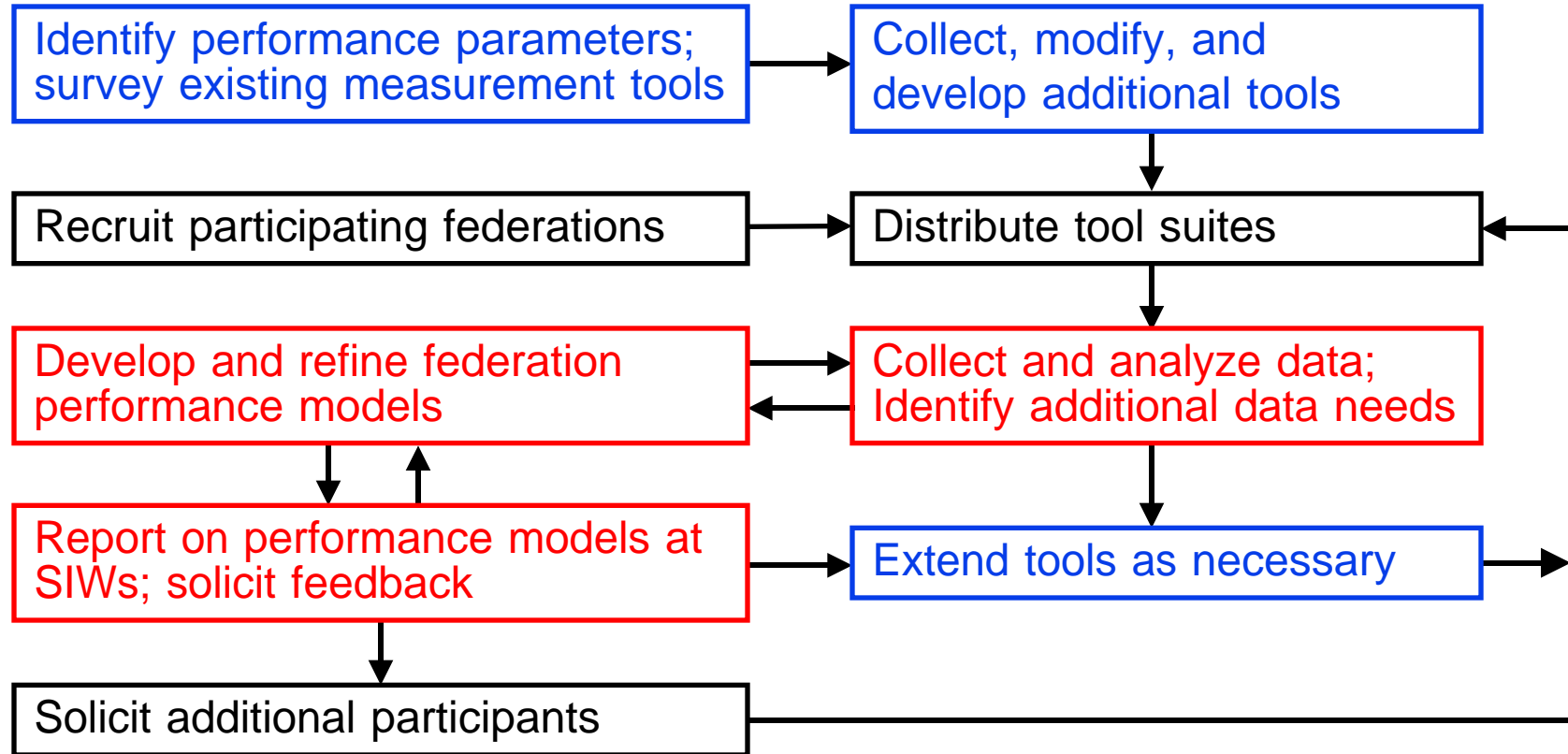
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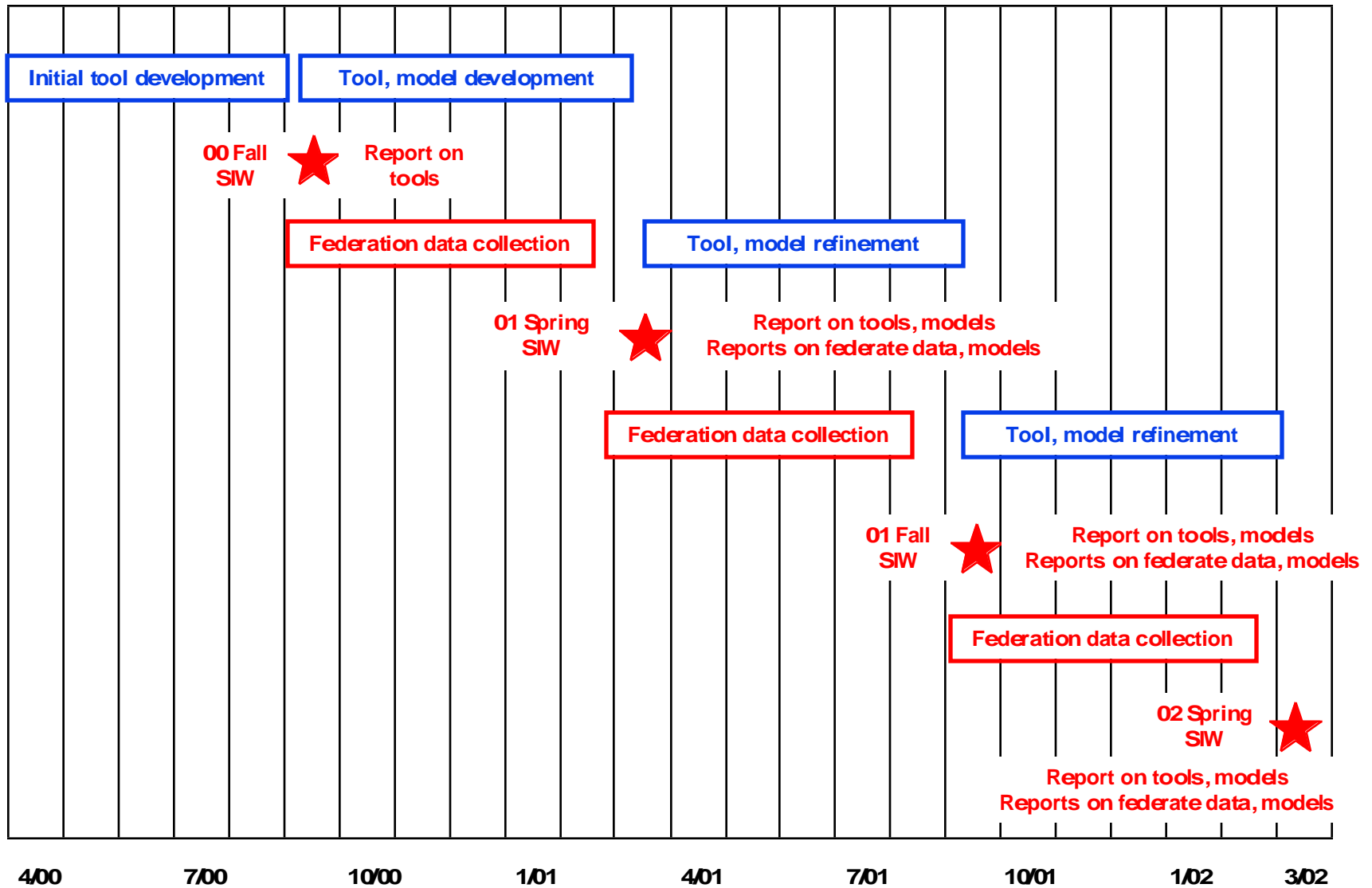
Consortium Operating Principles

- Members agree to **share data and models with the Consortium** and **report the results** of their federation performance modeling efforts at SIWs and other appropriate forums
- Members may port Consortium-developed tools to any computing platform/OS combination
 - Any such ports shall be placed in a Consortium repository (with documentation) for use by other members on an “as-is” basis
- Members may extend Consortium-developed tools to support specific applications
 - If such extensions are likely to be useful to other members, developers are encouraged to document them and place them in the repository for use on an “as-is” basis
 - The Consortium cannot promise that any such extensions will be supported in future releases of Consortium tools
- Membership is subject to DMSO approval

Iterative Approach to Federation Performance Modeling



Tool and Model Development Schedule




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