



CLIMBING TO NEW PEAKS IN
**INNOVATION
PERFORMANCE**

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Modeling and Simulation Impact on Research & Development

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Personal opinions of the presenter; not official government position



Creating Innovation Leadership Solutions

Environment and Questions



Environment

- Emerging virtual / digital age
- R&D globalization and open innovation
- Everything & everyone connectable

Questions

- How will rapid, broad virtual testing affect R&D?
- Implications of virtual testing facilities?
- Technical contributors to virtual age testing?



Terms

Conceptual Definitions



Modeling & Simulation

Mathematical or digital representation of a real-world phenomena

Physical Testing

Physical representation of a real world phenomena; e.g., lab testing

Cyber-Physical Systems

Connecting real world, physical testing, and modeling & simulation

Big Data Analytics

Emerging capabilities to make sense of data (Volume, Velocity, etc.)

Verification

Are we representing the right thing?

Validation

Are we representing it correctly?

Uncertainty Quantification

How accurate is the representation?



A Possible Progression for Mod-Sim and R&D



People

Complex System M&S

Enhanced Discipline M&S

Verification & Validation



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Verification & Validation

Pervasive
Connectivity
& Interfaces

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Evolving Foundation: High Performance Computing, Collaboration, Social, Knowledge Sharing, Networks, Security, Cloud, etc.

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*All Producing
Data, Data, Data*

Pervasive
Connectivity
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Testing as Service

Ideation – Streamlined,
Automated?

Uncertainty
Quantification

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Big Data Analytics

Machine Learning

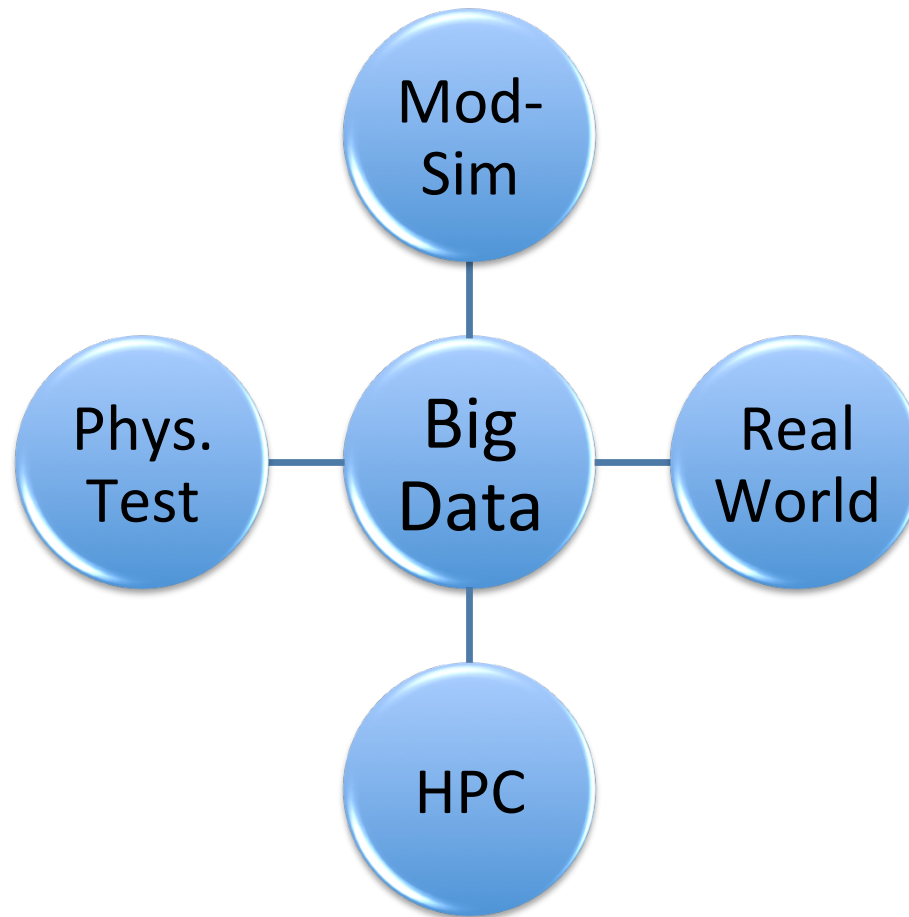
Testing as Service

Ideation – Assisted,
Automated?

Uncertainty
Quantification

Evolving Foundation: High Performance Computing, Collaboration, Social, Knowledge Sharing, Networks, Security, Cloud, etc.

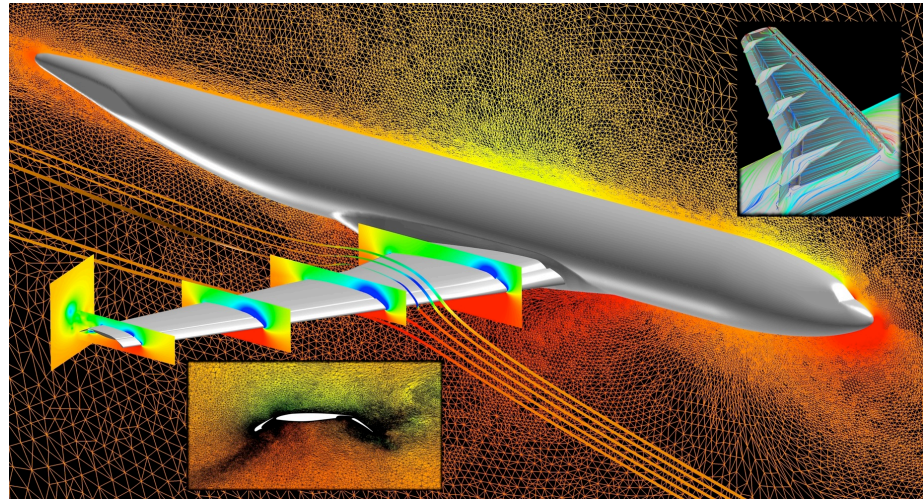
A Simpler View



Relationship of Physical Testing and Modeling & Simulation



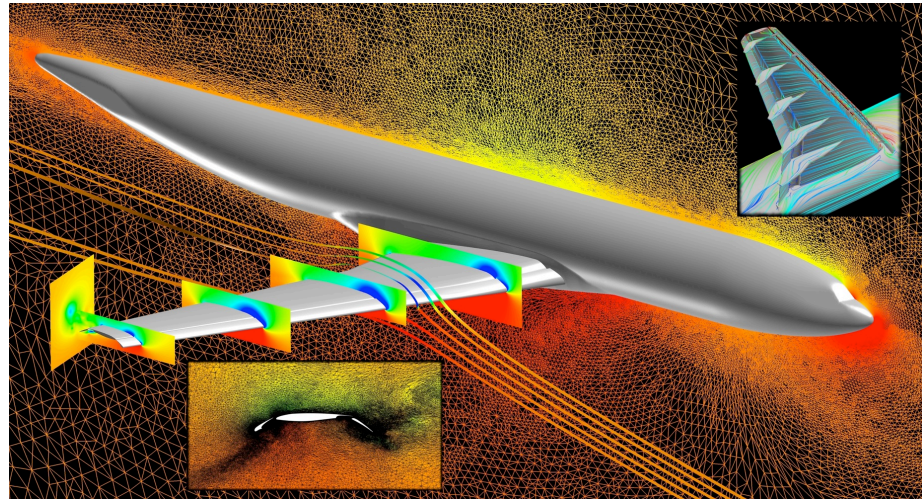
Versus?



Relationship of Physical Testing and Modeling & Simulation



+



**Integrate &
Rebalance**

Relationship of Physical Testing and Modeling & Simulation



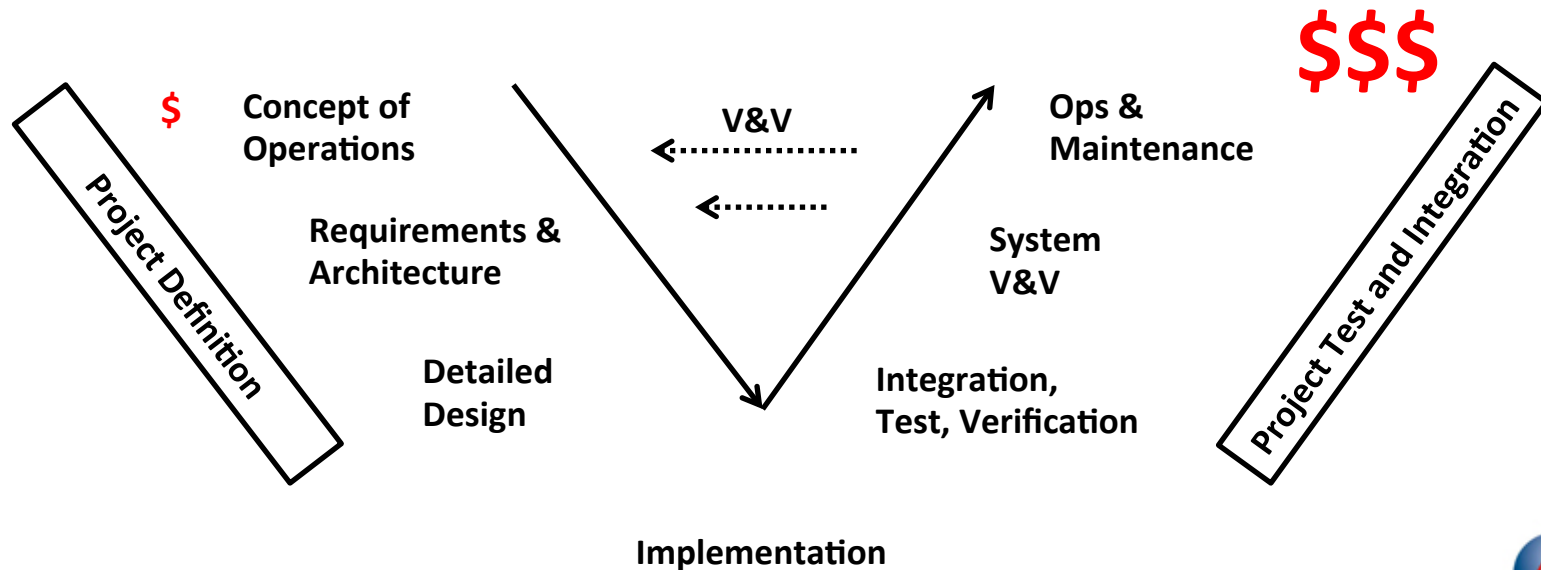
- Will Mod-Sim **REPLACE** physical testing?
- How to **CONNECT** Mod-Sim, physical testing, and real world?
- How the three **Integrate**?

To discover the answers, we must roll up our sleeves and get our hands dirty!

How Will Rapid, Broad M&S Affect R&D

System Engineering 101

- Early changes are cheap and easy
- Late changes are expensive and slow
- Leverage Mod-Sim to discover faults and make changes earlier
- Increase fidelity earlier in the process

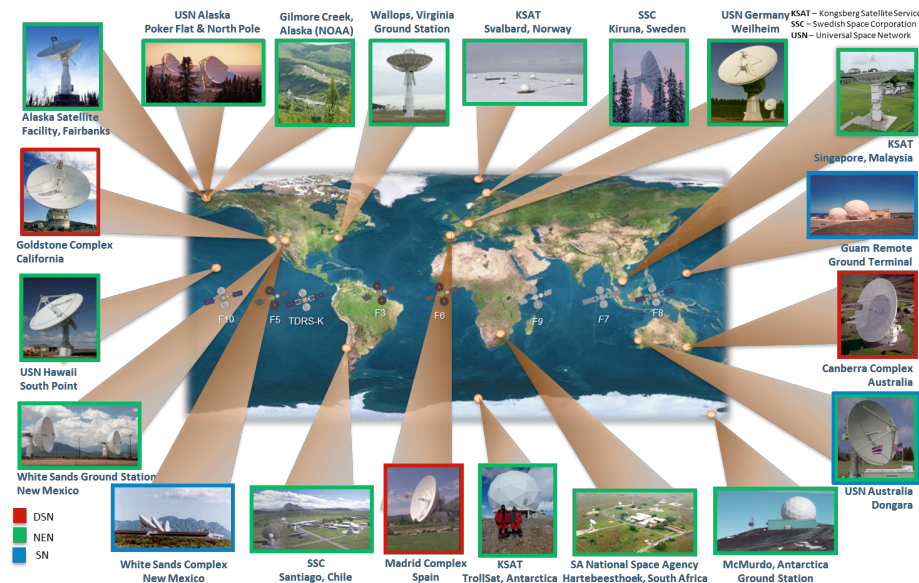


How Will Rapid, Broad M&S Affect R&D



Connect Anything & Anyone

- **Subscribe** to virtual or physical testing?
- **Subscribe** to real world sensors?
- Democratization of R&D
- Compose-able modules and interfaces – UQ and V&V required

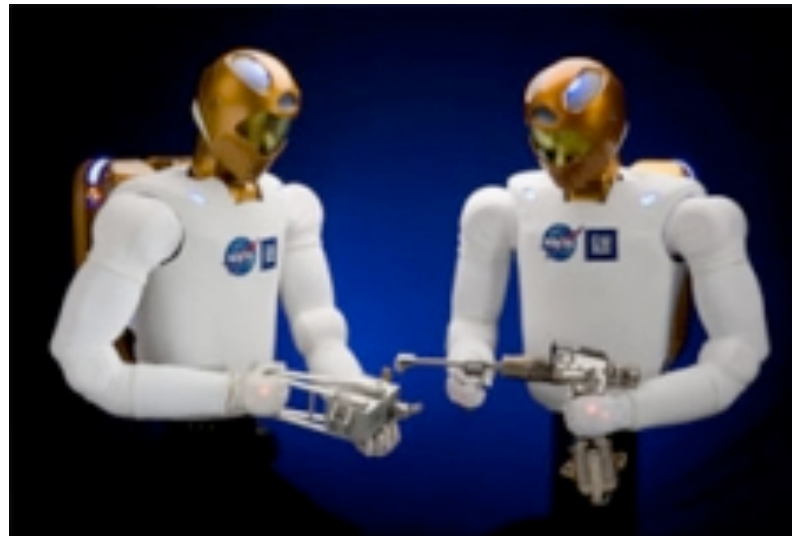


How Will Rapid, Broad M&S Affect R&D



Ideation – Assist and Automate?

- When will we have digital colleagues?
- What if we connect them to R&D systems?



Virtual Testing Facility Implications



More R&D per testing device or lab

- More output; less down time

Balance Connectivity and Safety

- Learn from national infrastructure issues
- On-site safety operators?

Uncertainty Quantification

- Quality and applicability of a given capability

Defeat Tyranny of Time-Distance

- Subscribe from anywhere on Earth (or beyond)
- Citizen scientists



Technical Contributors to Mod-Sim and R&D in the Digital Age



Data flood from everything we've discussed

- Big Data Analytics and Machine Learning
- 4th Research Paradigm

Increasingly Complex Systems of Systems

- Uncertainty quantification at module and system levels
- Verification & Validation more difficult

Human Expertise

- Continually self-reinventing
- Cooperate with digital colleagues

High Performance Computing Breakthroughs

- Optimize algorithms to new HPC
- Old code on new HPC = FAIL



Summary

Amazing R&D contributions possible from:

- Enhanced and integrated modeling & simulation
- Connecting with physical testing and real world systems
- Analyzing with big data and machine learning
- Optimizing the combination of all techniques

Realizing the Opportunity

- What is missing?
- How can we make it happen?
- What will you contribute?

