NRC Workshop on NASA Technologies

Modeling, Simulation, and Information Technology & Processing

Panel 1: Simulation of Engineering Systems

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10 MAY 2011

Charge to the Panel

- Read the TA11 Roadmap
  - Modeling, simulation, information technology & processing
- Understand what it says
- Assess it by answering a number of questions provided by NRC

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  - Named a "Space Technology Area Roadmap", and roadmap overview populated only with space missions, yet text points to mission drivers like NextGen ATM, terminal area ops, subsonic cruise efficiency,… → What *are* the mission drivers?
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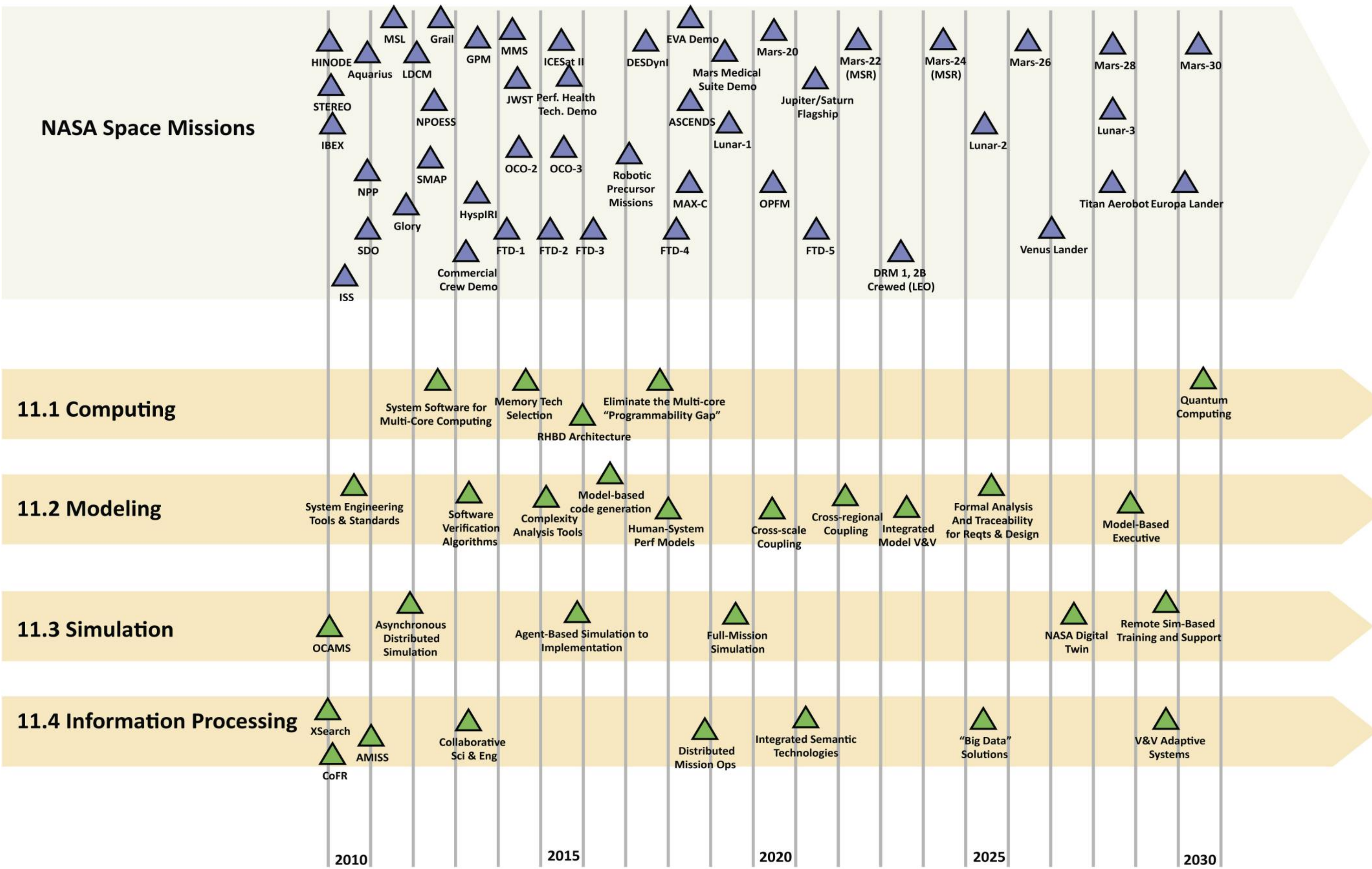
TA11 Roadmap



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  - Named a "Space Technology Area Roadmap", and roadmap overview populated only with space missions, yet text points to mission drivers like NextGen ATM, terminal area ops, subsonic cruise efficiency,… → What *are* the mission drivers?
  - TA11 has 4 major areas (computing, modeling, simulation, information processing), with 16 subareas (called TABS), 10 of which were selected/prioritized as "top technical challenges" → Where did these come from and what was rationale?
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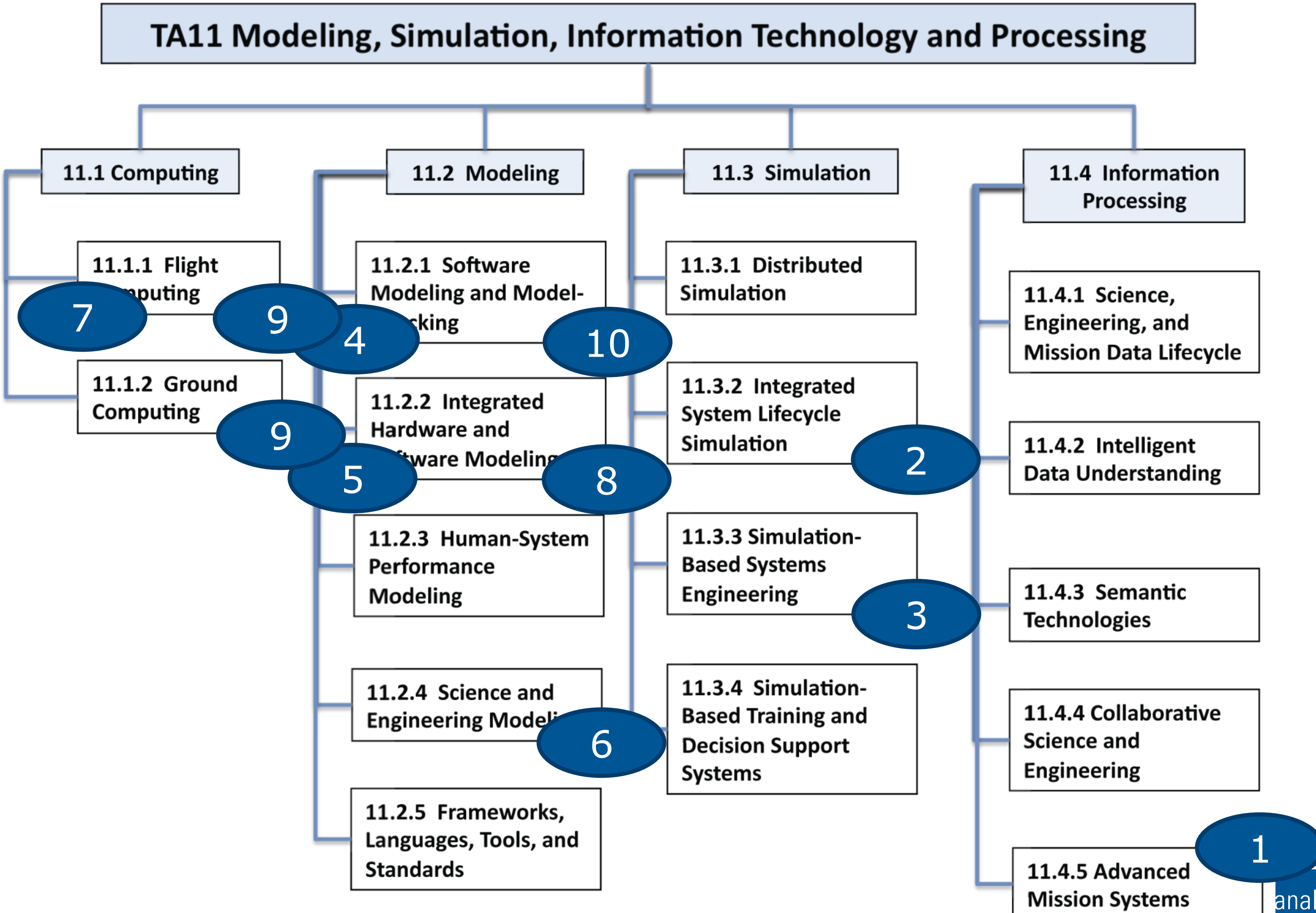
TA11: Modeling, Simulation, Information Technology & Processing TABS (with “Top Ten”)



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Top Ten Technical Challenges: Where did they come from?

Priority	TABS	TABS Name	Technical Challenge
1	4.5	Advanced Mission Systems	Adaptive Systems
2	3.2	Integrated System Lifecycle Simulation	Full Mission Simulation
3	3.3	Simulation-Based Systems Engineering	NASA Digital Twin
4	2.1	Software Modeling	Formal analysis and traceability of requirements and design
5	2.2	Integrated Hardware and Software Modeling	Advanced Integrated Model V&V
6	2.4	Modeling	Cross-scale and inter-regional coupling
7	1.1	Flight Computing	System Software for Multi-Core Computing
8	2.2	Integrated Hardware and Software Modeling	Complexity Analysis Tools
9	1.1 & 1.2	Flight and Ground Computing	Eliminate the Multi-core “Programmability Gap”
10	2.1	Software Modeling	Software Verification Algorithms

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  - TA11 has 4 major areas (computing, modeling, simulation, information processing), with 16 subareas (called TABS), 10 of which were selected/prioritized as "top technical challenges" → Where did these come from and what was rationale?
  - Roadmap overview shows milestones for each of the 4 major areas, but…
    - …for computing and information processing, milestones in text (tables 1 and 3) don't match
    - …for modeling and simulation, milestones not identified in text
  - So where did these milestones come from? And what was the rationale there?
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- Assess it by answering a number of questions provided by NRC
  - What are the **top technical challenges** in the area of your presentation topic?
  - What are **technology gaps that the roadmap did not cover**?
  - What are some of the **high priority technology areas** that NASA should pursue?
  - **Do the high priority areas align well with NASA's expertise**, capabilities, facilities and the nature of the NASA's role in developing the specified technology?
  - In your opinion, **how well is NASA's proposed technology development effort competitively placed**?
  - What specific technology can we call a **"Game Changing Technology"**?
  - Is there a **technology component near the tipping point**? (Tipping point: large advance in technology readiness is possible with a relatively small additional investment.)
  - In your opinion, **what is the time horizon for the technology** to be ready for insertion (5-30 years)?
  - Provide a sense of value in terms of **payoffs, risk, technical barriers and chance of success.**

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- Read the TA11 Roadmap
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- Understand what it says
- Assess it by answering a number of questions provided by NRC
  - What are the **top technical challenges** in the area of simulation-based systems engineering?
  - What are **technology gaps that the roadmap did not cover**?
  - What are some of the **high priority technology areas** that NASA should pursue?
  - **Do the high priority areas align well with NASA's expertise**, capabilities, facilities and the nature of the NASA's role in developing the specified technology?
  - In your opinion, **how well is NASA's proposed technology development effort competitively placed**?
  - What specific technology can we call a **"Game Changing Technology"**?
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Top Technical Challenges in Simulation-Based Systems Engineering

- Front end: Early tracking of the requirements specification and design generation phases (as contrasted with late tracking of coding and testing phases) (TABS 2.1)
  - Mission goals, context, and operating assumptions driving the requirements, including ranges/uncertainties
  - Tracking of different paths through the design space and associated trades, including risks/mitigators
- Midpoint: Adequate-fidelity representation of the subsystems and components, for the given use (TABS 2.3, 2.4, 3.3)
  - Includes hardware, software, and humans
  - Assumes multiple levels of fidelity for different needs, even within same simulation, not necessarily "high-fidelity" wherever possible
- Back end: Support for the long-term, including upgrades to hardware/software, and operator selection and training (TABS 3.3, 3.4)

Technology Gaps Not in the Roadmap

- Front end: Tracking requirements/designs hard because of informal nature of specification
  - To get these in "machine readable" form will require advances in semantic technologies, knowledge representation, machine learning, and "computational creativity"
  - Right now, TABS 2.1 focuses on formal methods once designs are "encoded"
- Midpoint: Selecting the right-level representation for all components at multiple spatio-temporal scales is difficult, and is strongly use driven
  - Modeling of *all* components implies modeling the human (s) at the right-level of perceptual/cognitive/motor fidelity. This requires advances in human operator modeling/simulation, which TABS 2.3 acknowledges, but TABS 3.3 does not (the "digital twin" includes no humans)
  - Multi-resolution modeling/simulation is still an emergent technology, not often used by the practitioner (eg, Zeigler in references, but not cited). Progress needs to be made here also.
- Back end: Providing advanced decision aids for real-time operations, and supporting operator selection and simulation-based training
  - Simulation-based decision aids needed for model-based fusion, COA evaluation, and planning, especially when ground-based aiding not available (not considered under TABS 3.4)
  - Simulation-based training requires more than just a good simulation. Advances need to be made in curriculum management and agent-based mentoring ("intelligent tutoring") (neither considered under TABS 3.4)

High Priority Technology Areas

- Potential "game changers"
  - Serious advances in semantic technologies, knowledge representation, machine learning, and "computational creativity" could accelerate our plodding design/ implementation cycles (30+ years in DoD), to something approaching that in commercial world
  - Modeling of the human operator, and inclusion in holistic human-system simulations. Requires significant advances in cognitive psychology, team behavior, and social psychology, but "good enough" computational representations could add immeasurably to understanding human-system dynamics and its impact on system engineering analyses
- Potential technology components near the tipping point
  - Multi-core processing treated like a problem to be solved. Can't it be an enabler for multi-resolution modeling/simulation, a real problem that needs solving? Work both issues as one
  - Simulation-based decision aids used all the time for off-line analysis/design. Bring them into the operational domain for real-time "what-if" data fusion and planning
- Time horizon for insertion
  - For four areas above: 20 yrs, 10yrs, 5 yrs, tomorrow
  - Who should work them: NASA, Computational Cognitive Science Community, NASA, NASA
- Payoffs, risk, technical barriers, and chance of success

Q&A