Brian Trease, JPL

Thursday June 23rd, 2011

KISS Study on xTerramechanics

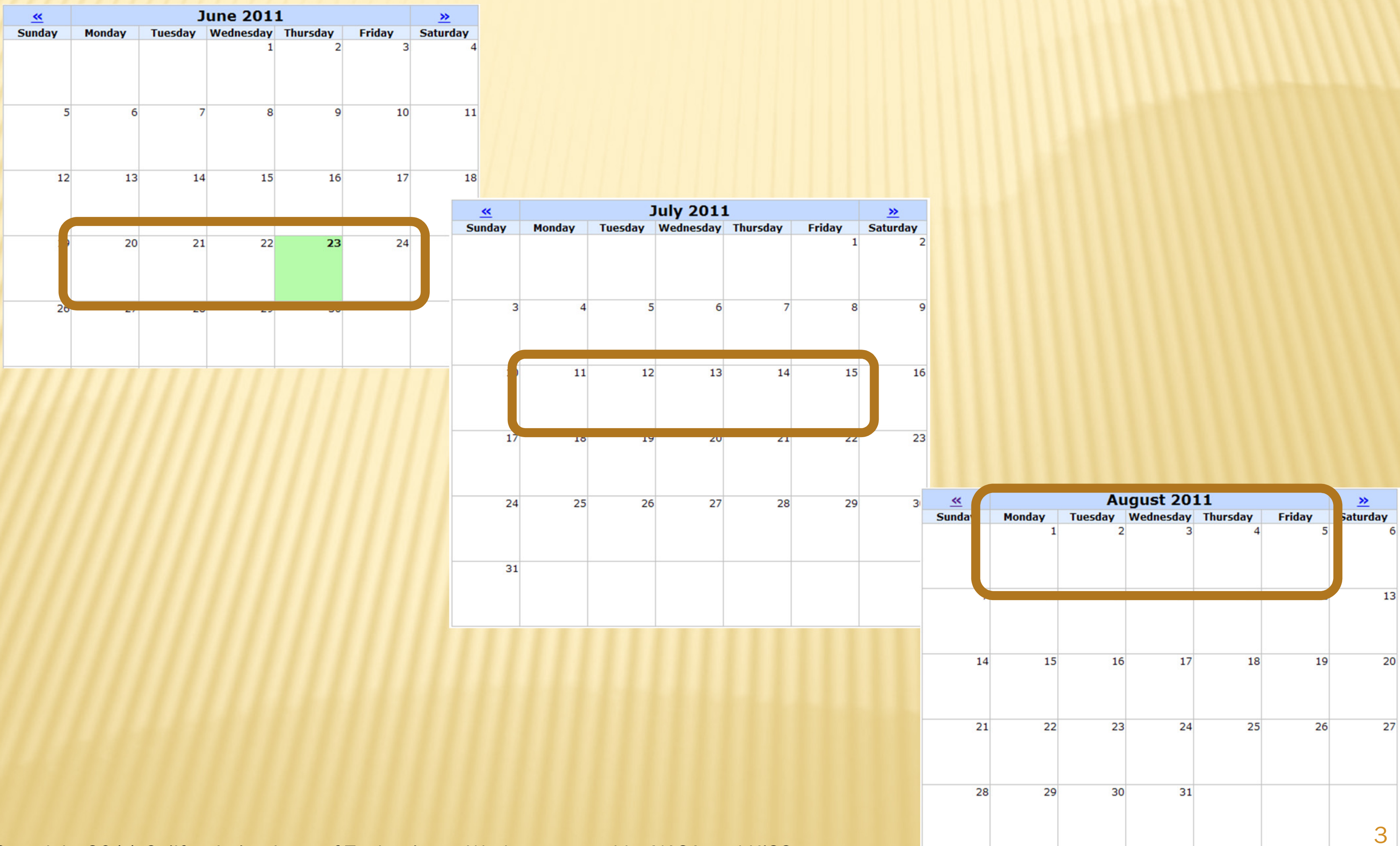
ARCHITECTURE OF COLLABORATION, DEVELOPMENT, AND OPERATION

 Work sponsored by NASA and KISS.

START THINKING ABOUT WHAT'S NEXT

- Interaction
- Collaboration
- Data-sharing
- Proposals
- Workshop #2
- .
- .
- .
- (The Money $$)

SUMMER OF XTERRAMECHANICS



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ARTEMIS – A CASE STUDY IN COLLABORATION

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DYNAMIC MODELING AND SOIL MECHANICS FOR PATH PLANNING OF THE MARS EXPLORATION ROVERS

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ABSTRACT

To help minimize risk of high sinkage and slippage during drives and to better understand soil properties and rover terramechanics from drive data, a multidisciplinary team was formed under the Mars Exploration Rover (MER) project to develop and utilize dynamic computer-based models for rover drives over realistic terrains. The resulting tool, named ARTEMIS (Adams-based Rover Terramechanics and Mobility Interaction Simulator), consists of the dynamic model, a library of terramechanics subroutines, and the high-resolution digital elevation maps of the Mars surface. A 200-element model of the rovers was developed and validated for drop tests before launch, using MSC-Adams dynamic modeling software. Newly modeled terrain-rover interactions include the rut-formation effect of deformable soils, using the classical Bekker-Wong implementation of compaction resistances and bull-dozing effects.

The paper presents the details and implementation of the model with two case studies based on actual MER telemetry data. In its final form, ARTEMIS will be used in a predictive manner to assess terrain navigability and will become part of the overall effort in path planning and navigation for both Martian and lunar rovers.

INTRODUCTION

Since 2004, the twin rovers dubbed Spirit and Opportunity have been exploring the surface of opposite sides of Mars. Driven via a robust mobility system, the rovers have been conducting scientific experiments focused on understanding the planet's climate history, surface geology, and potential for past or present life. After surviving 25X its target life, the Spirit rover finally completed operations after succumbing to mobility-related embedding. Opportunity continues to drive on, and will soon face rougher terrains and slopes than encountered before, as it climbs the rim of Endeavor crater.

To a large extent, the mission life and science objectives are determined by the robustness and capability of the mobility system, which consists of a rocker-bogie suspension configuration with six wheel drive capability [1]. In addition the outer four wheels have azimuthal actuators to allow arc turns. The rovers have now both operated in mobility regimes beyond the prediction capabilities of the simple analysis tools currently available to engineers. To this end, we have created a software tool named ARTEMIS, which combines the best of classical terramechanics with state-of-the-art multi-body-dynamics commercial software.

The paper presents the details and implementation of the model and software. A first case study specifically addresses the Spirit Rover embedding situation at the "Troy" site on Mars. A second study focuses on simulating the sol (Mars day) 2211 Opportunity terramechanics experiment in which ripple crossing was performed to test the dynamics across this terrain. This test supports drive planning to the next science destination at Endeavour crater, for which Opportunity must cross at least 7 km and perhaps a thousand ripples at a top speed of ~5 cm/s.

1

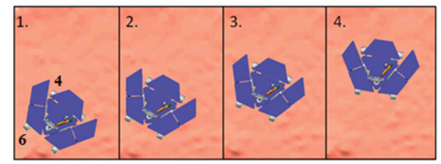


Figure 16: TIME-SERIES IMAGE OF YAW EXHIBITED DURING A FOUR-WHEEL BACKWARD DRIVE SIMULATION.
OPERABLE WHEELS: STATIC COF= 0.5, DYNAMIC COF=0.4;
WHEELS 4 AND 6: STATIC COF=0.7, DYNAMIC COF=0.6

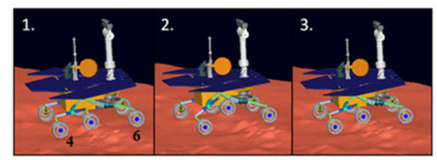
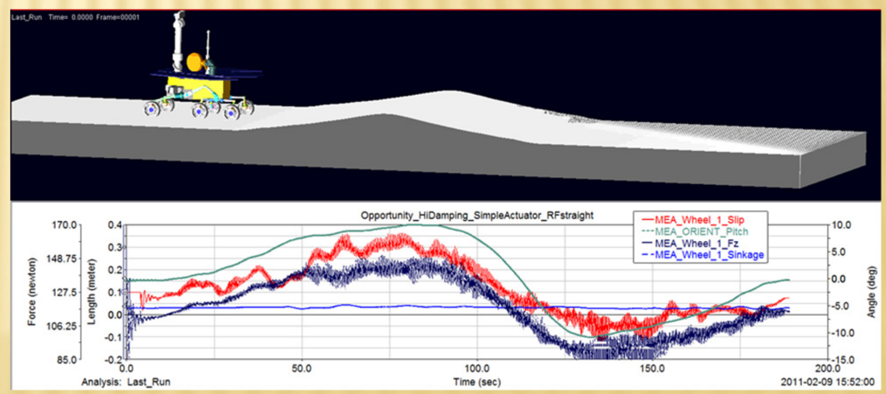
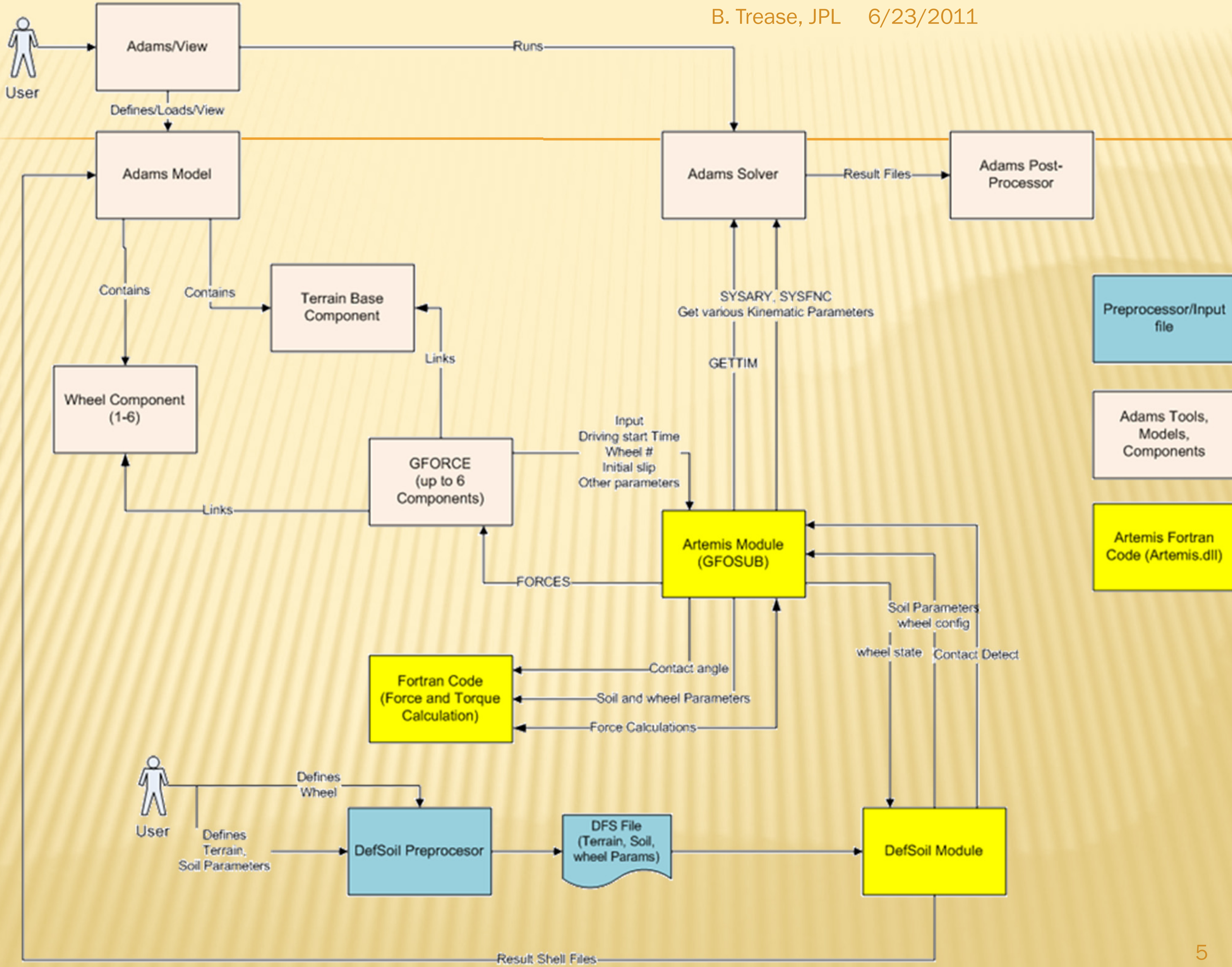


Figure 17: TIME-SERIES IMAGE OF STICK-SLIP MOTION EXHIBITED DURING A FOUR-WHEEL BACKWARD DRIVE SIMULATION.
OPERABLE WHEELS: STATIC COF= 0.5, DYNAMIC COF=0.4;
WHEELS 4 AND 6: STATIC COF=0.7, DYNAMIC COF=0.6

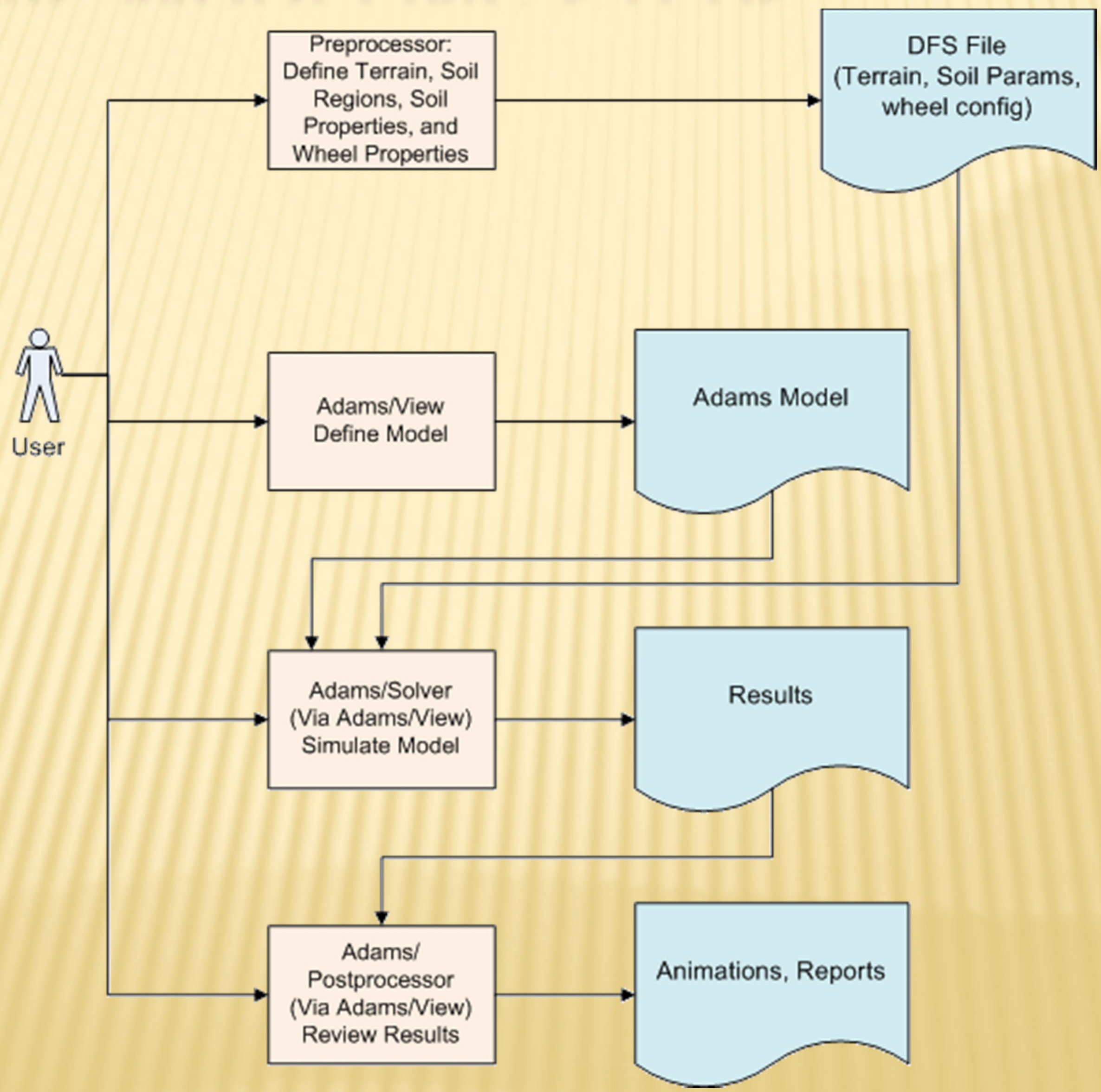


ARTEMIS

B. Trease, JPL 6/23/2011



ARTEMIS MODELING STEPS



MODELS OF INTERACTION

- Players
  - Design engineers
  - Control engineers
  - Operations / Drivers
  - Principle Investigators
  - Mechanics Modelers
  - Model / Software Development
  - Software Simulation
  - Experiments – Validation & Parameter Determination
  - (Project Managers)

MODES of Interaction

•Long-term Research and Development

•Short-term Tactical Planning, Coordination with Operations and Science

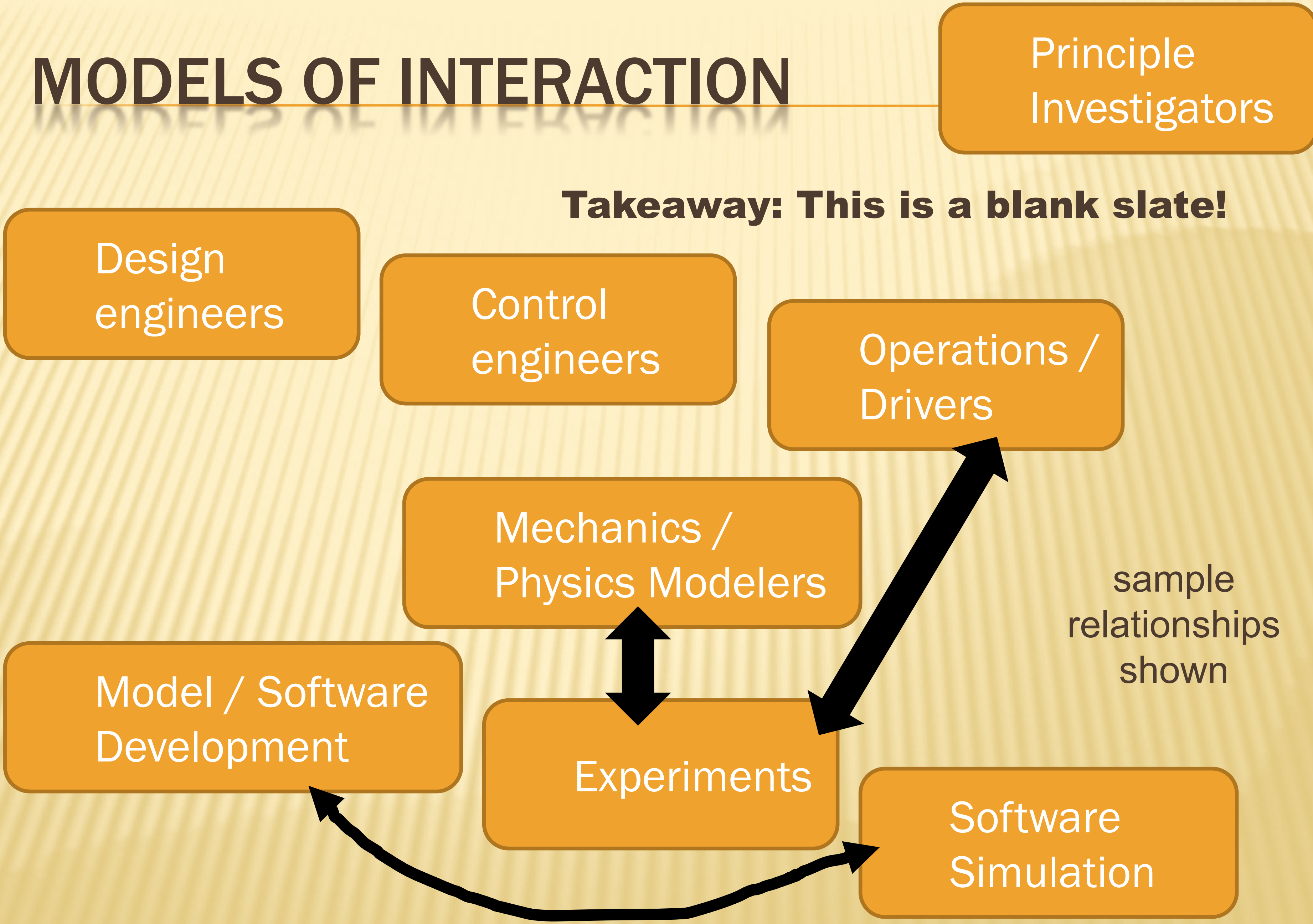
SOME POSSIBILITES

- So many methods, how will they all play together?
  - Separate components in a “Tool-box”?
  - Tiered, Integrated, “Multi-scale” Software?
    - *Higher-fidelity* models called as needed by *higher-level* models
    - What is the flow of data and experiments?
  - Independent sub-models that correlate and validate each other?

 Work sponsored by NASA and KISS.

MODELS OF INTERACTION

Takeaway: This is a blank slate!



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