Simulation Purpose

- Evaluate the coupled effects of the environment, the vehicle configuration, and crew and ground activities as vehicles evolve throughout their life cycle.
- Provide insight to project systems engineers and subsystem teams on the integrated effects of design selections.
- Support testing of hardware and software in environments and conditions that are expensive or impossible to recreate on the ground.
- Train operators on vehicle usage and provide insight into the effects of procedural inputs on the vehicle during operations.
- Generally, early simulation allows insight into emergent vehicle behavior during the development phase rather than during integration, test, or operations.
Simulator Types

- **Analysis**
  - Single or multiple subsystem simulations that provide insight into vehicle design or operation, running on an engineer's desktop

- **Hardware-in-the-loop Systems**
  - Single or multiple subsystem simulation supplying a realistic environment to one or more hardware elements for analysis, testing, software development, or software verification purposes
  - Robotics, Avionics, GN&C

- **Human-in-the-loop Systems**
  - Full team, single system, or scenario training in dedicated facilities with representations of crew and flight controller interfaces used for training and procedure verification

- **Many simulations cross these boundaries**
  - Begin life for analysis, and end up being used for hardware- or human-in-the-loop activities
  - A given simulation may be used throughout a program life cycle
Analysis Simulations

- Mobile Servicing System (MSS) sim - ISS robotics
Hardware-in-the-Loop Simulation

- Six Degree of Freedom Dynamic Test System (SDTS) – Stewart platform used to validate docking and berthing mechanisms
Human-in-the-Loop Simulation

- Systems Engineering Simulator (SES) – Real-time, crew-in-the-loop simulation of the dynamic flight phases of Shuttle, ISS, Orion, and future vehicles
Iterative Development Approach

![Diagram of Iterative Development Process]

- Campaign Description
- Physical Description
  - Launch Vehicle Sizing
  - Interior Architecture
  - Assembly Sequence
- Functional Description
  - Vehicle Configuration
  - Dynamics
  - GN&C
  - Power System
  - Thermal System
  - ECLSS System
  - Integrated Vehicle Performance
• Trick simulation environment provides model execution ordering, input processing, state integration, data recording, and post-processing capabilities
• JSC Engineering Orbital Dynamics (JEOD) provides environment models and 6-DOF dynamics
• General Use Nodal Network Solver (GUNNS) provides physics-based models of power, fluidic, and thermal systems
• Multibody Dynamics (MBDyn) provides kinematic and dynamic modeling of complex mechanisms including robots
• Pong and MechDyn provide modeling of complex contact surfaces, including terrain and mechanisms
• TrickHLA provides IEEE 1516 High Level Architecture (HLA) interface mechanism for all Trick simulations
• EDGE provides realtime graphics rendering capabilities
Environment Modeling
• **GUNNS** provides a common design and code generation development approach to three “aspects”
  – Fluidic (plumbing, life support systems, thermal control)
  – Electrical (generation, distribution, loads)
  – Thermal (structure temperatures, solar heating, albedo)
• **Data-driven component models are developed once and reused across modeled subsystem designs**
Crew Inputs
• Producing simulations early in the development phase allows leverage of the investment throughout the life cycle
  – The system design can be influenced by the results of studies that leverage the simulation capability
  – Model fidelity can be improved as knowledge of the vehicle design improves, providing appropriate detail for each study
  – Simulation can be incorporated into flight software development and testing processes
  – Simulation can be incorporated into testing environments, supporting eventual substitution of sensor and effector models with hardware
  – During operations, simulation can be used for operator training and procedure check-out