# *MS³ Overall Architecture – Nominal Mission Configuration*

**HARDWARE**

- IBM PC/Intel CPU compatible
- Generally one computer per monitor/display/scene
- One computer for system/simulation control and status
- Off-the-shelf 3D graphics hardware
- Ethernet connectivity between crew stations, scene generators, models/control workstation and Mission Control Center
- Keyboard & joystick interfaces for forward station & aft flight deck
- Digital input/output interface to optional external hardware to drive switches and lights
- Analog output interface for meters and gauges

**SOFTWARE**

- Windows Operating System
- C, Assembly and Vertex & Pixel Shader Languages
- DirectX and internally developed APIs

**GENERAL CHARACTERISTICS**

- Integrated, networked Space Shuttle mission simulation of launch, orbit and entry/landing
- MS³ provides SOFTWARE ONLY
- Detailed, textured out-the-window views during all mission phases
- Comprehensive emulation of Shuttle glass cockpit instrumentation and displays
- Simulation/system control and monitoring
- Accurate re-creation of Shuttle Heads-Up Display (HUD)
- Man-in-the-loop flying on-orbit and from Mach 1 to landing via joystick
- Crew switch throws and keyboard inputs can be monitored at sim control station
- "Mission Control Center" monitoring of crew displays
- Supports outputs for motion-base platform
- Simple to hi-fidelity modeling of Orbiter trajectory & dynamics
- Simple to medium fidelity modeling of Orbiter systems
- Easy software expandability to improve fidelity in Orbiter systems, trajectory & guidance
- System configuration (number of computers, displays, functionality) is extremely flexible (e.g. eliminate MCC, single screen visual, etc.)
- Integration of software and switch/meter/light hardware allows for software recognition of switch derived events (e.g. APU configuration, ET Separation Arm/Jettison)
- Support for various options as described in MS³ Options and Pricing document

- ***ARCHITECTURE IS EXTENDABLE TO ALLOW SIMULATION OF NON-SHUTTLE MISSIONS***

## *Shuttle Flight Deck - Out-The-Window Scene Generators*

- **Each computer receives position & attitude data from the Master CPU via Ethernet and generates its own graphics image**

- **Available views include flight deck left, forward, and right side windows; overhead window; aft flight deck window (looking into payload bay)**
  - **Optional additional visuals available to support MS$^3$ optional missions**
  - **Optional video monitor in Mission Control to view launch, crew activities, entry & landing via several "cameras" controlled from instructor station**

- **1920x1080 screen resolution in 32-bit True Color mode, employing Microsoft DirectX graphics interface**

- **Visual scene can be presented on standard monitor or displayed via an NTSC TV/projector**

- **Photo-realistic color images for out-the-window views**
  - 1 km resolution on-orbit earth scene with clouds and night-side city lights
  - Standard landing scenery is 1m to 25m satellite imagery of KSC
  - Realistic atmospheric effects
  - 3D clouds at KSC
  - Payload Assist Module (PAM) booster rocket model for baseline satellite deploy mission
  - Realistic sun lighting (changes as Earth rotates) & star fields

## *Crew Forward/Aft Stations Display Processors & Switch Emulation*

- **Detailed software recreation of "glass cockpit" instruments on one CRT**
- **Display processors provide forward and aft station crew data entry & monitoring "green screens" (one CPU per monitor, 640x480 resolution; currently have ~40 onboard displays emulated)**
- **One flight deck CPU is typically configured to accept keyboard & switch inputs and provide overall control of other remote display processors; typically also provides sound effects generation. (These functions can be provided by other machines as well.)**
- **Multiple joysticks can be supported, typically one each for commander, pilot, and aft flight deck. (Active joystick is selectable via "green screen" data display.)**
- **1 computer per screen, each containing a display processor to control CRT output**
- **Accurate re-creations of Shuttle on-board displays (Ascent/Entry Trajectory, Systems, Payload Bay Doors, etc.)**
- **Real-time rendezvous displays depicting Orbiter & target vehicle relative positioning (target vehicle is Payload Assist Module satellite for baseline mission)**
- **Ground track displays showing Orbiter and target vehicle positions over the earth, with orbital parameters and sunrise/sunset information**
- **Keyboard interface for entering data & selecting displays, emulates actual Orbiter functionality**
- **Orbiter attitude and Robotic Arm control via joystick during Orbit and Landing phases**
- **Software interface to physical switch hardware for system configuration (e.g. PLBD opening, OMS engine arming, etc.) via hardware switches if desired**

## *Simulation Monitoring and Control (the "Master" station)*

- **1 Computer, with one monitor for user interface**

- **Provides all trajectory, systems, guidance models**
  Numerically integrates models at user-determined step from real-time to 50x

- **Trajectory models**
  - "Canned" trajectories for ascent to MECO and Entry Interface to Mach 1 (no pilot control)
  - Baseline nominal orbit inclination is 51.6°
  - Numerically integrated on-orbit trajectory using spherical earth model, with manual and autopilot control available for attitude maneuvering
  - Accurate emulation of Orbiter flight dynamics & guidance from Mach 1 to landing
  - Landing phase pilot control options: Full autopilot; manual pitch control; manual roll control; full manual control; "Fake CSS" (trajectory is flown by autopilot, but joystick inputs are reflected in out-the-window scene, creating illusion that pilot is doing the flying)

- **Guidance model**
  - Simplified "attitude & burn time" inputs for Shuttle on-orbit maneuvers
  - Accurate Orbiter guidance emulation from Mach 1 to ground

- **System models**
  - Simplified flow rate models for major systems such as MPS, OMS, RCS, APU, SSME
  - Simplified switch configuration logic for Payload Bay Doors, control of satellite deployment, landing gear, OMS, RCS, APU, SSME, SRB's
  - Allows selectable automatic or manual deployment of landing gear & drag chute

- **Distributes all systems & trajectory data via network to other processors for scene generation and data display**

- **Provides single, centralized user interface for network status, sim initialization and control, and ground-based camera selection**
  - Selectable sim phase (e.g. Ascent, Orbit, Landing), start/stop/pause, sim clock speed, mission type (e.g., PAM Deployment, ISS Docking, AOA abort). Automatic or manual progression from one mission phase to the next.
  - Reliable network configuration which allows for remote systems leaving and/or re-joining the network without simulation terminating or "locking up"
  - Status light indicators for identification of complete environment configuration and status
  - Provides ability to remotely shut down and/or re-start any or all network computers

## *Baseline Mission Control Center*

- **Client-specified number of computers, each driving a single monitor for the control center operator position(s)**
- **Each position has up to 16 mission phase-specific displays available for viewing**
  - **Onboard-equivalent displays as well as MCC-specific formats**
- **Some displays offer graphical time history plots of specific parameters**
- **Software-emulated Caution & Warning and Event Light panels on each station provide indications of mission events and anomaly conditions**
- **Access to Flight Deck- and model-initiated events to drive console status lights**
- **Mouse-driven graphical user interface for presentation of data & selection of display formats**