# Case for Deploying Complex Systems Utilizing Commodity Components

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# Introduction

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- The primary focus of this presentation is the transition of a Space Station ground system from a client/server UNIX based system to a client/server system based on commodity priced and open system components
- In covering this transition, the presentation will discuss
  - A definition of the **HOSC Ground System** and its capabilities in order to lay the ground work for the transition
  - The reasons why the transition was necessary in **Motivation for Change**
  - Several methodologies or **Options** that were considered once the decision was made that some change was required
  - The **Goals** that were identified early in the transition process
  - The primary **Initiatives** that were identified, approved and implemented as part of the transition
  - The methods used to identify, define, gain approval and implement the initiatives in **Conclusions**

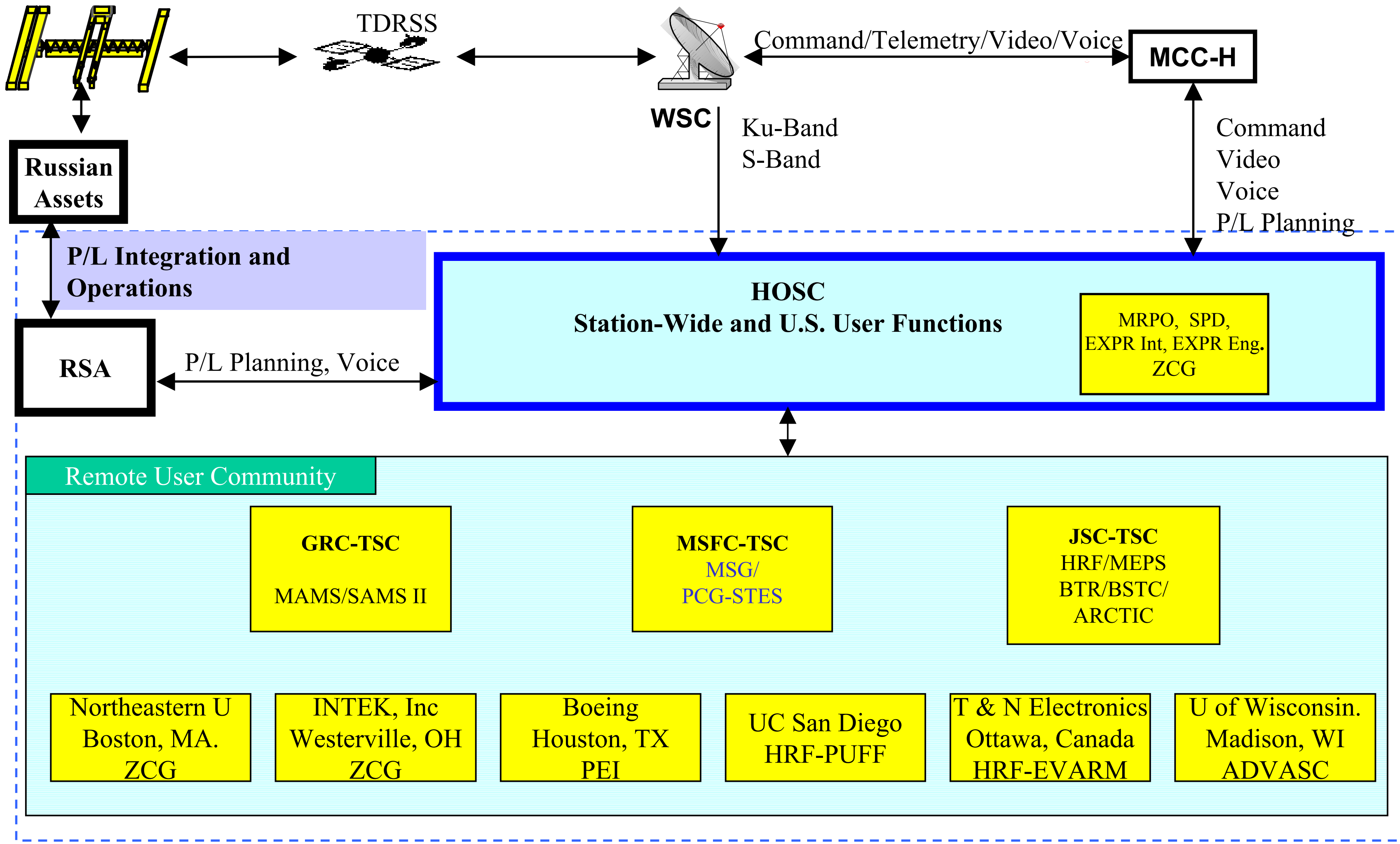
# HOSC Ground Systems

# HOSC Ground Systems

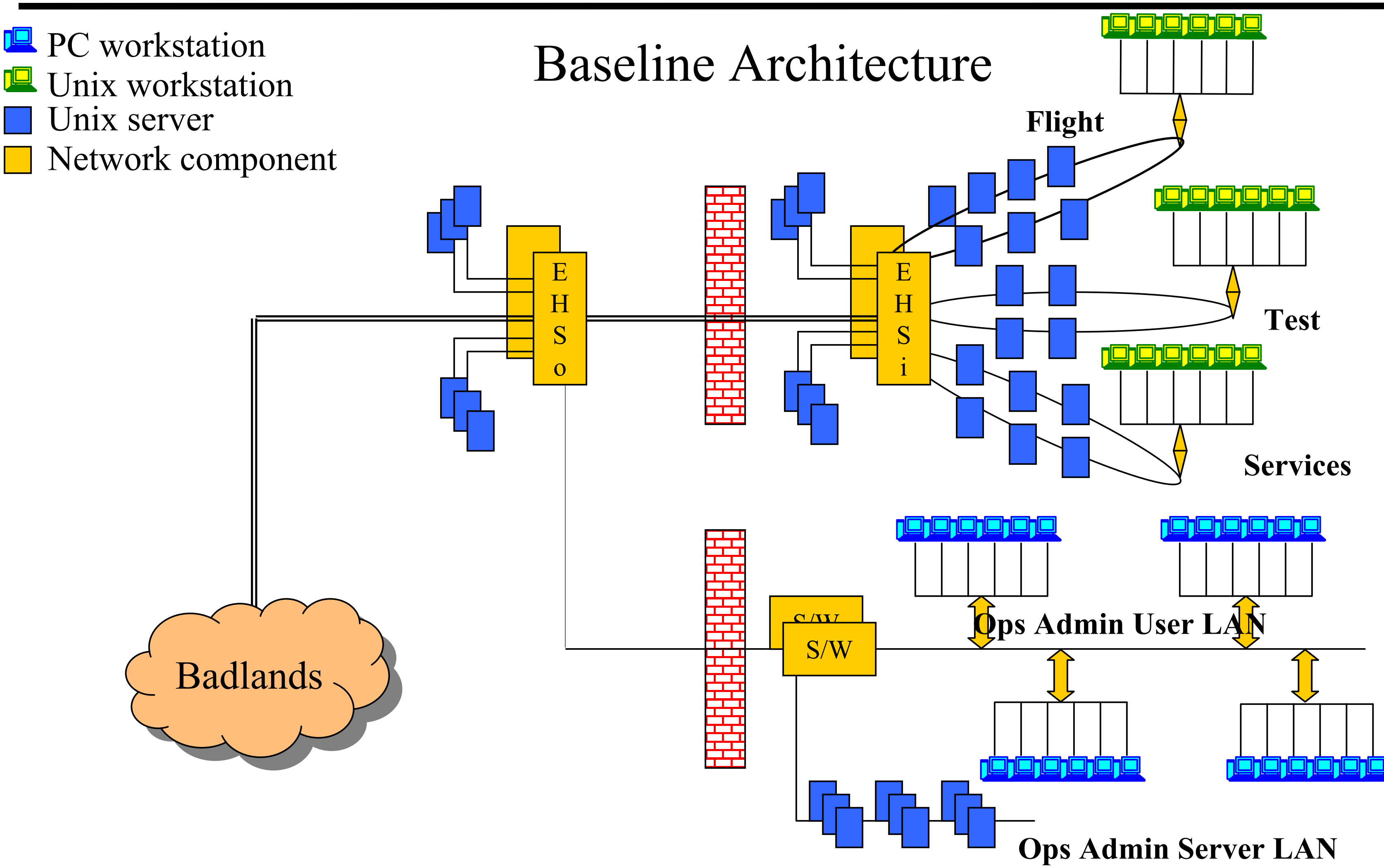
- The HOSC hosts the ground systems for all payloads in the US portion of the International Space Station
  - The HOSC is a multi-mission facility
    - ISS Operations supports a diverse user base of payload investigators
  - Payload systems managers (Cadre) are located at the HOSC
  - Payload users may be located locally or remotely with all services available
  - Two major systems in the HOSC architecture are
    - Enhanced HOSC System (EHS)
    - Payload Data Services System (PDSS)
  - The HOSC supports STS launch activities
  - HOSC systems are online locally at KSC to support ISS payload test and integration
  - A primary HOSC component (EHS) serves as the ground system for the Chandra X-Ray Observatory in Cambridge, Mass.
  - The HOSC systems are designed to provide support from single users up to large facilities

# HOSC Ground Systems

## Increment 5 Interfaces



# HOSC Ground Systems



# HOSC Ground Systems

- EHS is the ISS ground system utilized primarily by the HOSC Cadre (payload managers) located at the HOSC
  - Multi-tasking server environment developed and executing on a UNIX OS
    - ISO/OSI compliant communications stack implemented to approved and established standards
    - EHS applications are built to ANSI C language standards and are POSIX compliant
    - Database applications use a modern DBMS with the data presentation layer supported by a standard SQL interface
    - Standards based Data Presentation Layer for
      - EHS WEB based applications
      - X-windows protocol for EHS X-Windows based applications
    - Security for access control is based on user profiles/roles
    - System-wide Monitor and Control and Network Management functions
    - Failover capability for all EHS critical components
  - Homogeneous client-server UNIX workstation environment

# HOSC Ground Systems

- EHS is the ISS ground system utilized primarily by the HOSC Cadre (payload managers) located at the HOSC
  - EHS ground system services are
    - Command Processing
    - Telemetry Processing
    - Payload Information Management System
    - Data Acquisition & Distribution
    - Database  Services
    - Operations Control Mission Software
    - System Services
    - System Monitor & Control
    - Web Infrastructure
    - Utilities

EHS is the gateway ground system for users of the International Space Station!

# HOSC Ground Systems

- PDSS is the ground distribution system for ISS science data
  - PDSS receives input data as
    - 192 kbps S - Band ISS Realtime data stream
      - 36 packets per second
    - 43 (soon to be 130) Mbps Ku - Band ISS Realtime data stream
      - Approximately 8,000 CADU per second
      - Up to 82,000 CCSDS packets per second
  - Encapsulates CCSDS packets and BPDUs in EHS headers for further processing
  - Generates and distributes data stream statistics
  - Multithreaded UNIX server environment
  - Highly available storage for up to 24 months of user science data

PDSS provides a standard delivery method for science data to users of the ISS!

# Motivation for Change

# Motivation for Change

- The HOSC has a stable and generic requirements base
  - ISS and Chandra programs are supported on-orbit with solid capabilities
  - Application code was developed to encompass general operational capabilities
  - Redundant or obsolete capabilities and features have been identified
  - New capabilities and features can be incorporated and will reduce cost while enhancing operability
    - Highly available storage
    - Fault tolerant systems
    - Consolidation of COTS products which accomplish similar tasks
    - Introduction of high performance network hardware
    - Introduction CISC servers (Intel type processors)

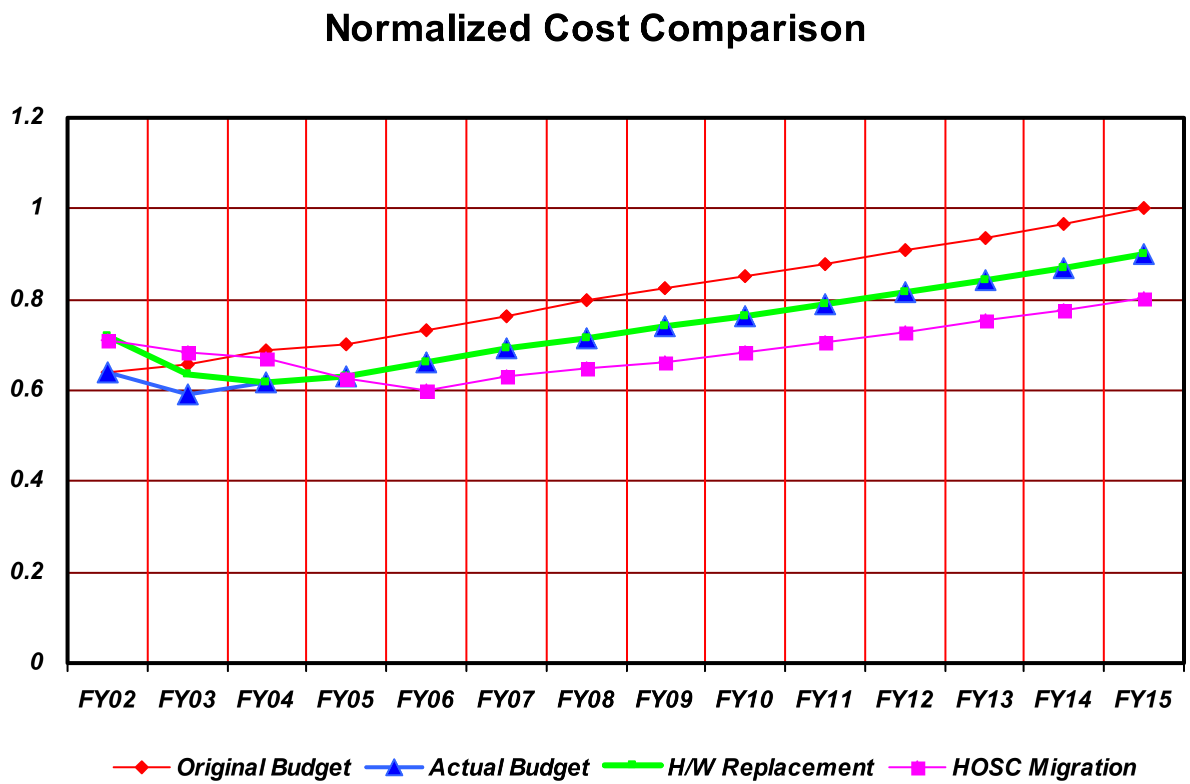
# Motivation for Change

- The HOSC has been a success and is vigorously supporting the ISS
  - Success brought in new users and more opportunity
  - ISS expansion has increased the number of HOSC users and the way the HOSC services are utilized
  - Payload users want to conduct operations at home
  - More users desire access to ISS related data; i.e. collaboration, schools
  - These opportunities are good but puts stress on the current system and points to new needs of the community
- Primary platforms (servers and workstations) were reaching the End-of-Life
  - Some in excess of 5 years old and could no longer be expanded
- Concern over long term vendor viability
- Waning/non-responsive support for COTS products on the primary vendor
- High cost per seat for replacement/maintenance
  - Over 130 workstations
  - Over 75 servers from low-end single processor to high-end SMP

# Motivation for Change

- Flight users requirements forced multiple platform types
- Other vendors platforms are in various stages of obsolescence
- ISS overruns in some areas required cut-backs across many ISS elements
- Projected budget would increase by 42 % by 2012 with no refurbishment
- A onetime hardware refurbishment would increase the total growth to 91% of the original budget with little discretionary money
- COTS packages contribute to an ever increasing cost spiral
  - Many COTS are underutilized
  - COTS have a life of their own and often are renewed beyond their need
  - Integrating COTS is expensive
    - COTS and O/S versions must be complementary
    - Vendor support may wane or force jumps in versions to support capabilities
    - Some vendors use proprietary methods which may not be interoperable
  - In 1999, the HOSC had over 60 COTS products

# Motivation for Change



# Motivation for Change

- Proposals were detailed and prototyped based on commodity items and open systems
  - Promote a cost model which is sustainable by using commodity hardware
  - By consolidating servers, less platforms will have to be managed
  - By building refurbishment into the model, our systems will not become obsolete
  - By using commodity platforms, market forces will keep cost down and users will be familiar with the interfaces
  - Wise use of COTS will reduce recurring cost and increase satisfaction with COTS
  - New technologies may significantly reduce cost during the refurbishment

# Options

# Options

- Continue On (replace servers and workstations one for one)
  - Replace systems without incorporating operational lessons learned
  - Risk to user services is minimal
    - Primary effort is to replace aging hardware
    - Minimal software changes required
  - One for one replacement would have cost nearly as much as the initial outfitting
- Complete Re-Baseline
  - One option considered was to transition to an entirely PC/W2K environment
  - Another option considered was a mainframe architecture with dumb clients
  - A major paradigm shift was beyond budgetary and philosophical scope

# Options

- Migrate the HOSC systems incrementally
  - Maintain some old
    - Migrate to like systems, incrementally
    - Preserve the large investment in user products
  - Integrate some new
    - Incorporate high value items that support the needs of the user base
    - Consolidate functions where there is an obvious return on investment
    - Re-evaluate all COTS and isolate or eliminate when possible
    - Evaluate commodity based platforms and opens solutions through prototyping and user testing
  - Migration allows the incremental upgrades while preserving stable user interfaces
  - Technology Insertion
    - Selectively replace pieces of the system where new technologies provide a large advantage over the current capabilities (applies to all baseline options)
    - Upgrade networks
    - Migrate firewalls
    - Migrate from prime/backup RAID storage to central storage

# Goals

# Goals

- The goals are high
  - Impact to ongoing operations and scheduled activities must be minimal
    - The Cadre is our primary customer therefore impacts at all levels must be minimized
      - The Cadre supports onsite, 24x7
      - The Cadre interfaces with station crew and ground users
      - Reuse of user products (displays, script, computations, etc)
    - The HOSC has an overall availability record of 99+% that must not be compromised
      - Current numbers for availability are for 98%
      - New systems and capabilities must exist and transition in parallel
    - The HOSC has International and National partners must not be disrupted
      - Users are widely dispersed geographically
      - Only a small subset of users are at the HOSC
    - Users extensive capabilities when operating either locally or remotely must be preserved by agreement

Certification of Flight Readiness (CoFR) will be observed

# Goals

- The goals are high
  - Impact to ongoing operations and scheduled activities must be minimal
    - The HOSC security model will be maintained and extended
      - The HOSC is IP based and subject to a broad range of attacks
      - The HOSC has tightly regulated internet access
      - A wide variety of counter-measure are employed
      - Security model is broad based and relies on personnel, architectural, and software measures
    - A compromise of security could jeopardize not only the HOSC but any interfaces
      - International Space Station and payloads
      - ESA, NASDA, CSA, RSA, ASI and CONUS partners (TSCs)
      - Johnson Space Flight Center

**Disruption of security could be catastrophic for the ISS program**

Initiatives:

- PC Migration
- PIMS Redesign
- PDSS Consolidation
- Server Migration

# Initiatives: PC Migration

- The primary focus of PC Migration is to move critical Cadre end-user applications from expensive UNIX workstations to lower cost Windows 2000 PC platforms
  - EHS PC (EPC) acts as an X-Window server with the workstation software (legacy) running on a UNIX server (RIS/X-Windows Server)
- Advantages
  - Fewer different types of desktop platforms in facility to maintain, test and certify
    - Now all end user client platforms are W2K PCs
  - Significantly cheaper than replacing the EOL UNIX workstations with new UNIX workstations (both initial purchase and recurring license costs)
  - Performance of end-user graphical applications (e.g. Display Ops) improved dramatically
  - New console hardware can be immediately deployed to operational areas
  - Provides low-cost capability for multiple CPUs and display monitors (for improved Cadre task automation/execution), vs. equivalent UNIX W/S implementation

# Initiatives: PC Migration

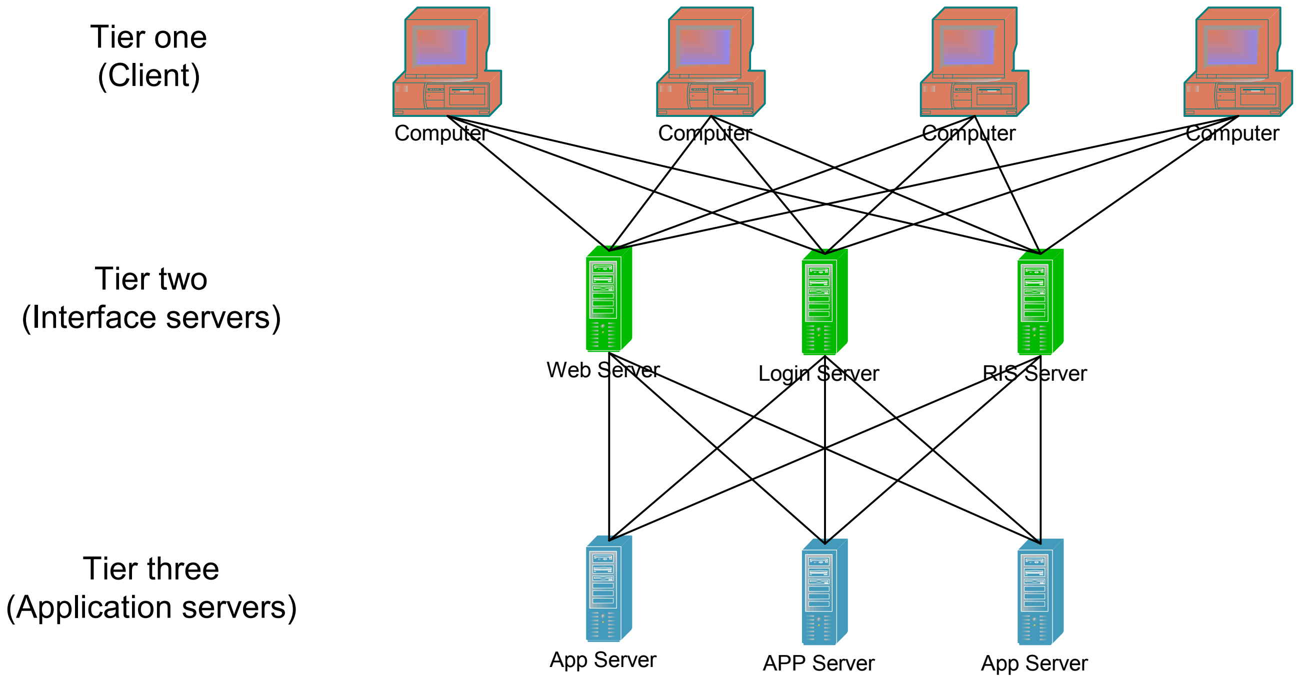
- Advantages
  - Provides more user-friendly desktop to Cadre user, including standard COTS tools (Microsoft Word, Excel, Access, etc.), which simplifies training
  - Available with Fast-E (Ethernet) network interface at minimal cost; eliminates "sun setting" Fiber Distributed Data Interface (FDDI) network interface and hardware
  - PCs priced at commodity level; large number of vendors
  - RIS/X-Window Servers provide more efficient usage of expensive UNIX CPUs/applications (through shared CPU/memory/disk vs. individual workstations)
    - Greater expandability options for CPUs and memory that benefit more than one user
    - The RIS/X-Window Server only performs the "x-client" function
      - The "X-server" function is offloaded to the PC, which has significantly better graphics performance and response
  - Reduced reconfiguration times and complexity (i.e., ~ 3-4 servers to reconfigure rather than 40+ workstations for a support activity such as flight)

# Initiatives: PC Migration

- Advantages
  - PCs have more/better development tools which increases development and maintenance productivity
  - Improved remote access to Cadre products
    - This architecture allows EPCs to be remote to the HOSC and view the same displays that the Cadre is viewing
  - Allows for the reuse of previously developed Cadre products
- Disadvantages
  - Required intensive software development investment
  - Increased risk of software defects due to the redesign and rewrite of certified EHS applications onto the PC platform
  - A single RIS/X-Window server failure will affect multiple users (as compared to the single workstation architecture)

# Initiatives: PC Migration

- A three tiered architecture was implemented to deploy EHS PC migration
  - This allowed the migration of capabilities independent of the client platform types
  - User workstations were almost immediately replaced with PCs for nearly all systems in the HOSC
  - Tier two devices act to decouple users from the application servers



# Initiatives: PC Migration

- The selected deployment strategy provides for support of legacy X-windows applications in parallel with new Native PC services until each new application is completely certified by the Cadre
  - Provides Cadre fallback position if problems experienced with new applications
- High performance and high throughput client-side applications will be re-written to run on EPC (native)
  - Will significantly offset the load on RIS/X-window UNIX servers
- PC Migration is being developed in multiple phases/releases
  - Phase 1.0 deployed EPCs in place of operational workstations (completed)
  - Phase 2.0 focused on migrating the initial set of X intensive applications to native Windows 2000 PC architecture (completed)
  - Phase 3.0 primarily focuses on moving the rest of the X intensive applications to native Windows 2000 PC architecture (on schedule 7/03)
  - Phase 4.0 focuses on moving the "generation" applications to EPC (on schedule 1/04)

# Initiatives: PIMS Redesign

- Change Overview/Description
  - Significant recurring cost reduction was achieved by removing a commercial off the shelf (COTS) product as PIMS workflow engine (replaced with custom developed code)
    - Only a small portion of the COTS product was actually used by PIMS
    - The developed workflow engine was written to meet the PIMS workflow requirements
  - Included several workflow related Engineering Change Requests (ECRs), HOSC Problem Reports (HPRs), and additional customer feedback comments (from Increment 2 users)
- Advantages
  - Eliminated largest recurring COTS software maintenance cost in EHS (>$300K per year, escalated over 5 years to >$500K/year)
  - Simplified PIMS server architecture; eliminates many failure points, processes, scripts, and data

# Initiatives: PIMS Redesign

- Advantages
  - Eliminated costs and risks to keep workflow engine and other COTS compatible with the operating system
  - Improved software transaction control, equating to better data integrity
  - Several related ECRs, HPRs, and other improvements rolled in
  - One year of savings in COTS costs paid for the labor to replace it
- Disadvantages
  - The development effort limited the ability of the PIMS team to incorporate other changes during the implementation timeframe (about 6 months)

# Initiatives: PDSS Consolidation

- Change Overview/Description
  - Consolidate Payload Data Services System (PDSS) packet processing, data distribution and data storage functionality onto single platform to reduce operational complexity and cost
  - Project Objectives
    - Reduce the recurring vendor licensing, support, and maintenance fees
    - Reduce the number of system elements to be configured, monitored, and maintained
    - Reduce the number of software lines of code
    - Simplify the Operations interface and system configuration
    - Provide auto fail over capabilities for real time operations
    - Position the system for future data rate increases (150Mbps)
- Advantages
  - Development performed by existing PDSS team
  - Design supports direct applicability into 150Mbps upgrade plans, reducing cost of 150 Mbps upgrade for payloads

# Initiatives: PDSS Consolidation

- Advantages
  - Significant cost savings generated by reduction in annual hardware vendor maintenance
  - Simplified PDSS facility operations by having one PDSS Distribution Server per activity (Flight, Test, Sim)
  - Auto failover capability for flight support
  - Allows end-user to control own real-time destination data routing (instead of PDSS Operator)
  - Phased approach minimizing risks vs. replacing entire system at one time
  - PDSS Server Consolidation estimated to save program over $1M in maintenance and labor over 5 years
- Disadvantages
  - Additional labor needed for FY02 & FY03 to develop software
  - Investments in hardware upgrades

# Initiatives: PDSS Consolidation

- Data Distribution and Storage – Phase I
  - Eliminate 12 production PDSS Data Distribution Enterprise Server class machines to be replaced with Intel/Linux PC workstation class machines
  - Consolidate multiple PDSS processes into a single, multi-threaded process which will perform limited packet processing and all Data Distribution and Storage functions (PDSM)
- Front-End Processors (FEPs) – Phase II
  - Implement alternative, less-expensive FEP system (supporting at least 150 Mbps) (+4 systems)
  - Decommission/retire current FEP system (TSI Telsys) hardware/software (- 8 systems)
  - Eliminate Asynchronous Transfer Mode (ATM) switches (- 2 switches)
  - Add full packet processing capabilities to the PDSM server process with auto-fail over capabilities

# Initiatives: Server Migration

- Change Overview/Description
  - Server Consolidation study task
    - Avoid significantly higher refurbishment costs
    - Identify additional cost reductions that can be realized
  - Major Considerations
    - UNIX servers reach product end-of-life (EOL) in 2003
    - The RDBMS vendor software support on on UNIX servers disappears (January 2006)
    - Potential RDBMS database pricing structure increases

# Initiatives: Server Migration

- The initiative is to port EHS software from UNIX servers to low-cost Linux OS/Intel hardware vendor platform and include some consolidation
  - Platforms involve little to no direct end-user interaction
  - Includes replacement of 30+ aging UNIX servers
  - Allows the server functions to be consolidated to a single platform to support more efficient development and testing
- Advantages
  - Greatly improves deployment and operations costs of services to KSC PTCS POIC, and any potential future "POIC Copy" remote user sites
  - Significantly cheaper than replacing UNIX servers one-for-one
  - Provides greater flexibility in test and operational utilization of EHS servers
  - Allows stepwise enhancements where feasible
- Disadvantages
  - Requires additional software development investment to perform consolidation as well as the migration from UNIX to Linux

# Initiatives: Server Migration

- The study also identified several supporting initiatives
  - Implement High-Availability Centralized Storage
    - Decreases system configuration, reconfiguration and administration requirements
    - Provides simpler, more flexible, failovers and flight-to-flight transitions
    - Storage for virtually all types of data; user products, Databases, COTS products, O/S images; short term telemetry data
  - Network Improvements
    - Continue transition of systems from "sunset" FDDI network technology to FastE/GigE
  - Banking of servers with no persistent data and dynamic load (to support growing user base):
    - As demand increases servers can be easily added to support additional load
    - Involves load sharing among multiple primes with common shared backup

# Initiatives: Server Migration

- The study also identified several supporting initiatives
  - Firewall and Security improvements
    - Integrate Mission Admin System and Enhanced HOSC System (EHS) firewalls and implement load sharing design (nearly completed)
    - Consolidate secure access methods, replace with Virtual Private Network (VPN) technology (complete)
    - Eliminates two technologies and 4 COTS products

# Conclusions

# Conclusions

- Remember
  - Start with the high value targets and make changes incrementally
  - Give commodity priced platforms more than a cursory look
    - Use rapid prototyping to prove concept
    - Take advantage of Moore's Law
    - Significantly reduces replacement and maintenance costs
  - Stay current by utilizing technology insertion
  - Reduce dependency on expensive, under-utilized COTS
  - Looks for ways to migrate while maintaining access to legacy systems
  - Don't try to do it all at once