Joint Enhanced Rotorcraft Test And Operational Capability for the 21st Century

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Abstract

The DoD procurement account fell by more than 70% during the past decade. The cost associated with rotorcraft design, analysis, testing, training, and support, using current techniques, promises to escalate in the predicted hostile fiscal environment of the 21st century. This cost must be reduced through the use of credible simulation and other analytical options. Conventional multi-service air vehicle flight testing is becoming more expensive and the test results may uncover problems late in the acquisition cycle, where making changes can be both costly and time consuming. Mission rehearsal training is normally conducted on operational flight trainers far removed from the battlefield site. A need exists to conduct joint service air vehicle testing analytically first, and to do mission rehearsal training at deployed sites. A need also exists to help integrate the design and test phases of the aircraft acquisition cycle and to do 21st century flight testing better, faster, cheaper, and safer. The Joint Enhanced Rotorcraft Test and Operational Capability (JERTOC) concept was formulated as one approach to help realize the generic better/faster/cheaper/safer criteria applied to test and evaluation (T&E), as well as, to help achieve local flight test objectives of reducing T&E cost and cycle time. The JERTOC concept involves testing and evaluating advanced technology programs available in the 21st century in aircraft and engine simulation modeling, design, test planning, and test reporting to better support acquisition, testing and training in an integrated environment. An initial goal of this program concept is to develop the capability to do analytically in one month what might currently take more than a year of actual air vehicle flight testing. A final goal includes using the capability of a high performance computing (HPC) center to analytically run a helicopter air vehicle test program in one 24 hr period. This advanced capability would not be used to replace actual flight testing, but would be used as a flight test planning tool to help predict flight results, identify potential flight limitations, and improve flight test safety. The initial focus will be on model structure validation and on applying collaborative network options to enhance rotorcraft test and evaluation.

Background

Aircraft testing and the associated training and support place large demands on flight vehicles, avionics, weapon systems, team personnel, and scarce fiscal resources. Factors such as declining budgets, reduced staffs, increased project cost, and tightened delivery schedules all point to the need to improve the current flight test process. The National Defense University [2] notes that "…acquisition reform, particularity transformation of test and evaluation from an arcane process to a robust, holistic, and functionally oriented process is essential." Joint Vision 2010 calls for full spectrum dominance, which implies a need for increased operational readiness and flexibility. Vision 21 [3] calls for a reduction in the current test and evaluation (T&E) infrastructure cost. The Simulation, Test and Evaluation Process (STEP) [4] and DoD Regulation 5000.2-R [5] require modeling and simulation throughout the system life cycle. Zittel [6] reviews the DoD Simulation Support Plan that calls for "… increasing emphasis on the use of modeling and simulation (M&S) in our acquisition programs to reduce cost and schedule without sacrificing quality or performance." Simulation based acquisition is considered an effective, affordable mechanism for fielding complex technologies, and may help to make DoD a "smart buyer" [7]. Flight test enhancement options, focusing on simulation, may play a role in reducing the cost and time required to test the next generation aircraft and related systems. Current rotorcraft simulation models are typically

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14. ABSTRACT

The DoD procurement account fell by more than 70% during the past decade. The cost associated with rotorcraft design, analysis, testing, training, and support, using current techniques, promises to escalate in the predicted hostile fiscal environment of the 21st century. This cost must be reduced through the use of credible simulation and other analytical options. Conventional multiservice air vehicle flight testing is becoming more expensive and the test results may uncover problems late in the acquisition cycle, where making changes can be both costly and time consuming. Mission rehearsal training is normally conducted on operational flight trainers far removed from the battlefield site. A need exists to conduct joint service air vehicle testing analytically first, and to do mission rehearsal training at deployed sites. A need also exists to help integrate the design and test phases of the aircraft acquisition cycle and to do 21st century flight testing better, faster, cheaper, and safer. The Joint Enhanced Rotorcraft Test and Operational Capability (JERTOC) concept was formulated as one approach to help realize the generic better/faster/cheaper/safer criteria applied to test and evaluation (T&E), as well as, to help achieve local flight test objectives of reducing T&E cost and cycle time. The JERTOC concept involves testing and evaluating advanced technology programs available in the 21st century in aircraft and engine simulation modeling, design, test planning, and test reporting to better support acquisition, testing and training in an integrated environment. An initial goal of this program concept is to develop the capability to do analytically in one month what might currently take more than a year of actual air vehicle flight testing. A final goal includes using the capability of a high performance computing (HPC) center to analytically run a helicopter air vehicle test program in one 24-hr period. This advanced capability would not be used to replace flight testing, but would be used as a flight test planning tool to help predict flight results, identify potential flight limitations, and improve flight safety. The initial focus will be on model structure validation and on applying collaborative network options to enhance rotorcraft T&E.

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vehicle specific and do not have the high fidelity rotor and fuselage components required to accurately predict loads. Current engine models are limited in their ability to predict dynamic events like compressor stall, are typically implemented for specific engines, and have little or no design capability. The current generation of T&E simulation models does not provide insight into the overall aircraft/system design process. The current modeling environment does not support helicopter/ship operational envelope development due to limitations in aircraft modeling and ship environment modeling.

Introduction

The JERTOC concept involves enhancing and integrating advanced technology programs in aircraft and engine simulation modeling, design, test planning, and test reporting to better support acquisition, testing and training. An initial goal of this program concept is to develop the capability to do analytically in one month what might currently take more than a year of actual air vehicle flight testing. A final goal includes using the capability of a high performance computing (HPC) center to analytically run a helicopter air vehicle test program in one 24 hr period. The complexity of helicopter rotor models and related loads and inflow modules, fuselage models, and engine models, plus associated ship airwake models, require improved software and high performance computing hardware. This program involves integrating and enhancing advanced technology programs in aircraft and engine modeling, design, and flight test automation to form a unified environment to enhance rotorcraft testing in land and shipboard environments. This unified environment could be used to support current and next generation aircraft/systems design and testing. The JERTOC program initial focus is on testing, validating and applying the technology developed to the multi-service H-60 helicopter. The generic nature of the technology developed make it readily adaptable to other rotorcraft, unmanned aerial vehicles, or fixed wing aircraft as required. The program concept includes starting with a physics-based analysis/simulation structure and adding/integrating, testing and validating enhancement modules in the areas listed below and illustrated in figure 1.

- Air vehicle design
- Load predicting ability
- Engine design/test
- Flight test interface
- Multi-media flight test plan and report automation
- VV&A with built-in validation
- 3-D component modeling options

The JERTOC concept focuses on acquisition, testing , and training. The program would address evaluating and validating methodologies to reduce the cost and time required for aircraft acquisition and testing, and reduce the cost associated with conventional flight trainers.

More than 80% of a total system cost is determined by decisions made prior to the end of the Demonstration and Validation Phase of the acquisition cycle. A robust design module may be used to help reduce the acquisition cycle cost and time issue, especially when enhanced and integrated with a high fidelity air vehicle model structure. The cost of each Engineering Manufacturing Development (EMD) phase aircraft is estimated at $100M. If a successful JERTOC program could reduce the number of EMD aircraft required for an acquisition program by one, the overall program savings would exceed $100M.

Rotorcraft flight test costs can range from approximately $5 to over 40K per flight hour, which implies a 50 flight hour test program could cost up to $2.0M just for flight/support time. A physic-based simulation model provides an option to help address the flight cost and time issue by permitting some tests to done analytically. The methodology includes evaluating and validating a generic simulation structure with a robust design module, CFD engine module, load predicting module, multi-media test automation, and built-in V&V options.

Conventional operational flight trainers (OFT) and weapon systems trainers (WST) can cost up to approximately $60M and are far removed from the deployed operational site. If a portable, high fidelity, low cost mission scenario trainer could be developed from high fidelity JERTOC engineering models, it could be readily deployed to operational scenarios.

Model Validation

Generic Structure

Air vehicles, in general, and rotorcraft, specially, come in a variety of shapes and sizes. Navy rotorcraft size ranges from the 3,000 lb TH-57 to the 75,000 lb C/M-53E. Helicopter shapes include the single main rotor/tail rotor configuration, tandem rotor configuration, tilt rotor configuration, co-axial rotor configuration, and intermeshing rotor configuration. Verification, validation, and accreditation (VV&A) is required as a sanity check of the basic model structure to determine if acceptable protocol was used in the model development, and to determine applications for which the model has been approved. Verification refers to determining that the overall model and its components have been implemented or programmed correctly. Validation refers to the process of determining how close the model compares to real world data. Accreditation refers to the process of approving the model use for specific applications. Formal VV&A definitions are available in current modeling and simulation literature [8-9]. From a flight test perspective, validation plays a big role in model acceptance and use. The complete model must be validated throughout the operational flight envelope to determine areas of model strengths and weaknesses and help ensure user confidence. A model structure designed for a specific single main rotor/tail rotor helicopter may be difficult to adapt to another single main rotor/tail rotor configuration, and very difficult to adapt to a tandem rotor or tiltrotor configuration. A physics-based, generic structure model could be readily adapted to different configurations, and modeling enhancements developed for one aircraft configuration could be applied to other configurations. Although the fidelity of the final model is paramount, it is important to check the fidelity of all the overall model components.

Specific Components

Major rotorcraft components include the main rotor(s), fuselage, engine(s), flight control system, tail rotor, and landing gear. These major components may be comprised of several sub-components. The main rotor may be implemented analytically as a rotor map or blade element model, and the rotor hub may be represented as articulated, bearingless, hingeless, teetering, or gimbled. Rotorcraft model components can be illustrated in a tree diagram like figure 2.

Figure 2 shows a blade element model selected that has a gimbaled hub (i.e., tilt rotor), a rigid blade, quasi-static airloads, and uniform inflow for the induced velocity. The tree concept can be used to select several levels of complexity/fidelity/cost of the model components that may be required for specific tasks. Model validation at the component level requires test data on the component, as well as, the complete aircraft.

Test Data

Instrumentation Requirements - Instrumentation systems are required to obtain quantitative data for performance specification compliance, for simulation model validation, and for accessing aircraft mission capability. Aircraft arriving at a test and evaluation activity to support basic air vehicle testing may require a "typical" flight test instrumentation system which could take several months to develop and install. This conventional instrumentation system could measure up to several hundred parameters at specified sample rates. Certain rotorcraft parameters, such as the rotor loads and motion, are difficult to measure due to problems in installing sensors on the blades and getting the sensor data out of the rotating reference frame. Special " instrumented" rotor blades may be used on research programs, but are usually too expensive for a T&E activity. Other parameters, like the rotor/fuselage interactional aerodynamics, and even low 3-D airspeed, are very difficult to measure and/or it is not currently possible to measure these parameters accurately.

Instrumentation Options

Micro-Processors for Model Validation - Model validation can be achieved by collecting flight data on loads, forces, accelerations and other aspects. Historically, it has been difficult to instrument the aircraft to gather the in flight data. However, new technologies such as network enabled Sentient Instrumentation Controllers (SIC) are making this task less difficult and less costly. SIC are tiny electronic microsystems that incorporate micro-processors, memory and sensors in a single package. Devices like the SIC have communication ports that link to data transceivers to provide the ability to query, collect, and transmit data via Internet protocols. SIC have been developed to both sense and control functions. Only the sensory capabilities are needed for model validation.

In operation, the SIC can be placed aboard the helicopter to gather data on loads and forces. The SIC has analog to digital (A/D) converters that process analog signals from the sensors into digital data. The digital data can be further processed in the SIC to digital information. Raw digital data or processed digital information can be connected directly to an on-board personal computer, or transmitted via data link to ground based systems. The values can be compared with those estimated by the simulator models.

Collaborative Network

Collaborative Network - The JERTOC effort will be accomplished by a team of experts comprised of individual specialists located at geographically dispersed sites, as illustrated in figure 3. In the past, the distances have made it difficult to share models, algorithms, and test data toward a common goal. The JERTOC team needs an efficient way to work together on a daily basis.

The Internet provides a unique opportunity for JERTOC. Commercial firms use the Internet to focus on issues such as product design, manufacturing, and quality. The Internet is used to connect the corporate teams for discussions on how to achieve goals. The JERTOC team can use this technology to work as a distributed team to improve the models. The geographically dispersed team members can use a virtual office environment called a collaborative network. During model validation the JERTOC team members can set up the test environment, collect and share test data obtained from sensors. Working individually, or as focus groups, the JERTOC team can analyze and process the test data.

For example, NAVAIR has sponsored development of a CN environment for its Integrated Product Teams (IPT). The CN combines conventional collaboration technologies with internet enabled sensors for real-time (or real timely) viewing of aircraft data. During model development the team can use the CN to discuss model parameters and algorithms. The team can incorporate the models into the simulation environment. The CN includes a focus group forum for generating and tracking issues, a virtual file cabinet, a team calendar, an email notification system, and an action tracker, as shown in figure 4.

Conclusions

The JERTOC concept has the potential to help revolutionize future rotorcraft T&E by enabling it to be done better, faster, cheaper, and safer. The program concept would also help integrate the design, analyze, test, and training phases of the acquisition cycle with emphasis on simulation based acquisition. The initial JERTOC concept focus will look at model validation options using data from electronic microprocessors and look at network collaboration to help facilitate multi-service/contractor program team member interaction.

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Dean Carico is an aerospace engineer in the rotorcraft shipboard suitability group in test and evaluation engineering at the Naval Air Warfare Center Patuxent River, MD. Dean initiated a high performance computing program on flight test automation, a rotorcraft simulation to support flight testing program, and over fifteen small business innovative research programs that focus on enhancing rotorcraft flight testing. Dean has masters degrees in Aerospace Engineering from Princeton and in Engineering Science from the Navy Postgraduate School, and is an engineering graduate from the USNTPS. He received the Meritorious Civilian Service Award for testing in a combat zone in 1973, and the Richard L. Wernecke Award for technical excellence in rotorcraft test and evaluation in 1997.

Kenneth G. Blemel is the Vice President and R&D Project Manager of Management Sciences, Inc, of Albuquerque, NM. He has a BS in Applied Mathematics (Engineering) from the University of Cincinnati and a MS in Applied Mathematics and Engineering from the University of Rochester. Mr. Blemel was the principal investigator (PI) for the JSF "Smart Wiring for Prognostic Health Management" project (Oct-97 to Oct-98). Currently, he is the PI for the NAVAIR Collaborative Networks Phase II SBIR for the development of a web methodology for coordinating smart sensor information with fleet support organizations, maintenance teams, and logisticians. The Smart Wiring project developed out of the ongoing Office of Naval Research Project to create advanced instrumentation controllers. Earlier, in 1997, Mr. Blemel managed a DARPA Very Fault Tolerant Systems Project (SBIR) and the USAF Structural Design Multi-Discipline Optimization SBIR project. Mr. Blemel also led the MSI contract for the DARPA RASSP project that developed a RAM-ILS toolset for in-design tradeoff of reliability, maintainability, and logistic support considerations.

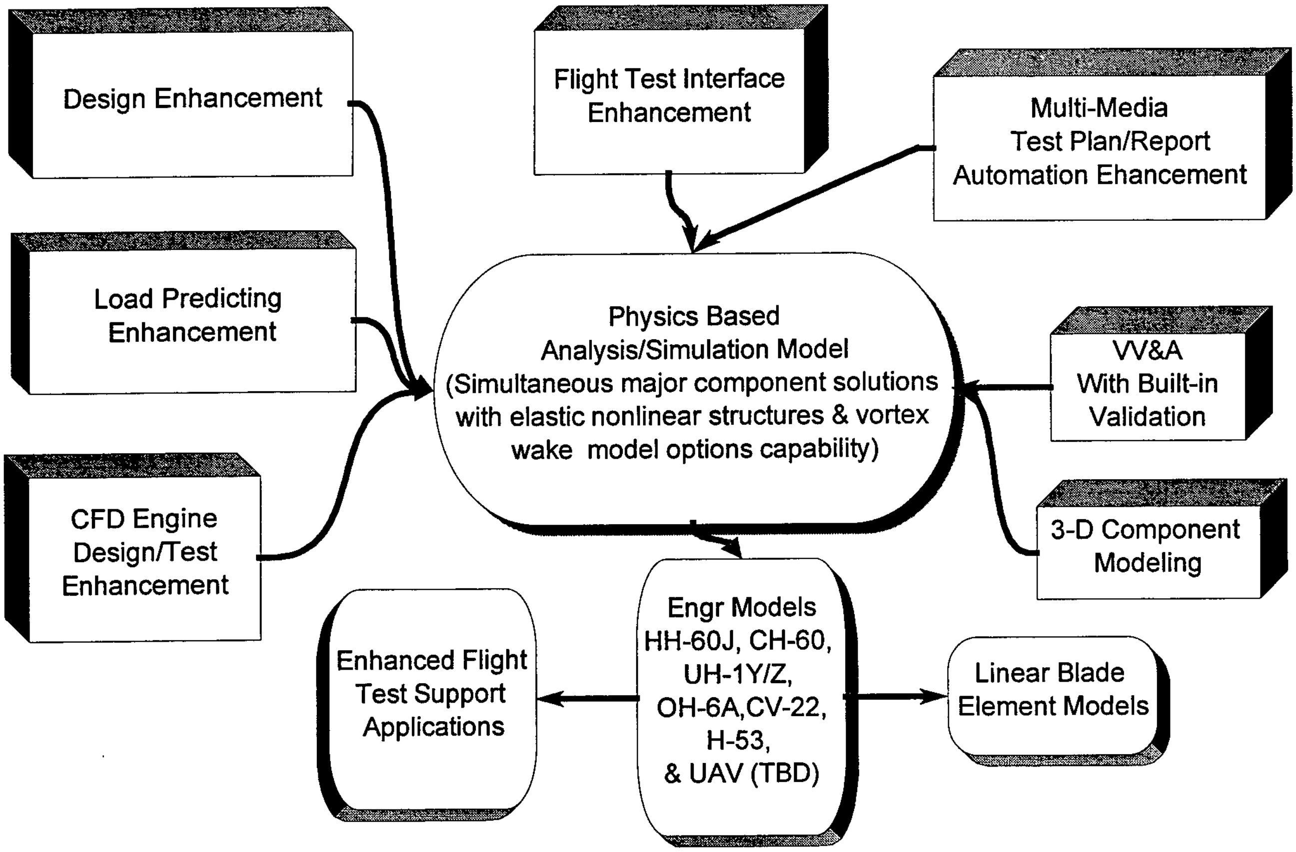

Figure 1
JERTOC Components

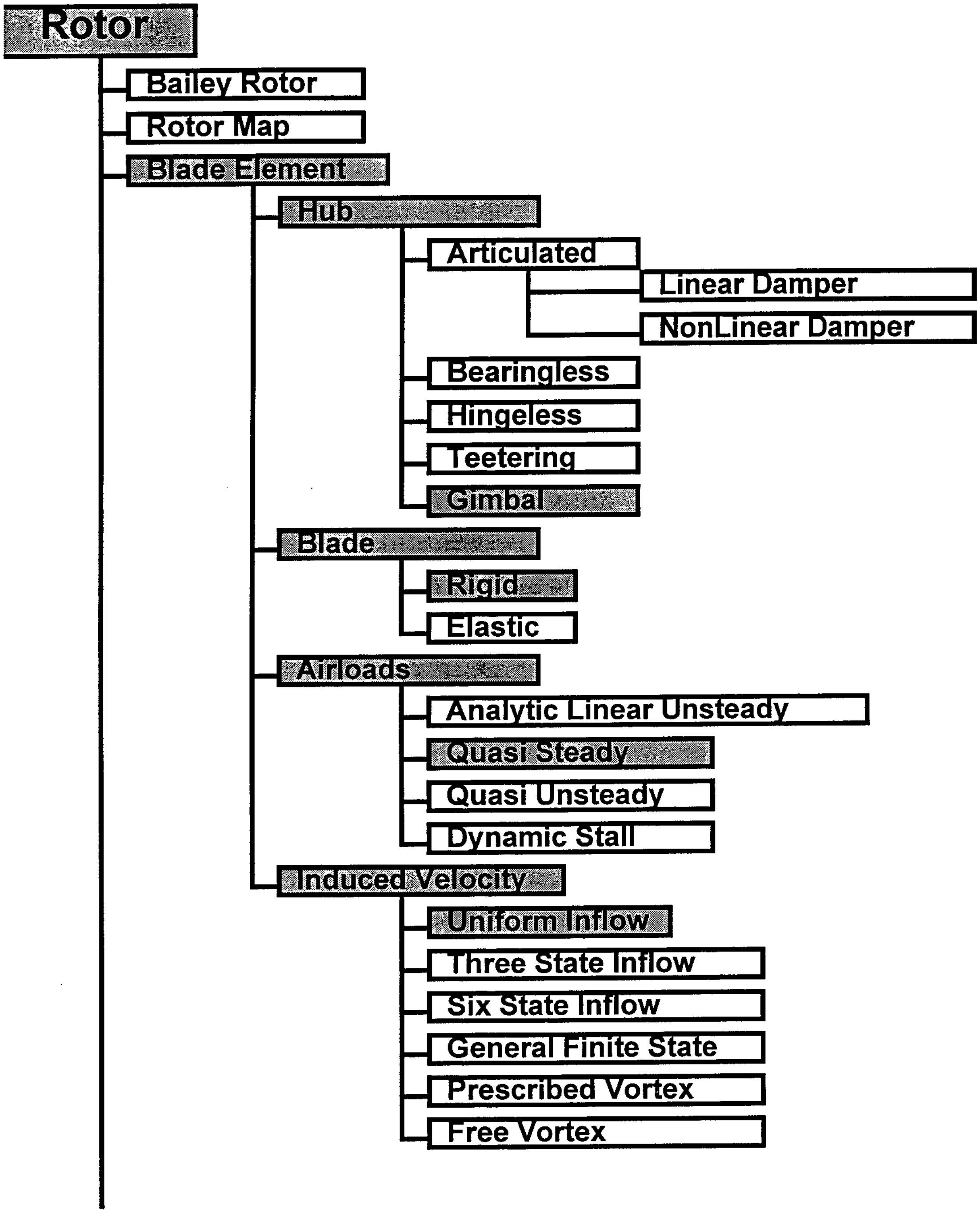

Figure 2
Rotor Model Tree Diagram

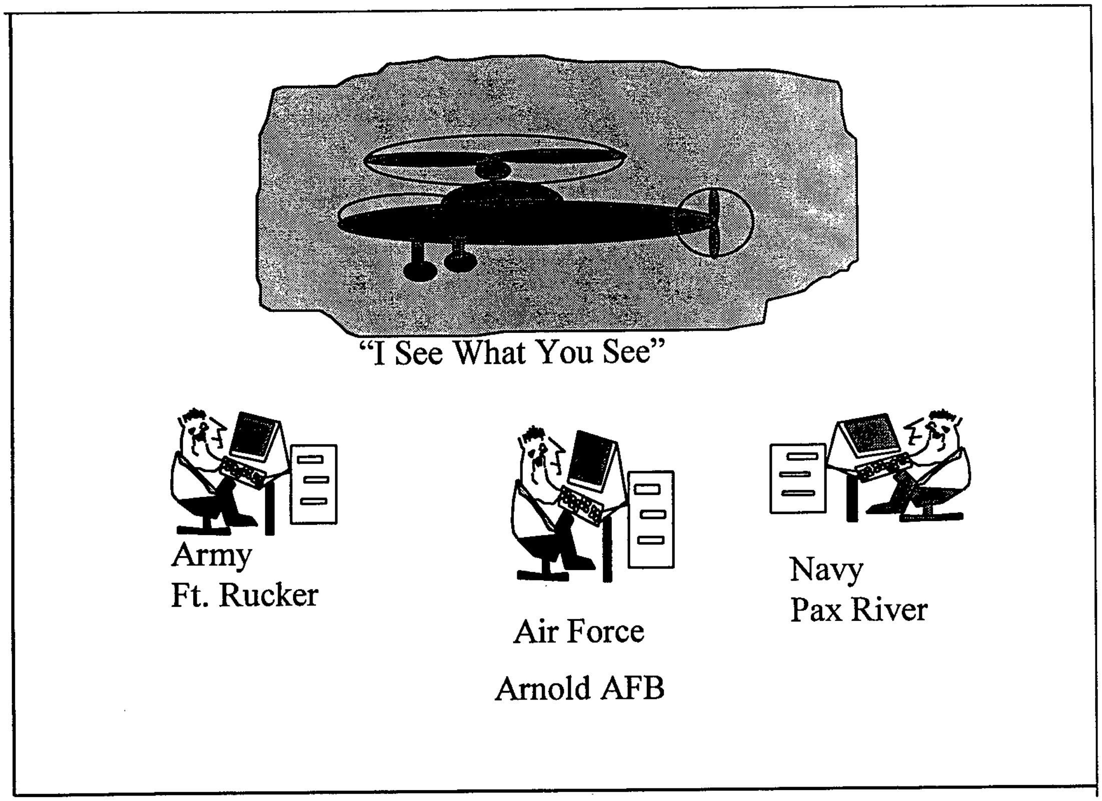

Figure 3
JERTOC CN Concept

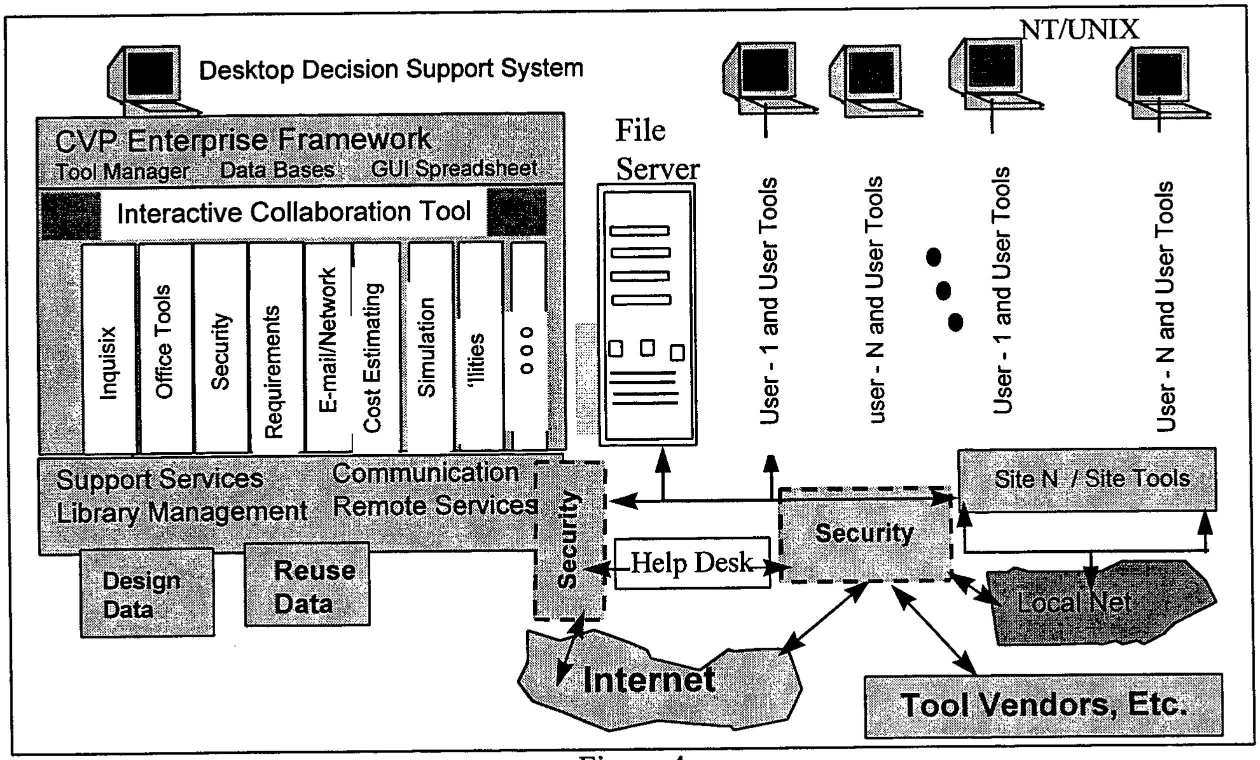

Figure 4
CN Network Environment