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# MULTIDISCIPLINE OPTIMIZATION OF AIRCRAFT STRUCTURES FOR FAA CERTIFICATION

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**13. ABSTRACT** *(Maximum 200 words)*

This SBIR project developed a multidisciplinary internet collaborative mechanical design optimization environment for users of the automated STructural Optimization System (ASTROS) software. The operational environment is worldwide web enabled, and is called Structural Analysis Requirement NETwork (STARNET). The STARNET environment lets team members with UNIX, Microsoft Windows, and Microsoft NT share the work to optimize a mechanical design in progress. The STARNET toolset uses standard internet protocols and displays accessible by any standard web browser. The current implementation has been used with commercial computer aided mechanical design tools that support the NASTRAN bulk data format for design information interchange. The STARNET environment provides a place for either asynchronous design activity, or team (synchronous) design activity to resolve conflicts among disciplines. The STARNET tools provide a multi-user display of goals and achievement for understanding by other design team members even when other members are not on line. The STARNET provides a versatile E-mail system, and a method for sharing work in progress at distanced sites. The Decision Support System (DSS) uses a spreadsheet to monitor and manage the display of goals and achievement along with interfaces to the ASTROS program, a team member address book, and other multidiscipline tools.

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## Table of Contents

# 1.0 Executive Summary

Management Sciences, Inc. (MSI) has prepared this report to document the Phase II Small Business Innovative Research (SBIR) contract entitled:

MULTI-DISCIPLINE OPTIMIZATION OF AIRCRAFT STRUCTURES
FOR FAA CERTIFICATION

**STARS-Networked Tools for Multiple Discipline Optimization (MDO)**
This SBIR project developed a methodology, infrastructure, and toolset for integrating geographically distanced disciplines engaged in mechanical design of aircraft structures. The many disciplines that have important input to MDO early in design are often located a distanced sites where manufacturing and production occur. Often the disciplines involve suppliers who provide standardized commercial off the shelf parts that are an essential part of manufacturing and support. (No aircraft company continues to make its own screws, nuts, rivets, bolts, etc.)

STARS is cross platform system of middleware, tools and interfaces among design tools, databases, spreadsheets and a decision support system (DSS). The toolset enables a dispersed team of planners, estimators, factory engineers and designers to work to an optimum solution. The multi-discipline design team works asynchronously and in joint sharing sessions to optimize the properties of a mechanical structure. The MSO team optimizes according to mutually agreed upon goals. The MDO team represents many organizations including production engineering, reliability, maintenance, cost, safety and weight.

For example, weight reduction has been a concern of aircraft designers as any unnecessary weight reduces the speed and range of the vehicle. But, adding other discipline goals and constraints tends to be in conflict with classic design considerations. For example, safety requirements tend to favor increased strength which is often achieved by increasing weight. But innovators like Burt Rutan have found innovative ways to satisfy several domains a worthy challenge. Meeting the challenges improves the design and the designers.

**The SBIR Team.** The team consisted of Management Sciences, Inc., Wright State University (WSU), and McGettrick Structural Engineering (MSE) during this period. The team leaders are: Mr. Kenneth G. Blemel, Principle Investigator (MSI), Mr. Peter Blemel, Engineering Programmer (MSI), Dr. Ramana Grandhi, Professor of Mechanical Engineering at WSU, and Mr. Michael McGettrick, President of McGettrick Structural Engineering.

**Commercialization.** The STARNET MDO design environment with the STARS tools for MDO was designed for use on local area networks, wide area networks, the Internet and private Intranets. The collaborative internet tool markets are the members of the structural design community of mechanical, structural, and aerospace products. The network makes MDO tools available to a many smaller design firms that use UNIX, PC and NT tools.

MSI first offered the MDO environment to the AGATE project. The toolset and network environment was scheduled for NASA funding, but funds were allocated to higher priority projects.

## 2.0 The STARNET for Multi-Discipline Optimization

The objective of the project was to build a network environment and toolset that lets distanced specialists of a design team communicate and interact to achieve an optimum design. The SBIR team developed the internet methodology called STARNET. The STARNET links collaborative designers using personal and team design tools under an object oriented decision support system (DSS). The STARNET can be implemented on local area networks, wide area networks or the internet. The STARNET DSS is a set of displays that makes it easy for distanced team members to see how progress is being made in achieving weight, cost and performance goals.

### *2.1 STARNET Workstation*

MDO offers many benefits that come from the synergism of tool integration. The STARS workbench provides a quick and affective work site accessible from the network nodes.

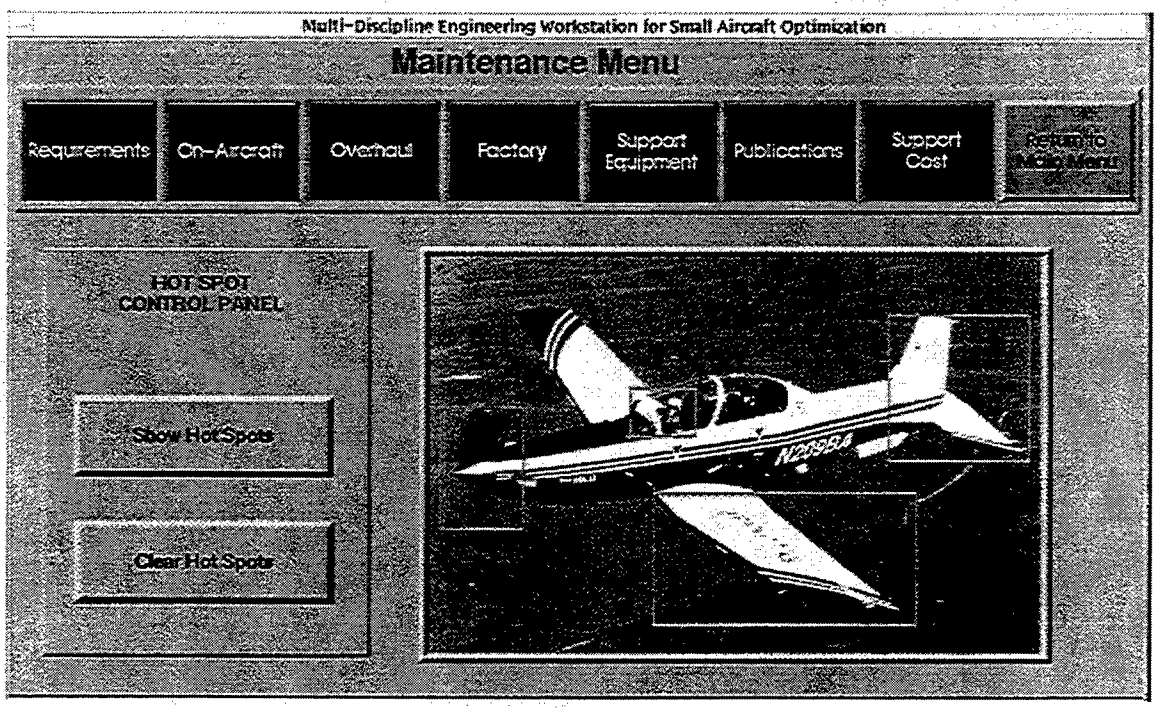


**Figure 1. STARS Desktop using the Integrated Construction Tool Set**

Figure 1 shows one screen from the STARS workbench (Maintenance Menu) with buttons for requirements, publications, support cost, and other factors. Hot spots are shown on the aircraft photograph.

The STARNET supports the designers running UNIX tools and other disciplines that use personal computers (PC) running Microsoft Windows 95, 97, 98, or NT. The cross platform (UNIX, PC, and NT) user environment allows dispersed persons to work in their design specialty such as; cost estimating, metallurgy, and aerodynamics.

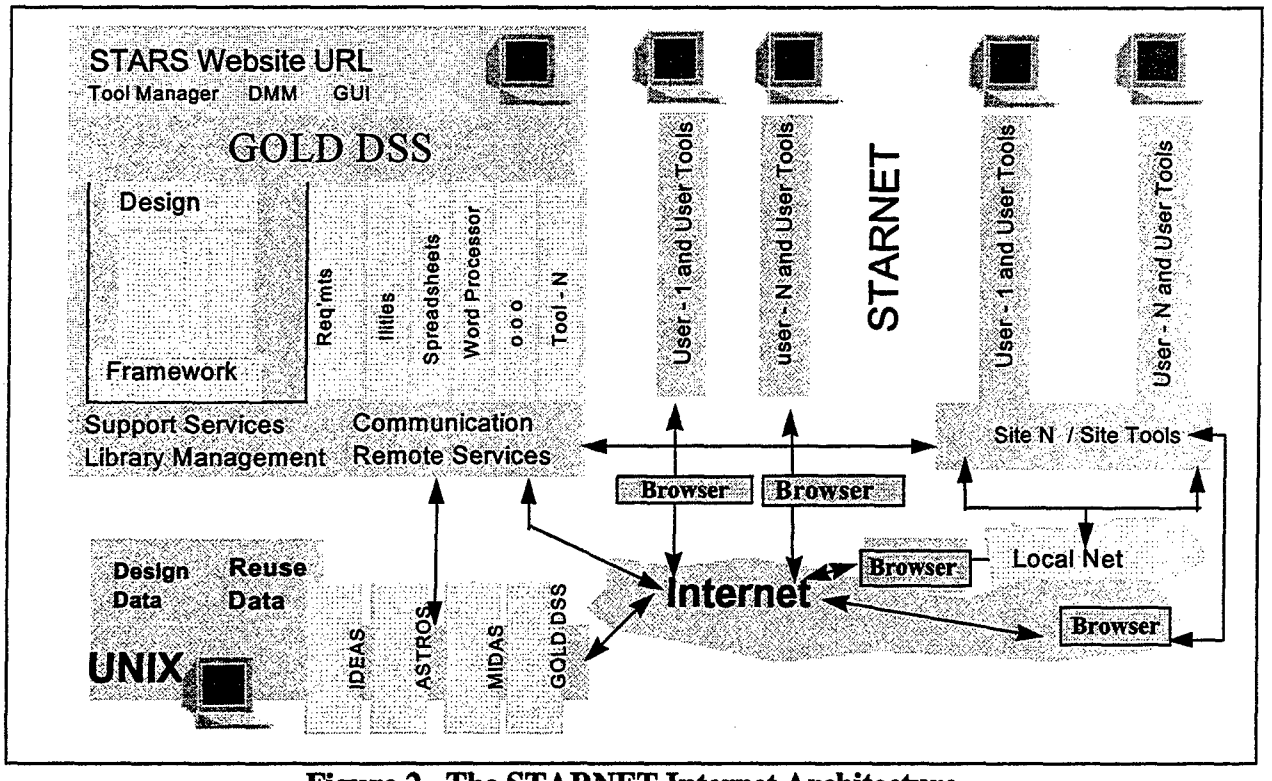


**Figure 2. The STARNET Internet Architecture**

### *2.2 Network Toolset*

STARS and STARNET provide an open architecture for a local network or an Internet environment. The open approach means persons of diverse disciplines can work to optimize a mechanical design from a wide variety of viewpoints. Often, the goals of several disciplines are in conflict with the designer's methods and objectives. In the past, mechanical design proceeded with little concern for manufacturing and cost. Aerospace and automotive engineers used a period of refinement and testing to define the final design. The STARS approach provides a methodology that lets designers quickly create and optimize simple design architectures, very early in the design cycle. STARS provides: a) an interface to ASTROS, b) collaboration tools, c) a collaboration environment, and d) an Internet website environment. This approach lets us use ASTROS "as is", as the program is constantly under development. When UAI updates the program, or new ASTROS programs become available from other sources, they can be immediately used by a slight modification to the GOLD interface.

#### 2.2.1 STARS Internet Web Interface

The Internet toolset can be used in a local environment or span to distanced sites with an Internet provider. The first user screen is the Home Page. The STARS MDO tools are accessed by a button from the Home Page.

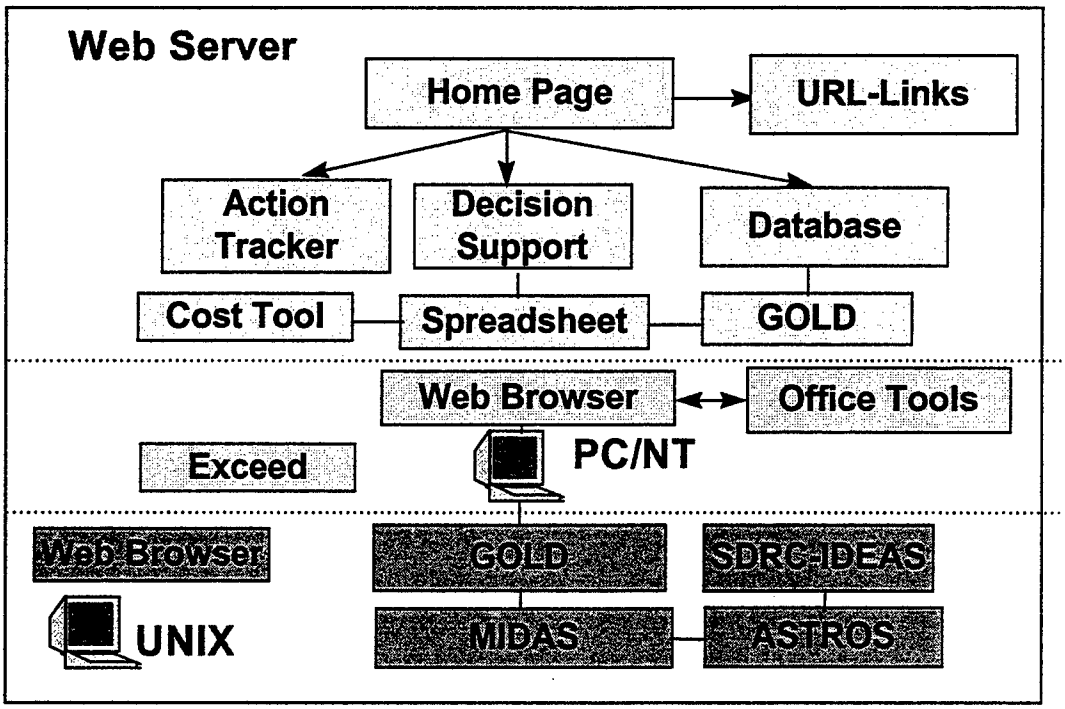


**Figure 3. Web Browser Interface to PC/NT and UNIX**

### 2.2.2 Web Based MDO Environment

Because the MDO team is geographically separated, the members need a shared decision support system with regulations, suppliers, reliability tools, spreadsheets, databases, CAD, and other office tools. A private computer network is excessively costly. Many companies use internet methods to connect with its legions of suppliers and co-manufacturers. The Internet is the simplest and most cost effective way to implement MDO. The tools and data can be placed on the Web-Server and accessed from the IPT Internet "Home Page".

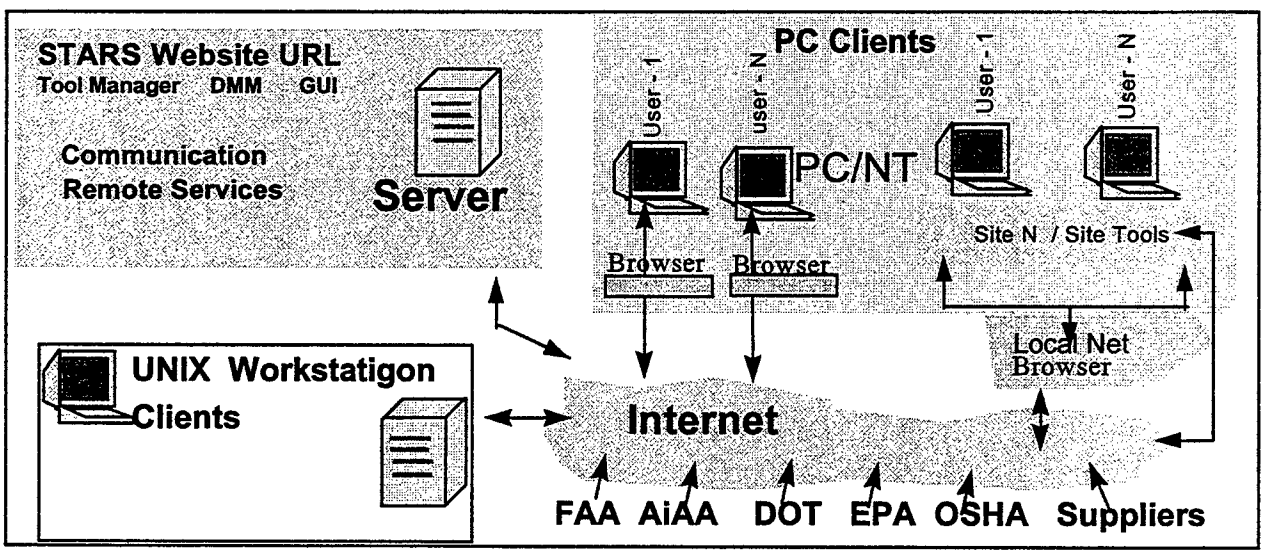


**Figure 4. MDO Intranet Website Access Architecture**

### 2.2.3 Internet Web Browser Desktop

The Internet has become the common workplace tool for everyone. An MDO team is usually geographically dispersed. Historically, designers have worked in a private corner using a powerful UNIX workstation. Cost estimators and manufacturing specialists usually use a personal computer with tools like Microsoft Office. Often, disciplines like cost conflict with design disciplines. The STARNET Decision Support System display keeps the MDO team aware of progress to optimization. MDO optimization works best when each discipline works on individual solutions derived from a common design database stored in a single server.

## *2.3 Private Network Tools*

The World Wide Web has generated products for using UNIX and interconnecting to PC's for MDO. The Sandia National Laboratory ICE program interconnects UNIX to UNIX sharing over a private dial up network. There is the Hummingbird Corporation EXCEED product to connect UNIX to PC. ICE and EXCEED work well with ASTROS, MIDAS, and SDRC IDEAS.

### 2.3.1 Web Browsers

Today, everyone sees the World Wide Web growing as the common source for low cost corporate information technology with America Online and other providers offering low cost service from web sites on personal computers, UNIX, MAC and NT. In fact, Windows 95 was bundled with the web browser called Microsoft Explorer. The Netscape Web Browser and Microsoft Explorer are household words. The use of a Web Server with a common repository of goals and status information using an Internet provider is an essential part of the STARNET. So are URL links to the FAA, DOT, AIAA, EPA and OSHA rules and regulations that directly affect design optimization. Access to suppliers of parts, metals, composites, components, processes and manufacturing are also very important as all aircraft manufacturers are assemblers of aircraft.

### 2.3.2 Lotus Notes and Domino© Database for Web Servers

Lotus Notes and Domino© are excellent web server-based database tools using HTML expressly for the internet. IBM Corporation quickly bought out Lotus Corporation. MSI searched the web for applications that used Lotus Notes as a foundation. Notes has become the largest selling web based application foundation.

### 2.3.3 Applix Builder® for Cross Platform Tool Execution

The Applix Corporation tools are able to be compiled without change to run on PC/NT and UNIX platforms. The Applix Builder built the MSI REALITY© tools to PC from UNIX. The Applix Builder created the cross platform Decision Support System graphical user interface (GUI). Wright State University also used Applix tools to build a common method to build the spreadsheet interface for MIDAS in concert with the MSI Decision Support System. The Applix Builder was used to create the GOLD interface to MIDAS and ASTROS.

### 2.3.4 Applix Toolset

There are not very many web enabled design and office tools. Even the Microsoft Office tools (Microsoft Word, ACCESS and EXCEL and PowerPoint) are not useable from a server. STARS integrates tools that can function easily with Microsoft Office tools. The Applix Anyware web browser desktop provides the functionality to import and export Microsoft Office product data.

**Applix Development Toolset**

The Applix development tools include the Applix spreadsheet, Applix database, the ELF programming language, and Applix Anyware for HTML web server applications. ELF macros provide hundreds of functional elements to develop graphical user interfaces, database tables, and relational spreadsheets. The Applix spreadsheet interfaces the MSI CASh cost estimating spreadsheet and the MSI tools for reliability, maintainability and supportability. The Applix Anyware toolkit provides the bridge to the HTML of the internet environment.

**The Applix ELF Methodology**

Many of the underlying programs of the STARNET were written in the general purpose Applix ELF language graphical application interface developer toolkit. Applix is a commercially available application toolset from Applix Corporation. Applix tools offer the ability to develop cross platform (UNIX and PC/NT) tools that maximize the commercial viability.

### 2.3.5 Microsoft Front Page® for STARNET Website Design

Microsoft Front Page is the tool to create their MSI web site and home page. Microsoft Front Page® makes it easy to create links to Applix Anyware©, Lotus Notes and Domino©, links to internet websites (FAA, AIAA, etc.) and links to each user resource location (URL) and website. Front Page© builds the STARNET web site to connect the MDO team and their computers. For example, the GOLD interface was implemented in Applix Anyware, and integrated into the Front Page website. The web browser interface enables a Microsoft Windows user to prepare and work with internet and local personal computers while accessing ASTROS through the MIDAS program interface linked to the SDRC CAD system. The results of design and analysis are stored in a common SQL database and a common spreadsheet. The SQL and spreadsheet are compatible with Microsoft Office tools.

### 2.3.6 InQuisiX Pro®

InQuisiX Corporation sells the InQuisiX Pro toolset to system engineers and others who work collaboratively. InQuisiX Pro is a Notes application with a Workflow Manager, Team Collaboration Forum, Notebook, Asset Catalog, Asset Action Log, and Notes E-mail.

### 2.3.7 Web-X© and Microsoft NetMeeting©

The MDO team needs a way to share user tools that are not part of the STARS or STARNET toolset. There are two very different user tool environments, UNIX and PC. There are several PC to PC sharing tools on the market. Most internet users use the popular Microsoft NetMeeting tool. NetMeeting is free, downloaded from the Microsoft web site. NetMeeting users on PC can share any PC tool, including the displays of the network browser. NetMeeting lets users each use their pointer device (mouse) in a team meeting. The pointer symbol has the initials of each user displayed. Users pass the pointer to let each use the common tool. NetMeeting also supports voice communication and a "white board" for marking up screen captures of design outputs. Most aerospace firms use a UNIX toolset. (Most small companies use a PC program for computer aided design.) The Web-X© tool is a companion to the NetMeeting© tool. Web-X© by Hummingbird Corporation lets multiple UNIX users share a common tool on one of the UNIX platforms with PC and NT users so that NetMeeting© is able to share UNIX programs like ASTRO, MIDAS©, and SDRC IDEAS©.

**Using the STARNET Environments**

The STARNET connects the members of the design team. Each MDO team member uses their PC workstation or UNIX computer with network access. The team members access the network to learn of team progress, to release design data, or to work collaboratively sharing a tool. As they log in, the STARNET DSS tool displays the current status of achieving the design goals of the project. When not on the STARNET, each participant works alone to develop new concepts that brings the design closer to meeting that person's aspect of the list of goals. For example, the weight specialist works to minimize weight; while a cost analyst uses a spreadsheet to optimize fly away and support costs. Each specialist releases new optimization results as they are developed. As conflicts arise, the MDO team specialists each log in and use the STARS tool sharing program to develop mutually acceptable ways to resolve the issues. The specialists view the released design information with the STARS toolset.

**The STARS Toolset**

The STARS toolset is an open mix of design and office tools shared by the diverse team members. Some tools are owned by individual team members. Other tools reside on a common server. The STARS toolset resides on the common server. The team toolset consist of computer aided design tools, analysis tools, simulation and modeling tools, optimizer(s) and office tools. Any member can authorize other members to share a common use of any tool. The STARS tools consist of the DSS, the team spreadsheet, the reliability availability and maintainability analysis tools, the project released information database, the GOLD tool and utilities for collaboration. The STARS toolset are placed on a UNIX or Microsoft NT server.

The Internet approach lets structural MDO with ASTROS as a piece of the new rapid prototyping process. (An internet can be a local area network, a wide area network (Intranet), or one that freely uses the world wide web (WWW) with access using User Resource Locator (URL) addresses.) The STARNET infrastructure handles most cases. Figure 5 shows the Web Based Client/Server STARNET environment.

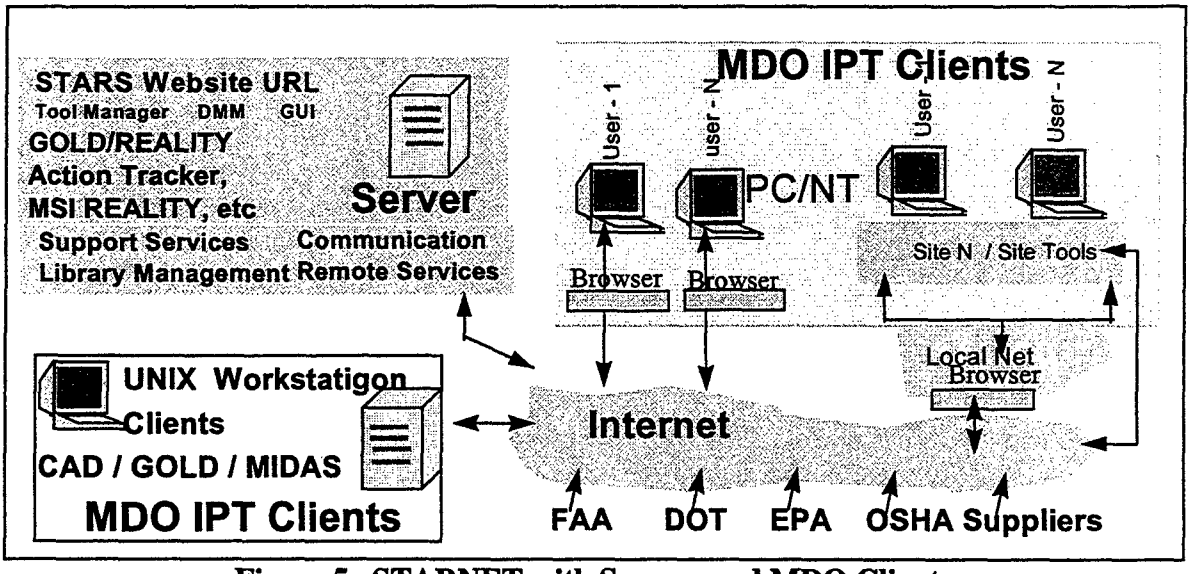


**Figure 5. STARNET with Servers and MDO Clients**

The MDO team members can get together to resolve conflicts. For example, the safety engineers tend to add weight, whereas the performance engineers want to remove weight. Innovations by the team members often can come up with mutually acceptable design features that optimize safety while optimizing weight. The DSS tool shows the relative improvement from the previous release to the current release for the parameters supported by the user. Safety engineers see reliability and cost information. Supportability engineers see reliability and maintainability information. Performance engineers want to weight, cost and aerodynamic parameters.

## 3.0 The Object Oriented MDO Design Environment

Most decisions affecting important aspects of ownership and life cycle costs are made during system engineering concept development phase. Results can be influenced by inputs to its constraints from tools including product databases, cost estimating methods, technical documentation, manufacturing, quality and production engineering. Historically, design engineers have used "guess and test" methods that often required many years to create the first production vehicle. The process was facilitated by craftsmen who created scale models that were tested in wind tunnels. Today, aeronautical engineers and aircraft designers use object oriented design (OOD) simulation and modeling to dramatically reduce the time from concept to delivered product. These persons work in integrated product teams (IPT) that bring together a multitude of disciplines. The IPT members make many vital MDO decisions before there is a real design. Many DoD experts figure that about 90% of performance and life cycle cost decisions are made in the first few months of system engineering.

Today, engineering designers use computer aided design tools to create three dimensional concept models that are "flown" mathematically. Theoretical shape models are combined to define feasible design architectures based on performance and technology. Wind tunnel tests are also performed by simulation. Once the technology and general shape of the structure is selected, trade off studies are used to select the best affordable architecture. Trade-offs include produceability, reliability, safety, supportability, and costs. MSI REALITY provides high level design assurance and system engineering tools for OOD. These tools interface with ASTROS.

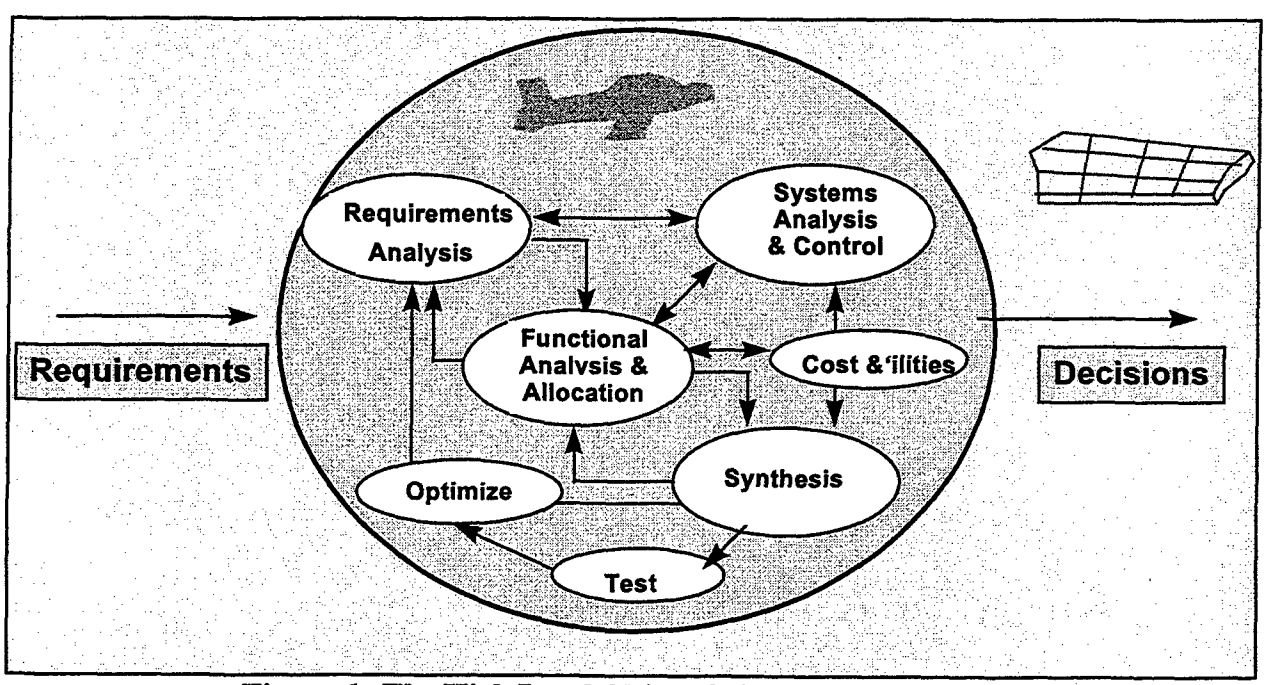


**Figure 6. The High Level Object Oriented MDO Process**

### *3.1 STARNET for Concurrent MDO Engineering*

The STARNET tools provide a way for specialists and designers to work concurrently for optimization. Automotive and aircraft firms employ "concurrent engineering" with participation

by a wide range of disciplines including manufacturing, cost estimating, hazardous waste management, human factors, reliability, quality, and maintenance specialties. It is becoming increasingly more important that these disciplines become more directly involved early in the design of a product in order to reduce the design cycle time, increase productivity and customer satisfaction. The input of the end user, product support, and product manufacturing teams have become an essential part of concept definition, system engineering, and virtual prototyping of a design.

STARS moves MDO up front for system engineering and classic MDO processes that feature the flutter, elasticity, strength and weight can be expanded to include external disciplines such as cost, manufacturing, safety and maintenance. Many disciplines participate in the making of complex products with a mechanical structure. System engineering turns the classical ways of "what you get is what we design" to "what you design is what we agree we want".

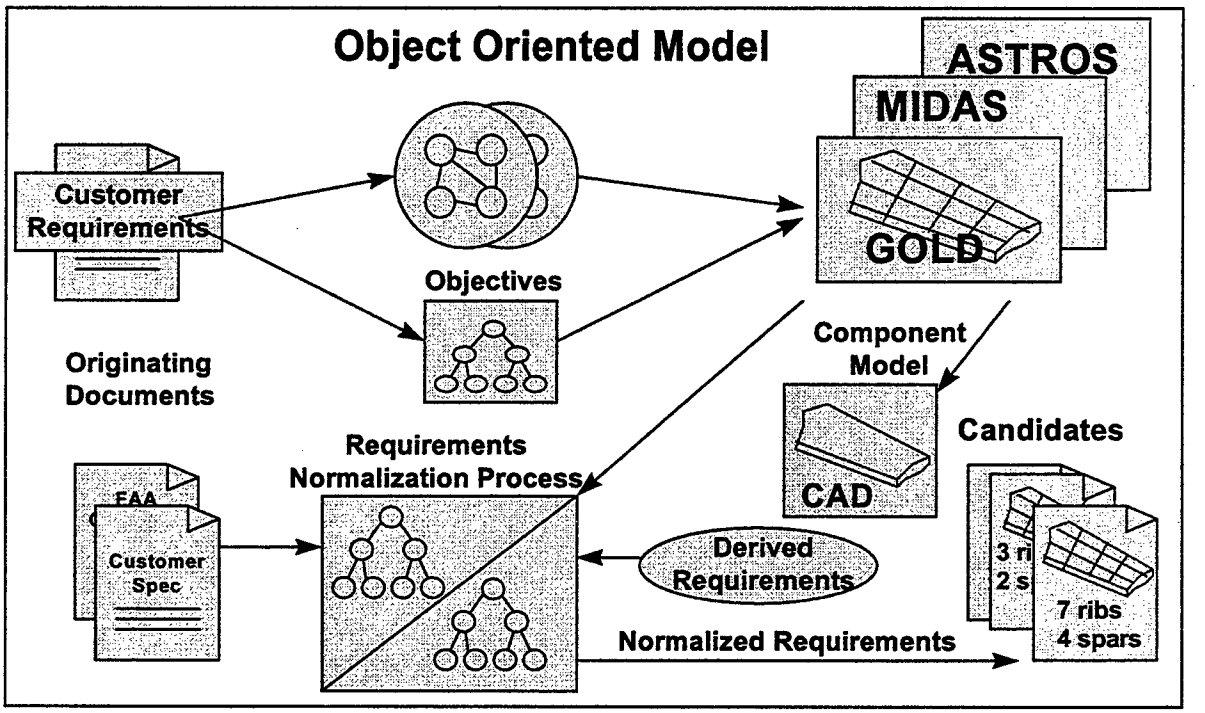


**Figure 7. Generalized System Engineering Object Oriented Models with STARS**

The STARS DSS and STARS database information tool, RAM-ILS, spreadsheet, and requirements data tools run on the network server computer but display on the team member's computer screen. The security manager and the update tool are only managed by the project supervisor. This assures that: a) only certified team members participate, and b) there is only one set of currently released optimization information and only one view of how optimization is proceeding. The released information is shared by all authorized team members. Team members have at least copy and read only permission. The MDO team can move data to their local computer to work on design, analysis, and optimization issues. When approved changes are ready for update, the information is moved to the network server and released by the update tool.

### 3.2 STARNET For Integrated Product Teams

For years, the best mechanical aircraft design has been done on mainframes with IBM's CATIA, and UNIX with Intergraph, SDRC and other CAD tools. Today, most government agencies and corporations are shifting to using PC tools like AutoCAD. Most companies have begun to use the Internet to provide a basis for supplier management and sales teams. The Internet can also be used for Integrated Product Teams (IPT). IPT focus on quickly bringing a quality product to market before it is made obsolete by technology growth. IPT can provide valuable collaboration in the MDO process with inputs from system engineering, customer quality deployment, economic, manufacturing, and support disciplines. The MDO opportunity lies in bridging the gaps from mainframes to UNIX, PC, laptop and palm held computers used by the various discipline specialists. The STARNET has an open architecture that handles most interfaces using commercial off the shelf tools. Security is handled by the web browser (e.g. Netscape), or by UNIX password and user authority set by the network administrators.

### 3.3 STARNET for Web Based Networked Collaborative MDO

The STARNET provides a way for cutting development cycle time, while reducing life cycle costs requires more that MDO include many disciplines ranging from marketing to customer support. Automotive firms use an MDO technique called "Quality Function Deployment". STARNET integrates access to discipline tools to CAD systems to include reliability, testability, maintainability, availability, manufactureability, safety, and supportability in the design of products.

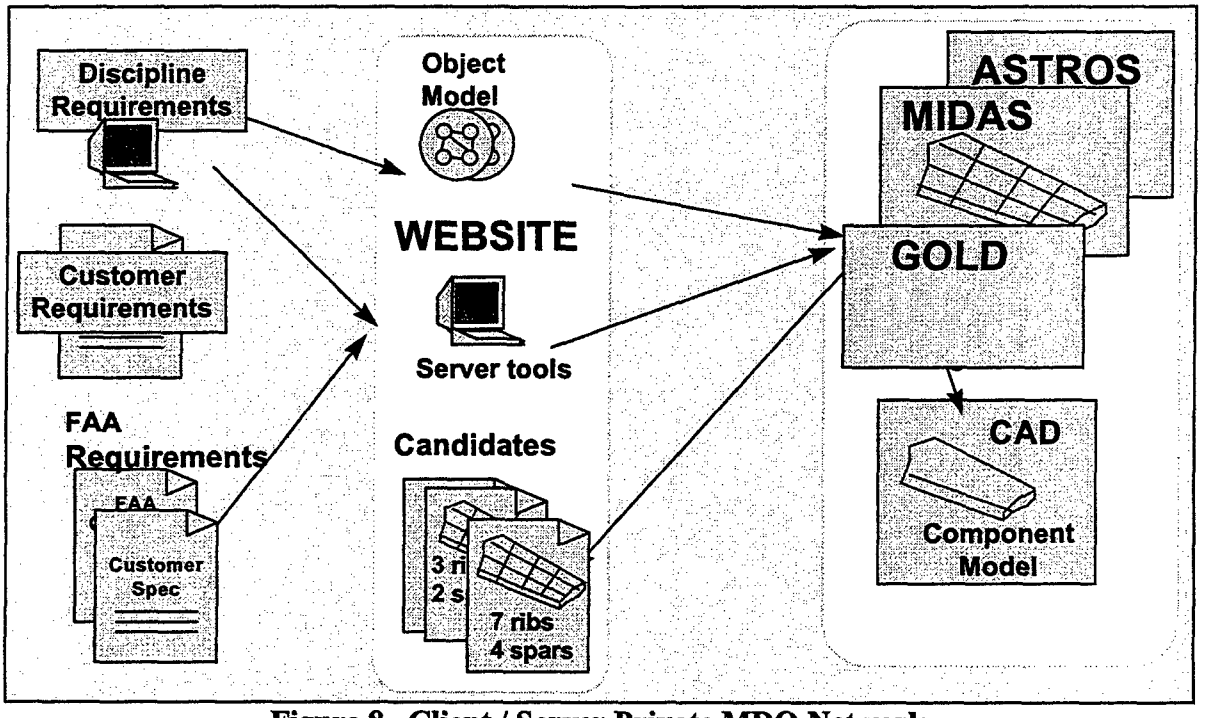


**Figure 8. Client / Server Private MDO Network**

### 3.4 Multi-Site MDO Collaboration Environments

The Web MDO environment includes tools for team tracking, cost estimating, design assurance, quality assurance, safety analysis, and system definition tools. The Web references hot links to regulatory agency web sites, and link to GOLD/MIDAS/ASTROS in a private UNIX network environment. The dispersed design team is able to use the Internet to connect to UNIX requirements, design, design assurance tools, cost estimating and ASTROS. Sandia National Laboratories (SNL) has developed a UNIX to UNIX sharing tool called Interactive Collaborative Engineering (ICE)©. The ICE tool was developed to tie together several sites using UNIX tools for design. ICE lets UNIX users share a single tool (such as SDRC-I-DEAS). ICE provided a way to let geographically dispersed UNIX team members collaborate on a single design.

### 3.5 Using the Web-Based STARS Toolset

The STARS toolset consists of the Internet enabled tools interfaced to UNIX SDRC I-DEAS, ASTROS, and WSU MIDAS and WSU GOLD. GOLD can be used in either PC or UNIX forms. MSI REALITY®, the MSI Action Tracker, MSI Cost Spread Sheet and database can be used in either PC or UNIX form. This lets geographically dispersed team members use PC tools interfaced to UNIX tools at other sites.

## 4.0 The STARS Toolset

The following pages discuss the technical and application aspects of the STARS tools. The STARS toolset is used with the DSS interface for high level requirements driven design using ASTROS with the interface from the requirements to the GOLD toolset. The STARS tools has a MDO cost estimating spreadsheet and interface with ASTROS. The spreadsheet program is used for process cost estimating in the decision support environment. The program associates part numbers with cost estimating as a set of process steps. This process can be expanded to include a robust suite of cost estimating relationships that include development costs, fabrication processes, and field support. The PC user of office tools is able to interface with the UNIX design environment by using Hummingbird EXCEED or other product for displaying UNIX screens in the PC environment. Figure 9 illustrates the STARS MDO process.

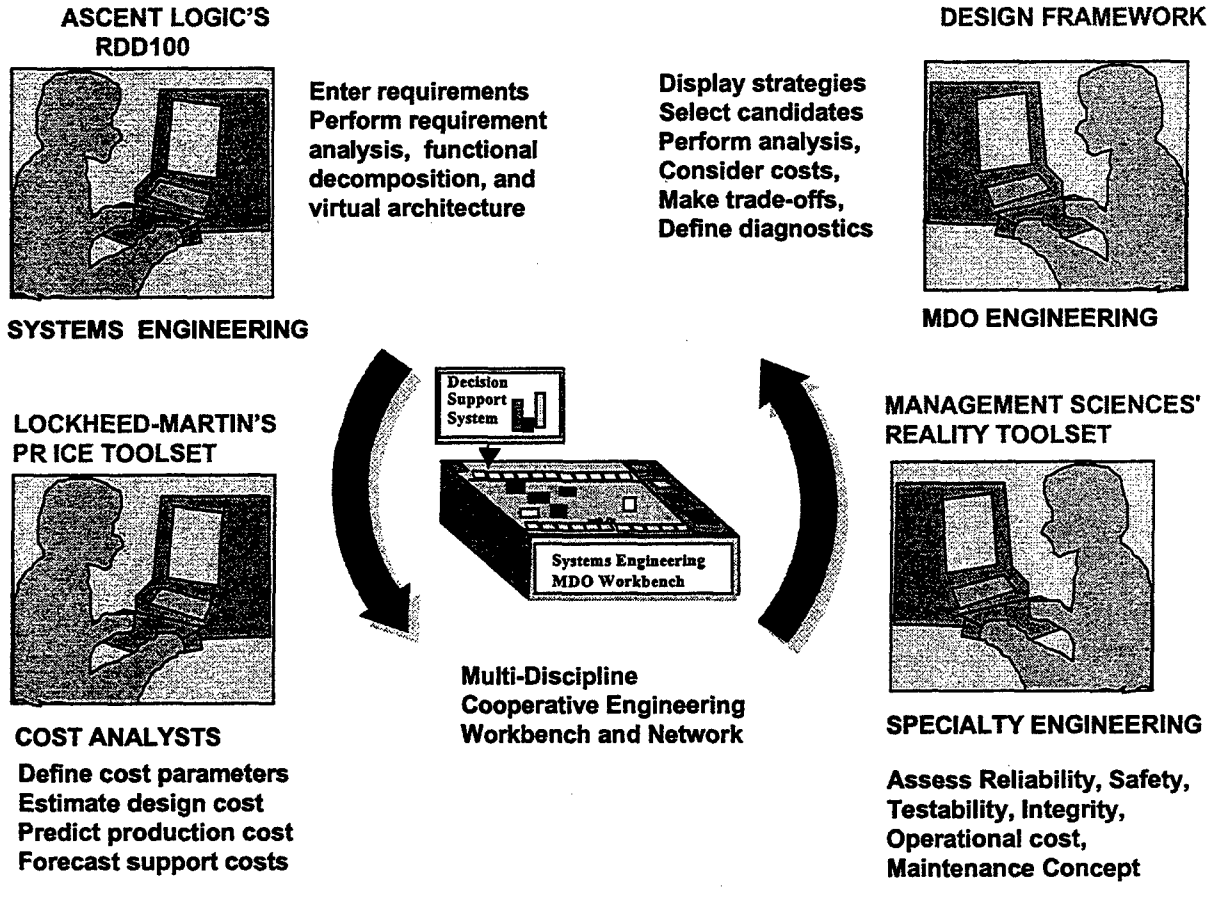


**Figure 9. Networked MDO Pays Off in Reduced Cost and Improved Quality**

The STARS innovations provide an asynchronous internet access infrastructure and tools so that any worthy discipline can be used in a client and server design environment optimized before, during, and after design. The internet environment lets each discipline member participate alone or in "mouse to mouse" collaboration with other team members. The design team can create mechanical designs that are "optimal" with respect to the participating disciplines. Synchronous team work occurs as necessary to resolve issues and discuss opportunities.

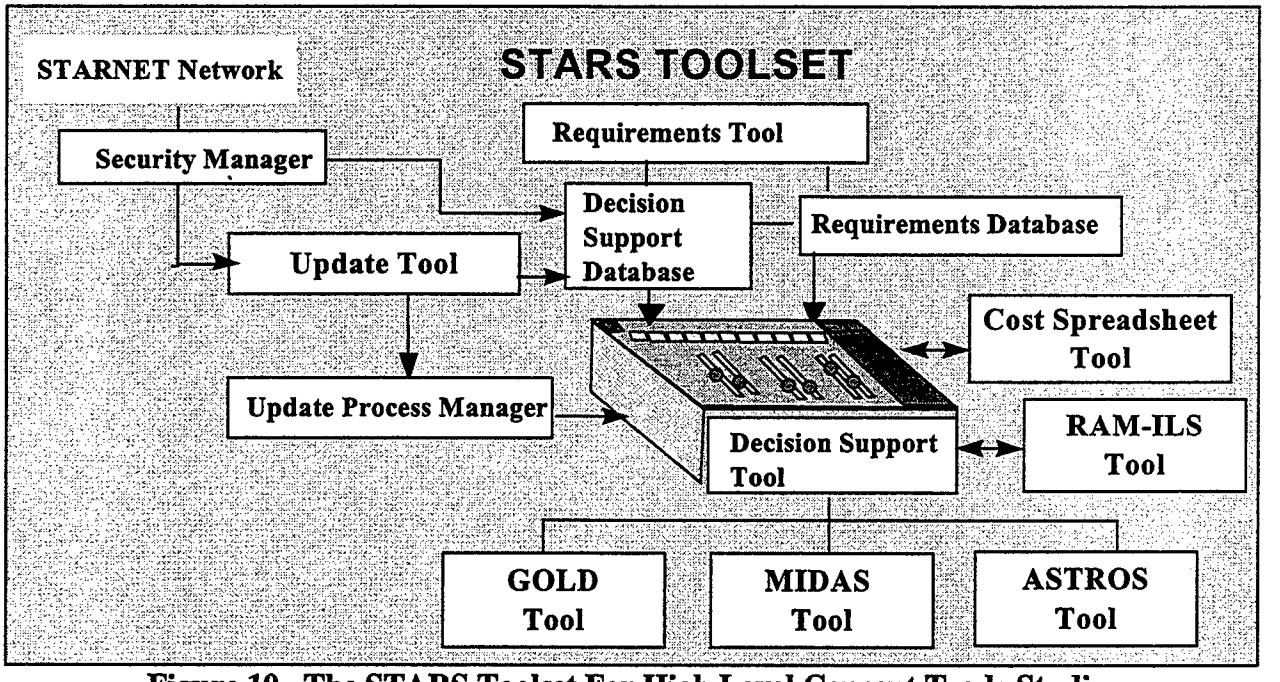


**Figure 10. The STARS Toolset For High Level Concept Trade Studies**

### *4.1 STARS Toolset Features*

**a. STARS has an Integrated MDO Methodology**

Aircraft designers need to meet certification requirements. Aircraft design is driven by meeting FAA regulations. The FAA requires validation of aircraft design methodology. STARS interfaces FAA validated tools like ASTROS. The STARS toolset integrates reliability, maintainability, cost estimating, safety with classic MDO performed by ASTROS.

**b. STARS Interfaces Tools for Maintenance and Inspection Planning**

Aircraft structures require inspection and maintenance to reduce effects of aging due to compression, decompression, flight stresses, corrosion and many other factors. The URL for the FAA RAPID program for maintenance interval analysis can be accessed and driven from the STARS user interface(s).

**c. STARS Provides Interfaces to Requirements Driven Design Tools**

The STARS methodology promotes a "Skinny" design that not only meets weight goals, but also meets other discipline goals as well. The basis for the structure will be the certification, design, production and support requirements given to the design team. The STARS method provides interfaces to tools for requirement's traceability to the paragraphs of the applicable FAA, OSHA, EPA, customer and ISO-9000 specifications. The RDD-100 tool from Ascent Logic Corporation provides a virtual executable specification that captures the FAA requirements.

**d. STARS has a Powerful Decision Support System and the MIDAS Display Software**
The users control the MDO process from the DSS interface. The STARS workbench has links to the WSU MIDAS display software. The "what if" capability available in MIDAS is used to capture and display parameters, options and results of MDO. Users can also utilize other finite element tools that are compatible with ASTROS.

**e. STARS Provides Tools for Reliability and Safety Analysis and Cost Estimating**
Safety and reliability must be part of FAA-certified design practices. The MDO processes need to automatically quantify the risk for the new and aged structure. The STARS workbench interfaces provides URL link access to the MSI REALITY tools for reliability, maintainability, safety, fault tree analysis, failure modes and effects analysis (FMEA) and other tools for design assurance. The STARS workbench provides an interface URL link to programs for automatic mapping to (and from) requirements and the structure. The DSS displays cost factors based on cost estimating parameters calibrated for each user site. The DSS also gives access to the individual design and analysis tools during collaborative one-on-one meetings.

The STARS tools are meant to be used very early in the concepts development. System engineers can use the STARS tools without learning to use a CAD system. System engineers can "build" an approximate design. The first release of STARS provides the ability to develop simple box and wing structures. Other structures can be easily added by using the Applix ELF language to work with cylinders, beams and other basic structural types. System engineers access the STARS MDO tools by coming in through the security program to access the decision support tools. The high level OOD tools provide an easy way to perform cost, safety, reliability, and performance trade-offs.

### *4.2 The Internet Collaboration Environments*

The STARNET lets the many disciplines that use PC tools join in MDO with those that use UNIX tools. The Internet web browser provides an easy to use, user friendly Hypertext Markup Language (HTML) environment. The environment can be run wholly on web enabled UNIX computers, or a mixture of UNIX, PC, and NT computers. The Applix cross platform development system as a way to develop middle ware tools for UNIX, PC, and the web.

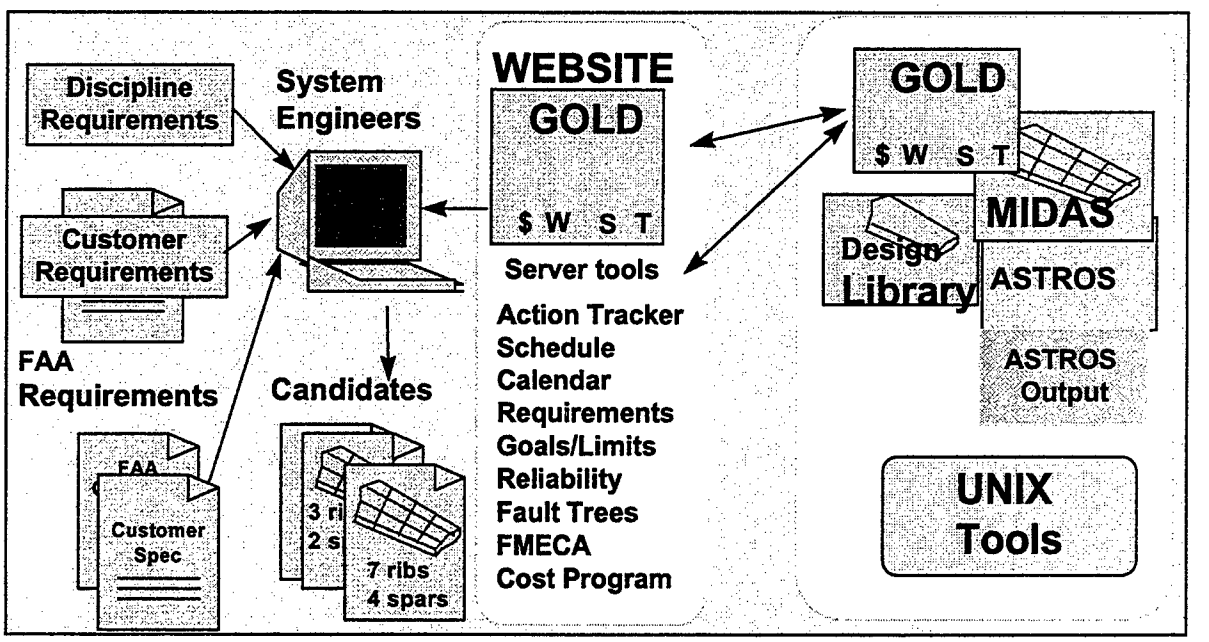


**Figure 11. The Internet Based System Engineering Toolset**

## 5.0 Design and Decision Support Environment

The purpose of the DSS (or Decision Support System) is to provide the STARS MDO team with a common look and feel user interface that acts as a control panel, status display, and process manager. There is no limit to the number of engineering design and specialists that can participate.

### System Engineers

The system engineers deal in requirements, concepts and design candidates. The DSS provides a place to load requirements, allocate goals, and establish design guidelines. The DSS serves as a place to define, view, and manage the strategies for the design. The DSS database is a place to set rules and limits for variability consistent with requirements. Critical rules are assigned to the indicator buttons.

### Safety Engineers

The safety engineers (including the FAA) have a major say in the use of techniques, technology, and materials. Safety engineers are responsible for protecting not only the pilot and crew but also civilians and other "collateral damage" of an aircraft disaster.

### Mechanical Engineers

The design engineers view of the DSS should be as the process manager for repeated runs of MIDAS. The DSS provides a place to set preferences for MIDAS, ASTROS and I-DEAS. The DSS also serves as a reminder of the goals for the design project. The DSS also accesses libraries and network information that are part of MDO design.

### Cost Engineers

For a new product design, the cost engineers rely on past experience or industry factors to develop "rough order of magnitude" (ROM) estimates. The cost engineers use spreadsheets such

as Microsoft EXCEL, the Applix Spreadsheet, PRICE Systems, Cost Expert, and Cost Advantage. The STARS GUI has a fully functional Applix spreadsheet program and a ROM cost program based on process costs.

**Reliability Engineers**
The reliability engineers are concerned with loads, stresses, and fatigue that eventually lead to failure in airframe structures. The reliability engineers place design constraints on stress ratios and related issues. ASTROS develops the stress ratios from the loads data. The ASTROS constraint definitions can cause optimization to meet minimum stress conditions.

**Managers**
The DSS serves as a place to define broad guidelines to the system engineers, designers, and other MDO team members. The DSS display is used to view the relative progress of the design process. The DSS is used to gather metrics.

**Supporting Non CAD Disciplines**
Not all members of the MDO team need to know how to use I-DEAS, or how to use MIDAS. The control panel provides a display of the relative results of the last two iterations and the relative effects of their disciplines on the structure and meeting the goals of the other team members. The WSU GOLD graphical user interface interfaces to the MIDAS program and ASTROS. The GOLD tools interface to the DSS toolset to create a common goal optimization interface that is used in the Internet environment (STARS), and the UNIX design environment of SDRC I-DEAS© and ASTROS.

### *5.1 The Stars Decision Support System*

The Decision Support System with MSI design evaluation tools run on NT displayed as HTML. The collaborating design team (1 to 5 simultaneous users) accesses the ASTROS on UNIX using a link from the STARS website tools a network browser (Netscape). MSI finished the conversion of the REALITY and DSS toolset to NT. An identical UNIX GOLD provides access to MIDAS, ASTROS and SDRC I-DEAS© accessed on the UNIX machine.

### DSS Preferences

The DSS preferences are stored in the "DSS_Preferences" spreadsheet. The preferences are used to control the colors, font sizes, and local options of the DSS display for a user. This file should be stored in the setup sub-directory.

### DSS Preset Controls

Preset controls are the basis for MIDAS start up. The paths and script parameters should be stored in the "DSS_Controls" spreadsheet. The parameters are used in the ELF coding of the "MIDAS" button.

### DSS Display Controls

Display controls are stored in the "DSS_Controls" spreadsheet. The data is used in statements to control:

a) The movement of the icons that show design progress.
b) Indicator lights for design compliance.

c) Text for buttons and sub-menu selections.
d) File names and paths for Help and other documents.
e) Script parameters.

### DSS Option Control

Options are buttons on the DSS display area that are unique to MIDAS functionality, such as access to programs such as MIDAS, I-DEAS, ASTROS, etc. Optional data controls are stored in the "DSS_Controls" spreadsheet. The data is used in ELF statements to control:

a) The start up of programs.
b) Hourglass or clocks to show background activity.
c) Text for option buttons and sub-menu selections.
d) File names and paths.
e) Script parameters.

### DSS Remote Processing Feature

The user should be able to perform ASTROS runs and other compute intensive operations in a background mode. The ELF programs can perform "trigger" actions that change displays and activate "Bells" when the batch processing is done. The feature is used to make complex reassessments when materials are substituted, labor rates are changed, and for other "what if" processes that do not necessarily require a mechanical engineer familiar with ASTROS.

### DSS Program Controls

Ideally all path, control, and constants variables should be stored in the DSS_Controls or DSS_Preferences files. The DSS_Controls file is stored in the Controls sub-directory and the DSS_Preferences file is stored in the Setup sub-directory. These controls files should be in an APPLIX spreadsheet format. The Setup and Controls sub-directories should contain a file which describes both and directory's contains and the format of the contains.

### DSS Executable Scripts

The script files are stored in the Bin sub-directory. All shell scripts and utility programs are stored in the Bin sub-directory. Please include a file in the Bin directory which describes the functionality and usage of the files in the Bin sub-directory.

### DSS Data Files

The data files are stored in the server data sub-directory. The files include the help documentation, bookmarks, and other files related to the DSS (MIDAS files, ASTROS files, and other files are stored in another directory).

### DSS Goal and Requirement Setting

The purpose of any DSS is to aid in the achievement of the projects goals and requirements. In Figure 12, the progress report goal indicator graphic is one method in which a DSS can assist in the achievement of the goals and requirements. The action of setting goals and/or requirements is a manager function. This function is protected against general user manipulation. Generally, such functionality is guarded by a password restriction. Any goal and requirement setting must require confirmation of such action by the user before execution of any change.

The STARS Interface was designed as an Applix*Ware* builder application. The Interface provides a common execution platform for the DSS and the GOLD applications. Its appearance is such that it is familiar to GOLD users. Additionally, the STARS Interface displays a conglomeration of projection information on a single screen. This Interface tool was designed for users of the GOLD and the DSS programs. Potential users might include designers, analysts, and engineers. For the STARS Interface, the file must be in the same format as a GOLD spreadsheet. This file contains information from both the GOLD program and the DSS program. The data source file is a fully functional spreadsheet. As such it can be used in all the normal ways of a spreadsheet. Additional data can be added to the data source file to fit the user's needs. The data used by the STARS Interface and the GOLD program is position dependent. Immediately after the opening of the data source file, the STARS Interface main screen appears. This screen is titled STARS Result History.

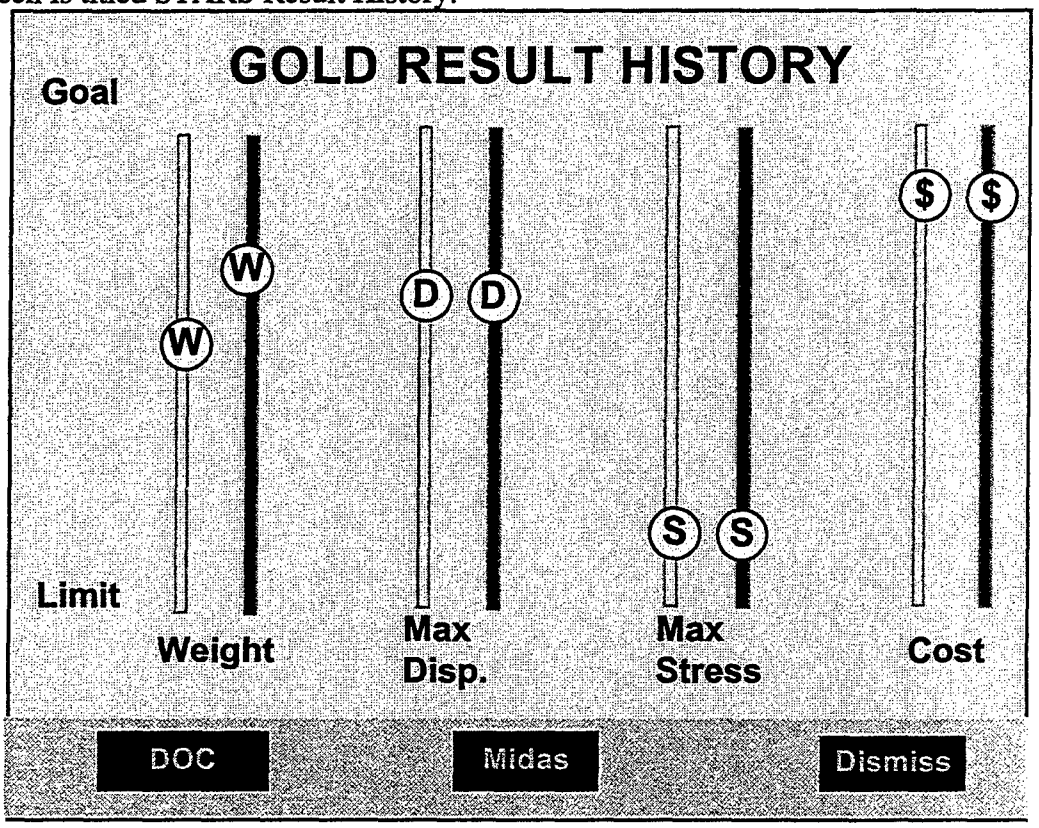


**Figure 12. STARS DSS Interface Main Screen**

Users who are familiar with the GOLD program notice that the Interface main screen is very similar to the GOLD Results screen. The main screen is positioned on top of the data source (the spreadsheet) screen. To access either screen, users simply bring the required screen to the foreground. The main screen has two parts. These parts are the controls (the buttons and the menu bar) and the goal status indicators.

**Main Screen: The Goal Status Indicators**

The STARS Interface main screen displays four goal indicators. These goals are Weight, Maximum Displacement, Maximum Stress, and Cost. The first three are supplied by the GOLD

program and the last is supplied by the Process Cost report generated with the DSS program. The goals are objects and any set of goals can be displayed from the data in the spreadsheet that comes from the analysis tools.

A goal status indicator is composed of four parts. These parts are: a title, limits, bars, and icons. Each goal status indicator displays the last and previous iteration's results. The title indicates which project attribute the indicator is displaying. The limits are the valid range for the project attribute. The bars give a scale of reference for change. The icons give the last and previous iteration's attribute values. Each of the goal indicators use a different icon to show the value of attribute displayed. The icons are a weight for weight, a gamma for displacement, a sigma for stress, and a dollar sign for cost.

**Main DSS Screen: The Controls**

There are two parts to the controls on the main screen. These are the menu bar and the tool buttons. The menu bar consists of a file and help menus. The File Menu contains a single entry: Exit. The Help Menu contains two items: About and Help. There are three tool buttons labeled DSS, Gold, and Dismiss. The DSS button launches MSI's DSS program. The Gold button launches WSU's GOLD program. The Dismiss button exits the STARS Interface.

## 6.0 The ASTROS Program

The era of computer aided structural design using finite elements began with the writing of NASTRAN by R.H. MacNeal and associates[1]. NASTRAN quickly became the fountain for analysis techniques by a number of theoreticians and engineers. NASTRAN has been used to perform dynamic and static response analysis. Due to computer memory limitations at that time, NASTRAN describes a structure in terms of a mesh of points and edges called a 3-Dimensional (3-D) finite element model (FEM). Physical property information is attached to each edge element which represents a material part of the structure. NASTRAN has evolved to a number of 3-D mechanical CAD programs.

The ASTROS project was started in 1983 by the Analysis and Optimization Branch, currently part of the US Air Force Research Laboratory at Wright Patterson Air Force Base, Ohio. Dr. V. B. Venkayya managed the project. ASTROS has evolved to a powerful parametric design optimizer of finite element models used in the design of aircraft structures. Since 1983, ASTROS has been constantly enhanced, primarily under contracts to Universal Analytics, Inc. (UAI) of Torrance, California.

ASTROS is unique in its ability to modify the thickness of finite elements of a structure model to optimize for weight, performance and other properties. The process is called multi discipline optimization (MDO). The MDO disciplines include aeroelasticity, aerodynamics, load and stress analysis, and other physics. Originally, ASTROS was developed to optimize weight, strength, flutter, aeroelasticity, lift and other characteristics of military aircraft, especially lifting surfaces of the wing and tail. Done manually, MDO is a very difficult and time-consuming sequence of complex mathematical processes. A modern wing design has hundreds of structural elements. There are literally millions of calculations to optimize a single variable. ASTROS automates the process of optimization by using matrix gradient methods to modify the thickness of elements after the design meets performance requirements. The ASTROS process searches for maximum effective changes in thickness using complex matrix methods defined by the finite element model used to define the structure. Figure 13 shows the flow from CAD Finite Element Model to ASTROS optimization using the Bulk Data file.

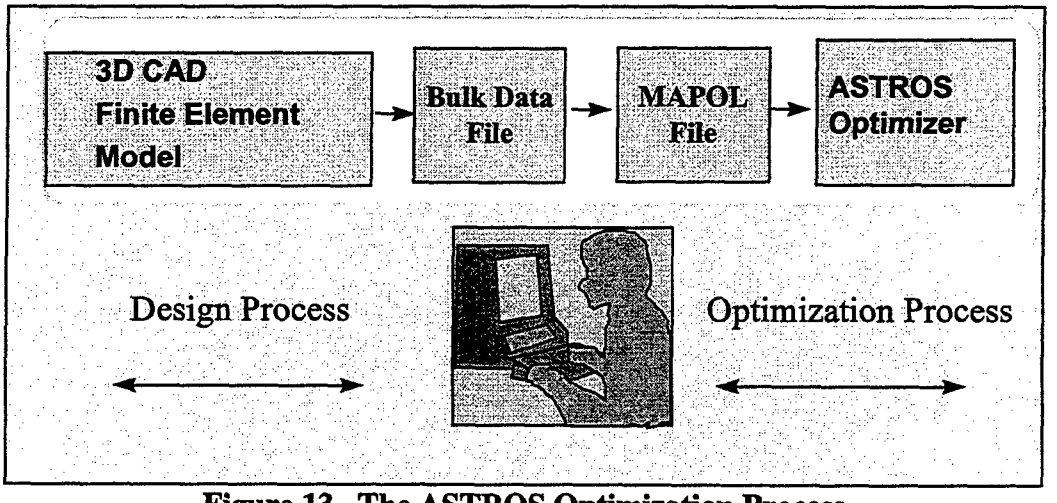


**Figure 13. The ASTROS Optimization Process**

[1] MacNeal, R.H. The NASTRAN Theoretical Manual, NASA SP-221(01) April 1971

ASTROS changes the amount of material (metal, etc.) in a design. ASTROS does not change the original finite element design. The number of structural members, shape and spacing are not changed. Rather, ASTROS varies parameters of the design to search for local optimum conditions that meet specified design constraints. For example, if any member exceeds specified stress limits under specified load conditions, ASTROS adds or subtracts thickness to meet the constraints. Conversely, if any member has stresses below specified stress limits under specified load conditions, ASTROS reduces the thickness. The process of thickening and reduction is performed for any member that has been defined as variable. ASTROS has adapted NASTRAN load generation to define the finite elements. Like NASTRAN and most scientific and engineering programs developed in the years from 1955 to 1983, ASTROS is written in FORTRAN.

**ASTROS Can Be Used as a Generic Basis for Structural MDO**

ASTROS was designed to minimize weight while maintaining performance of structures. ASTROS can also be used in optimization with non-weight factors such as cost. The idea works well in developing wing structures. The PRICE cost estimating system was used to evaluate a structure built from extruded stringers to replace more expensive machined stringers. ASTROS optimized the wing with respect to cost and weight. The same process can be generalized to other parameters such as noise, durability, and maintenance.

**MDO with ASTROS Adds Value to Designing of a Wide Range of Products**

The power of ASTROS solves very difficult problems encountered in design of structures. Our research proved that ASTROS brings reality to MDO that can be benchmarked and validated for use in development of a wide range of products. The modified use of ASTROS in MDO adds value as higher quality and less cost to automobiles, medical products, bridges, buildings, and hundreds of other defense, aerospace, and commercial products. The design team needs to consider that safety, quality and life cycle cost have wide commercial applications beyond aircraft design. Automated structural MDO is needed to address combinations of any or all factors before and during design of a broad range of applications such as automobile parts, earthquake-proof structures, aircraft assemblies, and commercial products such as bicycles and sailboats. Medical appliance designers need MDO to optimize strength, durability, and safety.

**Using ASTROS with MDO Tools Adds Value to ASTROS**

Using ASTROS in MDO assessments extends the useful life of ASTROS. By coupling other design programs with ASTROS, the benefits of ASTROS can spread to many other disciplines such as, architectural design, civil engineering, electronic systems and commercial aircraft. As a result, ASTROS will continue to develop and improve.

**Ongoing Development of ASTROS by Universal Analytics, Inc. (UAI)**

UAI has the exclusive license to develop ASTROS under a cooperative research and development agreement (CRDA) from the US Air Force. Like many scientific computer programs, ASTROS is constantly being improved and computing technology is constantly changing, and new materials and methods require changes in ASTROS. ASTROS is constantly being refined Universal Analytics Inc. and others.

Dynamic matrix assembly in ASTROS (and in NASTRAN) has a large number of options and becomes very complex. UAI had added new MAPOL formats for loading parameters and control of static aeroelastic analysis, flutter analysis, dynamic analysis, and nuclear blast analysis.[2] The materials optimized by ASTROS also has been expanded from the aluminum to include laminated composite materials (Ibid.). For example, Knowledge Systems, Inc. has implemented damage tolerance analysis into ASTROS[3].

**Use of ASTROS for MDO in Detailed Design**

STARS makes MDO easier for decisions very early in the concept development phase. The STARS tools can be used even though FEM programs like NASTRAN have only a limited value to most of the disciplines associated with modern product engineering teams. Later during product design, the wire frame models lack a robust representation of the process and problems in manufacturing, maintaining, and owning a product. As the speed and memory of modern computers increase, finite element model methods are giving way to 3-D solid modeling (3DSM) where the material information is described as a solid 3-D object.

[2] ASTROS Enhancements, WL-TR-95-3006, Universal Analytics, Inc., May 1995

[3] Implementation of Damage Tolerance Module Into ASTROS, WL-TR-97-3044, Knowledge Systems, Inc. March 1996.

## 7.0 The MIDAS Program

Another important tool of the STARS toolset is the MIDAS optimization display tool. The AFRL team has been working on the interface from ASTROS to 3D CAD for several years. Wright State University students have been developing an automated interface from SDRC IDEAS to ASTROS called MIDAS. WSU MIDAS links to CAD models to ASTROS by using the NASTRAN bulk data output file created by the CAD program. ASTROS reads in the NASTRAN "Bulk Data Deck" as the basis for the finite element design data. Today, the NASTRAN data is automatically placed in a bulk data file by most 3-dimensional (3-D) computer aided design (CAD) programs.

The ASTROS process is transparent designers as they can simply select a program option to "punch" the output data deck used by the ASTROS program. Figure 14 shows the flow using MIDAS.

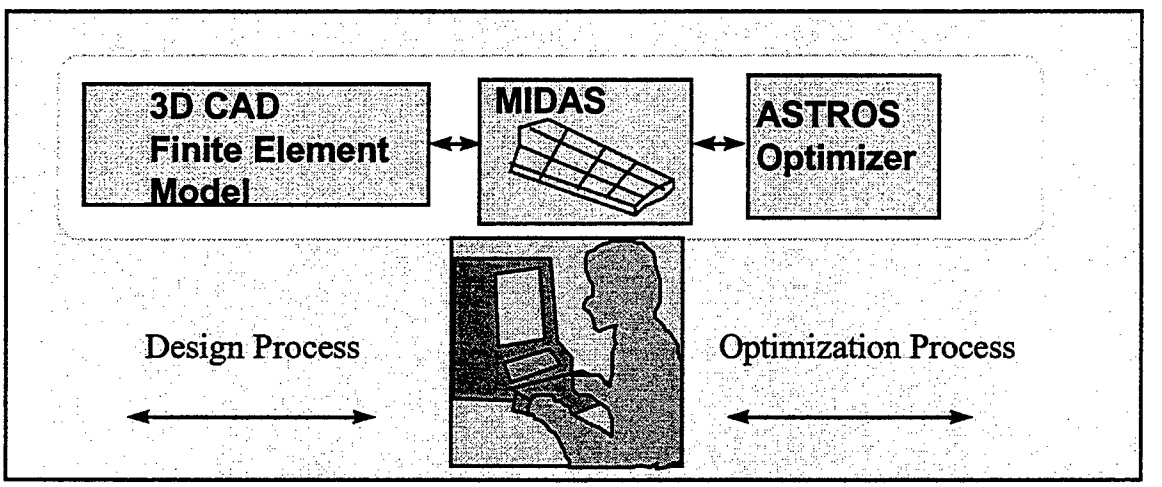


**Figure 14. MIDAS is the Display for the SDRC Optimization Process**

The WSU MIDAS tool modifies the NASTRAN bulk data file from the 3D CAD for ASTROS optimization. The modified MAPOL and bulk data are passed to ASTROS. When ASTROS finishes, WSU MIDAS displays the results calculated by ASTROS in 3-D color representations to show optimized flutter, thickness, loads and other data. WSU MIDAS is a powerful MDO visualization tool that makes it relatively easy to use ASTROS with a 3D CAD model. However, the system engineers must learn to use the 3D CAD program to use the power of ASTROS. System engineers are usually not designers. System engineers need a way to circumvent using the 3D CAD tools by having a OOD GUI for setting the parameters of a structure.

## 8.0 Programs for High Level Object Oriented Design

Many disciplines that influence mechanical designs use PC tools and most do not have any idea of how to use mechanical CAD or ASTROS. STARS makes it easy to run ASTROS automatically. This is a major innovation since most MDO decisions are made early in the concepts phase by system engineers who work from requirements to "dream up" a new design using high level concepts. Most system engineers do not know how to use a CAD system.

### *8.1 The GOLD Program*

GOLD is a STARS tool that interfaces with Wright State University's robust MIDAS interface to ASTROS. GOLD works with MIDAS which provides a seamless interface to manipulate and view the results of ASTROS in the SDRC I-DEAS program. WSU developed GOLD as a high level structural design tool that minimized the necessity for non-engineers to learn ASTROS. The STARS GOLD toolset uses the ASTROS EBASE feature to create complex multi-variate equations. The toolset interface was developed by using the APPLIX Corporation developer kit. GOLD is a middleware front-end user interface to the MIDAS. The GOLD program interfaces to office and other engineering tools for UNIX and PC. GOLD is a common cross platform MDO interface from PC users to the UNIX designers using ASTROS. GOLD is used to generate conceptual designs that are sent to ASTROS for analysis and MIDAS to display the results of ASTROS optimization.

The STARS GOLD to ASTROS approach is used to consider diverse high level goals as part of the high level design system engineering process. The GOLD program eliminates the need to use the CAD program. GOLD can create a wing model from a few parameters that describe the root and tip sections, and the number of ribs and spars. The GOLD program generates a bulk data deck and a MAPOL deck interfacing directly to ASTROS. The MIDAS program can be used to display the results of the high level optimization process. However, even MIDAS is optional if the system engineer justs wants to study the possibilities of changing the number of ribs and spars, materials, or chords. Using GOLD ASTROS and MDO can be of major benefit in system engineering where ideas are developed into architectures. The inputs from the diverse disciplines form the basis for selecting the best architecture by trade-offs made with modeling and simulation using ASTROS.

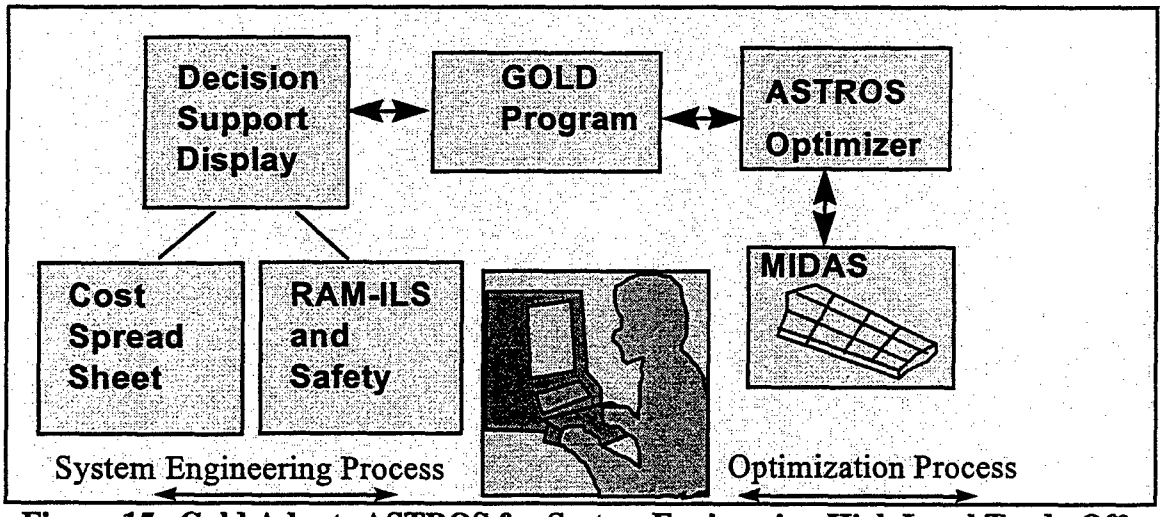


**Figure 15. Gold Adapts ASTROS for System Engineering High Level Trade-Offs**

### *8.2 System Engineering Tools*

The Ascent Logic RDD-100 tools are widely used by aircraft and aerospace manufacturing tools to capture design requirements and model behavior. Ascent Logic has built an interface to the MSI RAM-ILS tools and to the PRICE cost estimating programs. The RDD-100 tool captures the functionality and implementation architecture as it evolves. By a simple click, the candidate architecture is passed to the RAM-ILS tools and to the PRICE tools for analysis needed to make high level trade studies to choose the best architecture.

### *8.3 Cost Estimating Programs*

The STARS toolset has access to computer programs for estimating the cost to design, manufacture, test, operate and support a product. The process is called Life Cycle Costing. The STARS toolset includes the MSI CASh operating and support cost model spreadsheet and accesses the Lockheed Martin PRICE models.

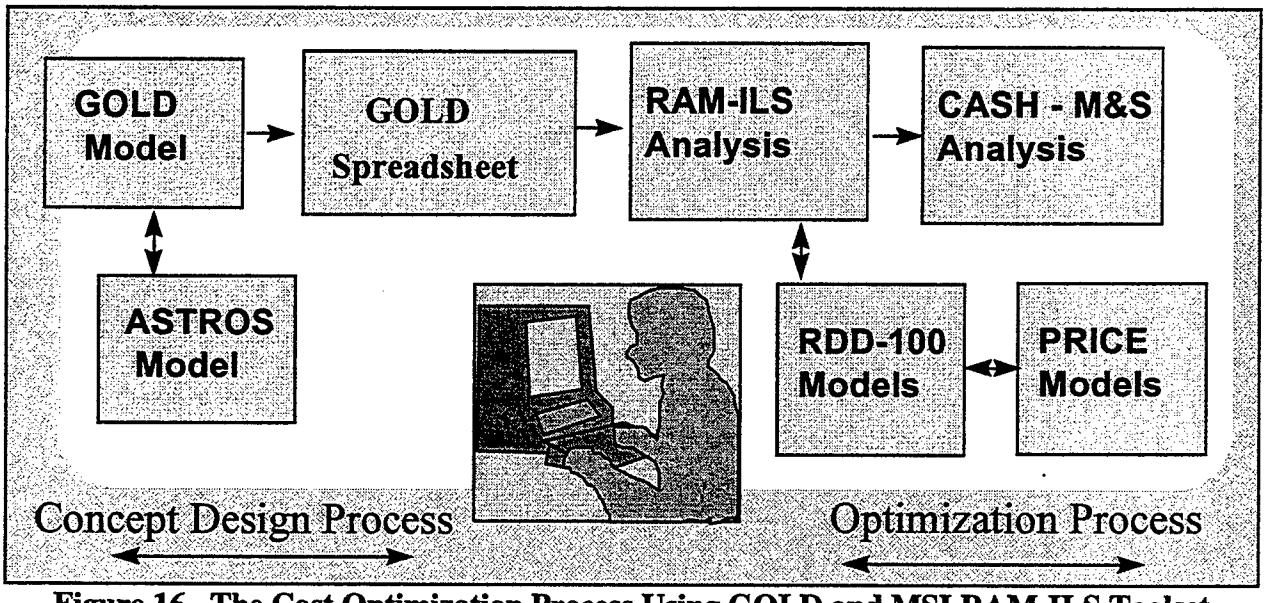


**Figure 16. The Cost Optimization Process Using GOLD and MSI RAM-ILS Toolset**

#### 8.3.1 The Lockheed Martin PRICE Cost Models

The PRICE models are widely used by the aerospace industry to estimate the costs to design, prototype, manufacture, and support a product. PRICE is a parametric cost estimating tool (not a spreadsheet) that uses cost estimating equations based on statistical measures. The PRICE tool is calibrated for the recent history of the aerospace industry and for the company using the tool. The PRICE models can be used independently or with the RDD-100 and MSI RAM-ILS tools.

#### 8.3.2 The Management Sciences' CASh Program

The MSI CASh program is a spreadsheet that is especially formatted to build a STARS tools provide a way to design products that consider cost as an independent variable (CAIV) with increased emphasis on safety. Product designers have begun to use and rely on "Virtual Design and Rapid Prototyping" to cut product development time. (Automobile models used to take over five years to design using wooden forms and test tracks; today, CAD designs are produced in less than one year.)

### *8.4 The Management Sciences' RAM-ILS Tools*

The STARS toolset contains a comprehensive set of tools for Reliability, Availability, Maintainability, and Integrated Logistic Support (RAM-ILS) analysis.

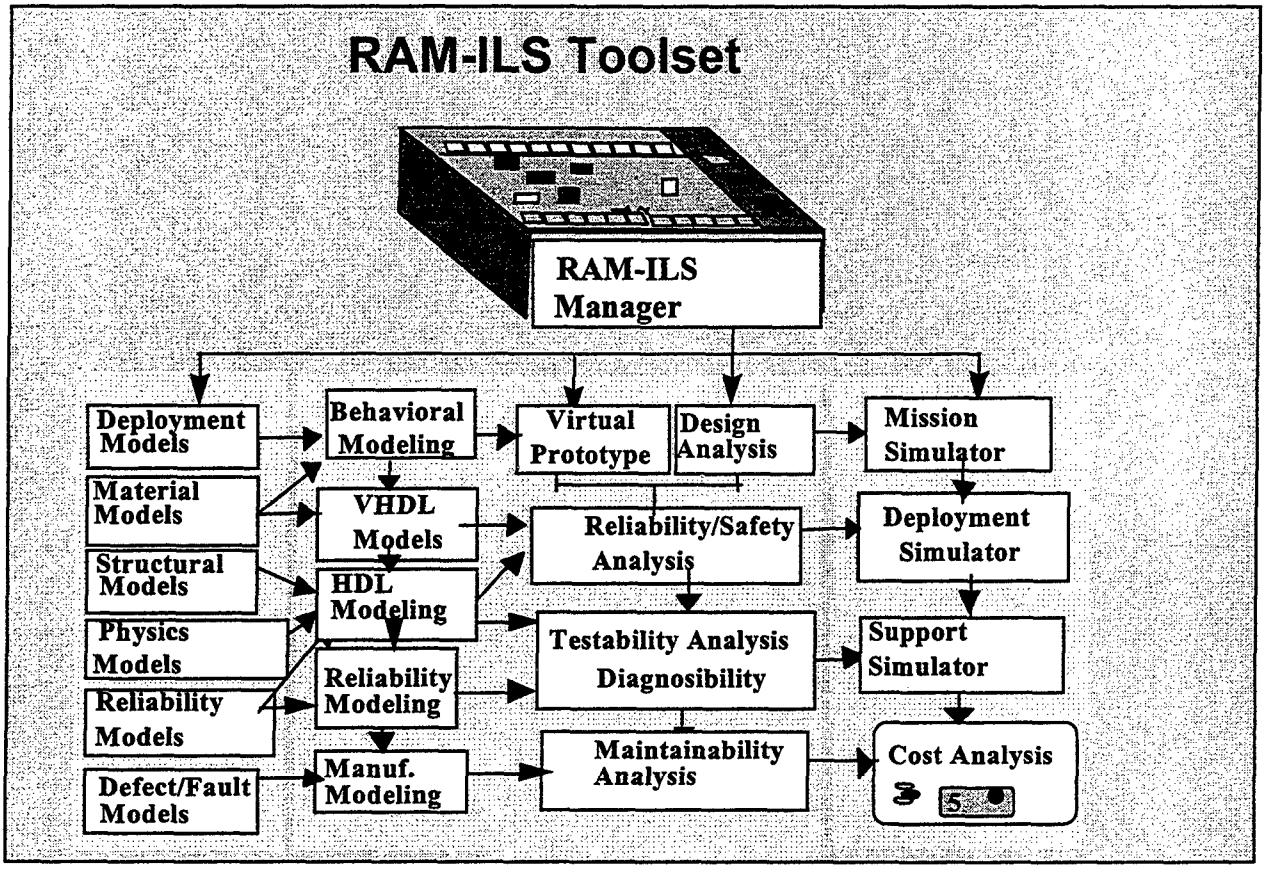


**Figure 17. STARS RAM-ILS Toolset Functionality**

## 9.0 Commercialization

**The Product:** Our product is an innovative collaborative MDO "Rapid Prototyping" workbench called STARS, built on ASTROS, SDRC IDEAS, MIDAS and GOLD. The STARS product is used for optimization of "Virtual Designs" by a team of engineers connected by a STARNET. The designers first create candidate structures and use STARS to pick the candidate that best meets their objectives. STARS provides links to specialty analysis tools that cover a broad range of interests such as noise reduction, product safety, cost estimating, and manufacturing planning. Alternate design candidates will be evaluated quickly with affective multi-discipline optimization. The product set will save time, money, and improve product quality.

The commercialization phase is underway. MDO optimization should be a part of every hardware oriented design project. Commercialization of Collaborative MDO Networks for Mechanical Design are a small but significant subset of collaborative MDO networks and tools for product design. Because of the focus of AFRL on aircraft systems, the focus is on the aircraft design markets. While most products have a mechanical structure, mechanical design remains an art.

**The Significance of MDO with STARS:** Structural design used to follow the adage "When in doubt, Make it stout; Out of things, You know lots about". Market demands make long development cycles with "guess and test" a thing of the past. Rapid prototyping with STARS for multi-discipline optimization plays an important role as part of corporate multi-million dollar plans to meet world demands for time to market and quality. Aircraft and automotive design firms have to "design skinny" to reduce fuel consumption, increase safety, and reduce costs. Other markets include construction, process plant design, defense, energy, and medical equipment.

**The Importance of the STARNET:** Aircraft and automotive firms are integrators of mechanical sub-systems. The designers and system engineers of engines, wheels, and others work at sites across the country. STARNET connects the designers and production specialists to save time and money. STARNET lets design teams develop optimum virtual prototypes using the speed and power of the information superhighway in a business secure network (Intranet). Various discipline experts use STARNET to collaborate with designers on issues like fatigue and noise. The STARNET MDO team optimizes structures for a mix of factors such as production cost, safety, weight, reliability, noise and durability. Experts and consultants can be paid for their services. STARNET can be used by small businesses and large engineering and aerospace firms.

**Significance of STARS and STARNET to Small Business Customers:** Small businesses design most of the products made in America. Small businesses need to shorten development cycle time and improve product quality to meet market demands, with limited resources for analysis.

At commercialization, thousands of other small businesses will access STARS and STARNET on a "pay-per-view" or PPV basis. STARS tools will be available from the STARS Tool Store (STS). The STS will be operated by MSI to distribute STARS PPV tools and services via the

information superhighway. Small firms will be able to license and use low cost PC programs like FEMAP[4], ADAMS[5] and Excel[6]. PPV STARS tools will be provided by STARNET consultants or be licensed for cost-effective short-term use.

**Importance of STARS and STARNET to Large Businesses:** Large firms, like aircraft manufacturers, mass transit vehicle producers and automotive companies will purchase STARS and establish their own STARNET, connecting dispersed designers and discipline experts. These firms already have their own copies of most current design tools, and pay universities and consultants for expert design assistance. Large businesses tend to build larger products like mass transit systems, pleasure and cargo ships, buildings, bridges and tunnels, railroads, trucks, automobiles, and commercial aircraft. Each large business is concerned about product safety, manufacturing costs, support costs, and meeting OSHA and EPA requirements. STARS and STARNET have major significance to large businesses.

**The Opportunity in Certification of Commercial Aircraft:** There is well over 500 firms designing aircraft structures affected by FAA regulations. Design for FAA certification is a very difficult, costly, and time-consuming effort. Aerospace, mechanical, safety, reliability, manufacturing and customer service engineers must work together to develop a safe, affordable, certified aircraft. Several companies are involved in each project subsystem. Small aircraft manufacturers need a formal ASTROS toolset for FAA requirements-driven design. This means that compliance with the complexity of FAA regulations is left to each design engineer.

**Application and Benefits in the Aircraft Industry:** STARS and STARNET will have positive and significant benefits to the Air Force, FAA regulators, designers, small business manufacturers, and major manufacturers of aircraft and aircraft products. The FAA and the U.S. aircraft manufacturers that have seen the prototype demonstrations are excited about the benefits of collaborative MDO engineering. Talks with the USAF, aircraft manufacturers, the FAA, university professors, and aircraft equipment suppliers had a consensus that FAA-validated MDO using ASTROS offers significant improvement over current structural design practices.

Each prospect can have wide-reaching benefits that:

- Provides a methodology for meeting requirements while optimizing the design.
- Collaboration on STARNET speeds validation and certification.
- STARNET implements a networked infrastructure to support MDO design.
- Includes using ASTROS optimization with other approved tools.
- Reduces cycle time by virtual prototyping.
- Provides a decision support system to help make better decisions.
- Improves the quality of aircraft structures by using MDO processes.
- Reduces manufacturing cost by MDO with certified cost estimating tools.
- Improves the viability of the U.S. aircraft industry by improving productivity.
- Reduces maintenance and life cycle costs by cost centered analysis.

[4]FEMAP is a finite element modeling analysis program for personal computers
[5]ADAMS (Automated Dynamic Analysis of Mechanical Systems)
[6]Excel is a spreadsheet product from Microsoft Corporation, Redmond WA

**The Opportunity in Automotive Design and Manufacturing:** The opportunity for commercialization to automotive firms is far larger than to the aircraft sector. All customers demand affordable, efficient, practicable, safe and reliable products. MDO is a universal process with application in a broad range of design disciplines. Designers have to trade off issues related to safety, durability, and reliability against many other factors such as weight, cost and profit requirements. The trade-offs are a part of doing business caused by product liability laws, government regulations, and customer demands.

Just about everything in an automobile is structural, and has to be optimized for cost, reliability, weight, durability, and warranty. Large automobile design firms like Ford Motor Company use robust 3-D design tools like SDRC I-DEAS[7] (the I-DEAS program was used for 3-D design with MOCA/ASTROS).

**Government Agencies and National Laboratories:** Government engineers and scientists will access and use STARS to develop concepts for diverse projects. The government is the largest single user of structural design tools. Government agencies employ and contract for major structural designs, or approve structures for public use. The FAA provides oversight to the aircraft industry, the Department of Transportation provides oversight to the automotive industry, and NASA designs space vehicles and structures. Our Beta Sites for STARS and STARNET include the FAA, the USAF, NASA, and the Department of Energy at Sandia National Labs. Government agencies will be a major revenue source from STARS and STARNET, and for consulting services.

**The Department of Defense (DoD):** In August 1994, the Secretary of Defense issued directives that downstream support and life cycle cost must be the primary concern of all weapon system procurements. This requirement introduces new factors for planned upgrades, reduced maintenance, and increased reliability. STARS is an ideal focus for new and better optimized designs.

**Air Force Research Laboratory Collaborative Modeling and Simulation Environment**
MSI is a member of the SAIC and BALL Engineering team awarded the contract for creating the collaborative engineering environment for the Air Force Research Laboratory. The STARNET is being evaluated by the PRDA management review committee. If selected, the STARS tools will be accessed by all AF laboratories as a part of the reorganization of research.

**US Naval Air Systems Command (NAVAIR) Design Project**
The NAVAIR systems command is leveraging the networking abilities of STARNET for use by Multi Discipline Integrated Product Teams (IPT). NAVAIR IPT are truly dispersed with team members at several Navy facilities and contractor sites. By using the STARS tools on the STARNET, the NAVAIR IPT members can work in system engineering and follow through to detailed design MDO. MSI is currently adding tools for action tracking, project scheduling, asset management, spreadsheets, word processing, and security. The structural and mechanical MDO engineering tools are readily interfaced by making a link to the ASTROS STARS website.

[7]I-DEAS is a structural design program from SDRC, Columbus OH.

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