Problem Statement

STARS: Sticky Technology for Augmented Reality Systems

1. Introduction

With the increasing complexity of systems such as automobiles, trucks, airplanes, trains or power plants, access to maintenance procedures at the place of work is essential. Current maintenance procedures for these systems are costly and inefficient. Information quickly goes out-of-date and maintenance manuals are often only available as hardcopy or on workstations far away from the airplane or automobile. In addition, the maintenance information is not tailored to the actual work order, requiring the mechanic to perform unnecessary steps before viewing the information that is actually needed to perform the repair.

2. The Problem

The F/A-18 "Hornet" Program Office, PMA-265, has been asked to reduce the cost for logistics support and maintenance while improving or at least maintaining current aircraft readiness.

The cost of electronic data required for the aircraft, especially when it has already been authored in a proprietary format or is available only in paper form, is enormous. Some solutions to the problem of reducing costs are available. For example, an Automated Conversion System (ACS), when coupled to an Interactive Electronic Technical Manual (IETM) authoring tool, lowers technical manual conversion cost significantly.

This process has allowed the program office to lower by more than 33% the cost of converting its F/A-18 C&D organizational-level technical manuals to IETMs. However, the program office cannot afford to do the same for F/A-18 A&B technical manuals and related data (e.g., logbooks) because they are all paper-based documents, i.e., not available in electronic form.

Another source of high costs is the business process currently used to acquire the data for an aircraft. Today, the prime contractor (e.g., Boeing for the F/A-18) receives the technical data for the various subsystems from the Original Equipment Manufacturers (OEMs), such as General Electric for F/A-18 engines. The system prime contractor then integrates the data into the technical manuals that get delivered with the system. The

labor and overhead rates of these aerospace contractors are very high and are compounded by the charges added by the system prime to integrate, provide quality control (QC), and deliver the technical manuals.

3. Proposal

In this project we are asking you to build a system called STARS - **S**ticky **T**echnology for **A**ugmented **R**eality **S**ystems. STARS attempts to reduce the cost of logistics support and maintenance while improving or at least maintaining current aircraft readiness.

To address the problem, we propose the implementation of two major processes: developing & managing interactive electronic technical manuals and performing maintenance with advanced capability IETMs.

The process of developing&managing of IETMs itself consists of three activities: 1) authoring of IETMs, 2) release of IETMs to maintenance organizations and 3) authoring and release workflow management.

The authoring of IETMs from paper documents is to be done in two stages. The digitizing stage is to be done by Alaskan Native and American Native firms. They will use text and graphic conversion tools and apply QC techniques to produce electronic data, which is then provided to IETM authoring systems. The White House, Congress, and the Native American Marketing Corporation (NAMCOR) are backing this effort to provide meaningful employment for Alaskan Natives and American Natives without leaving their current communities.

The conversion stage, performed by F/A-18 engineers and technical manual writers at the F/A-18 Fleet Support Organization in San Diego, California. Converts the now-digitized data into IETMs. Over time, this conversion may also be done by the Alaskan Natives and American Natives.

The digitized data is then converted into IETMs using the authoring systems located at the F/A-18 Fleet Support Organization at San Diego, CA where F/A-18 engineers and technical manual writers do the work. Over time, this authoring may also be done by the Alaskan Natives and American Natives.

IETM authoring is also done by the OEMs and Boeing (for the aircraft itself) using a standard authoring system and data direct from the engineering CAD systems used in the manufacturing design process.

The output of the various IETM authoring efforts is transferred electronically to a central IETM Integration Database at the F/A-18 Fleet Support Organization for QC and integration into a release version of the IETMs. The release version is then transferred electronically to the IETM Operational Database where the new IETM versions are used to incrementally update the IETMs in use by the F/A-18 maintenance organizations. This is done by electronically updating the IETM databases in those

organizations.

This IETM release process is to be supported by a Distributed Development and Management System (DDMS) that provides support for collaboration and coordination among the various organizations, visibility into the structure and state of the IETMs under development, awareness of the process state, and validation of the IETM development tool set.

The process of performing maintenance with advanced IETM capabilities consists of two activities: 1) IETM-based inspections and 2) IETM-based repair. In the F/A-18 maintenance organizations, inspections of the aircraft are performed with check lists provided in one section of the IETM. The result of an IETM-based inspection is a listing of discrepancies that are assigned as repair tasks in work orders for technicians to correct them (Repair tasks are also created by system faults identified during flight or from periodic maintenance schedules). The technician makes an IETM-based repairs by interactively following a procedure provided in another section of the IETM.

4. Scenarios

In the following sections we describe several scenarios that the STARS System must support to deal with the above processes. These scenarios must be demonstrated at the end of this project.

4.1 Authoring of IETMS

Jim, one of the Document Specialists from the Arctic Slope Regional Corporation (ASRC) receives the task to convert the paper technical manual to digital data for the GE 404 engine used in the F/A-18 A&B aircraft. He scans the technical manual into the Automated Conversion System (ACS) to convert the text and into a companion tool to convert the graphics. Jim then checks the digitized document and corrects the errors introduced by the ACS and graphic tool. The digitized document is then transferred to Anne, a Quality Controller, who checks the digitized document and returns it Jim for more corrections. After that iteration, the document is signed out for release to the next step in the process, the addition of links and structure to the digital document using an AIMSS IETM authoring system by a Technical Manual Writer.

4.2 Process Workflow Management

Court, the Process Manager at ASRC checks the status of work in his Distributed Development and Management System (DDMS) and notes that the GE 404 engine technical manual digitized document is due out today. He checks with the Document Specialist and finds that the document will be ready in one hour. He then initiates a Video Teleconference (VTC) with Andrew, the Process Manager at the F/A-18 Fleet Support Organization at San Diego, and they coordinate transferring the engine document to the IETM Integration Database at the Fleet Support Organization.

At the Fleet Support Organization, the digitized document is transferred to the AIMSS

IETM authoring system and converted into an IETM by Sam, a Technical Manual Writer. Using the DDMS, the IETM is checked by Anne, the quality controller. An engineer from Boeing is brought into a VTC to correct a technical detail in a procedure. Finally, the new IETM is signed off, and again using the DDMS, the IETM is transferred electronically for integration into a release version of the IETMs and final QC.

The manager of the IETM Integration Database process coordinates with the IETM Operational Database manager using the DDMS and the release version is then transferred electronically to the IETM Operational Database for release to fleet maintenance organizations.

4.3 Release to maintenance organizations

The manager of the IETM Operational Database authorizes the new IETM versions to be incrementally added to the IETMs in use by the F/A-18 Maintenance Organizations. This is done by electronically updating the IETM servers in those organizations.

4.4 Inspections

Airman Smith reports to work at his Fighter Attack squadron aboard the USS Carl Vinson and logs into the maintenance computer in his Airframes shop to see what jobs have been assigned to him. He sees that his first work order is to perform a 14 day periodic corrosion inspection of an F/A-18E aircraft, bureau number 176089. According to the computer, this aircraft is parked in Hangar Bay 1. He dons his new wireless Portable Electronic Display Device (PEDD) inspection assistant and performs a quick calibration and operational checkout before heading down to the Hangar Bay to perform his corrosion inspection. Once at the aircraft, Airman Smith begins the inspection by reading IETM instructions from his Head-Mounted Display (HMD). As he looks over each part of the aircraft on the inspection list, he enters discrepancies by touching the part of the aircraft which has a problem, and then selecting the appropriate discrepancy (corrosion, crack, fluid leak, etc.) and severity (minor, major) from a short list. The system notes the location of the discrepancy on the aircraft based upon the inputs from Airman Smith's data glove. The discrepancy is then entered in the system as a virtual "sticky note" on the computer model of the aircraft. The sticky notes contains all the necessary details. Once Airman Smith has completed the inspection, he returns to his Airframes shop where he downloads the inspection results into the maintenance computer system. His discrepancies are then incorporated into work orders by Maintenance Control for dispatch to the appropriate work centers for repair.

4.5 Unscheduled Maintenance

Aviation Electronics Technician First Class (AT1) Chandler is beeped on her wireless PEDD to proceed to the Flight Deck and trouble-shoot a problem with the APG-73 radar on aircraft 301. She needs to determine if the aircraft can be made mission ready for a flight in 65 minutes. In the three minutes it takes Chandler to reach the aircraft, her her PEDD has downloaded the work order with the problem reported on the radar and the troubleshooting IETMs. As Chandler crawls under the aircraft to reach one of the

system components mounted inside the belly of the aircraft, the area becomes too tight to use her HMD, so she switches to audio control. The trouble-shooting steps are then read to AT1 Chandler through her earphones. By carrying on a dialogue with the PEDD, the trouble shooting IETM leads her to discover that the Radar CPU is malfunctioning and needs to be replaced.

She transmits this information to her supervisor requesting that the spare part be delivered to the aircraft by the other technican required to aid in the repair. Her supervisor, Senior Chief John, checks with both Material Control and Maintenance Control, who finds that an acceptable spare CPU is available and that the work can be accomplished in time for the aircraft to launch in 42 minutes. John then notifies Chandler to start removing the defective CPU and dispatches AT2 Nusebaum to obtain the replacement CPU and deliver it to the aircraft. Together, the technicans remove the defective unit and replace it with the spare. AT1 Hartley from QC verifies that the repair is correct and all involved apply electronic signatures to the work order releasing the aircraft for its next mission with 12 minutes remaining to fuel and arm. Nusebaum takes the removed component to turn in for repair while Chandler downloads all information collected about the defective CPU from her wireless PEDD to the squadron maintenance system server.

5. Preliminary Analysis

A preliminary analysis of the problem has already been performed which has resulted in a set of functional and nonfunctional requirements describing the functions to be performed by the system and constraints. Please use the scenarios and these requirements as the basis for your interviews with the client during the requirements analysis phase of STARS. We expect that the requirements will undergo several incremental and iterative changes as a result of the analysis phase.

6. Functional Requirements

The STARS System must support the following functions:
- Create and annotate IETMS
- Provide a web-based display tools for IETMs
- Interface to ACS
- Interface to AIMSS
- Provide a review and quality control process for IETM documents
- Submit IETM documents to a IETM database
- Detect changes/annotations in IETM documents and notify the author
- Create a repair work order and notify subscriber for this type of repair
- Provide synchronous and asynchronus notification for the inspection/repair scenarios
- Provide a web-based navigation through a 3-D model of the airplane
- Provide location information of the airplane (Where is the airplane and how is it oriented with respect to a 3-D coordinate system?)
- Provide location information for the mechanics performing the maintenance (where do the mechanics stand, and where do they look at?)

- Provide an inspection checklist based on an IETM document
- Create an annotation ("Virtual sticky") by pointing to a specific location at the airplane, indicating the discovered discrepancy and type of repair
- Provide audio/visual maintenance procedures as described in the work order
- Be able to locate the space stickies associated with an airplane
- Provide capabilities to perform the maintenance procedure interactively without traditional input/output means (no keyboards, no mouse....)

7. Nonfunctional Requirements

When designing STARS, the following constraints must be taken into account:
- STARS must provide concurrent access by multiple users, accessing the system locally and remotely. STARS applications run independently from each other as separate processes, while still allowing the applications to communicate with each other.
- The software architecture must be extensible to deal with the optional scenarios
- Any new code written as part of this development effort must be platform independent.
- Model-based software engineering techniques have to be used. The application domain must be modeled with UML. The system design and implementation must be derived from the UML models developed during the analysis phase.
- Every STARS user has access to a portable/ wireless computer. The user interface must take these conditions into account during the development phase.

8. Target Environment

It is expected that the development environment at Carnegie Mellon will be used for demonstrating the prototype. The exact target environment will be specified by the client during the requirements analysis phase.

9. Design Issues

A system dealing with the scenarios described in the previous sections will be complex and will require a multi-team effort. We have decomposed the system into a software architecture shown in Figure 1.

The authoring subsystem provides the capability to author and annotate IETMS which can be viewed with a web-based display tool. It interfaces to existing commercial products ACS and AIMSS that provide part of the required functionality. The work flow subsystem provides a review and quality control process for IETM documents submitted by authors. The subsystem also detect changes in IETM documents and notifies the author. The subsystem is also used to provide notification for mechanics when work orders have been created for them. The modeling subsystem allows authoring of a description of an F18 airplane with a CAD tool, providing different views, such as a wireframe view, that can be overlaid on the real airplane. The augmented reality subsystem provides location information of the airplane with respect
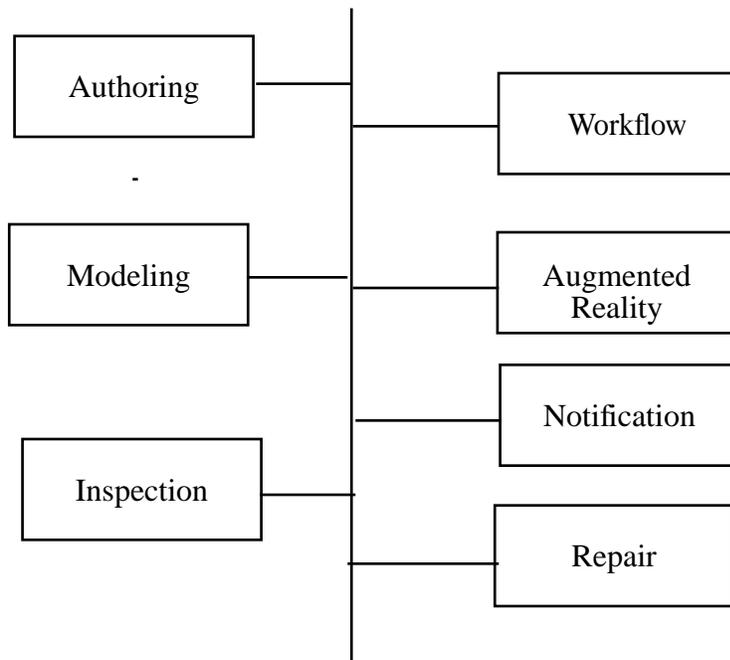
Authoring

Workflow

Modeling

Augmented
Reality

Notification

Inspection

Repair

Figure 1. Top Level System Design of STARS

to the mobile mechanic performing the maintenance. The inspection subsystem provides the capability to do an inspection based on IETM documents. The mechanic adds an annotation ("virtual sticky") to the repair location, by pointing to a specific location at the airplane, indicating any discovered discrepancy and type of repair. The repair subsystem provides the capability to perform maintenance procedures as described in a work order. It helps the user to locate the stickies associated with a specific airplane, and to perform the maintenance procedure interactively by using voice input and output.

The notification subsystem provides a publisher/subscriber mechanism , which allows creators of information to reach authors or mechanics within the organization that have expressed their interest, explicitly or implicitly, in receiving this information.

10. Development Environment

The developers of the STARS System may make use of the facilities offered in the clusters on the CMU Campus as well as the Software Engineering Laboratory located in Building D, room 154A. While the clusters are shared with other students taking other courses, the resources at the software engineering lab are to be used solely for the development of the STARS System. The Software Engineering Laboratory offers a set of 9 PCs running Windows NT and Linux as well as 6 Macintosh running MacOS 8.6. These machines are connected via a local Ethernet. The following software tools are used during development.

Lotus Notes. This is a groupware tool, designed to facilitate communication between

members of a large, geographically diverse group working on the same project. It provides persistent document storage and address book functionality. Inherent security features allow content to be provided over the Internet, with complex permission options.

Together/J.   Together/J is a CASE tool supporting the model-based development of systems written in Java. It provides capabilities for UML modeling and supports round-trip re-engineering between models and source code. It also automatically generates relevant documentation off comments in the models and source code.

JavaDoc. This tool generates API documentation from the comments of Java source code. The documentation is provided in HTML format.

CVS . CVS is a version control system. Users check out code, work on it, and check functional code back in. The system allows for multiple users to be working on the same code, and supports the merging of multiple changes by different users to the same version of code. It uses a client-server model, allowing the checkout of code from remote locations. CVS was originally linux-based, but a WWW interface (CVSWeb) is now available.

ACS. ACS (Automated Conversion System) converts legacy technical manuals into IETMs. ACS consists of a series of automated steps that minimize the human interaction necessary to convert paper-based documents into IETMs. More information on ACS can be found at http://www.lmco.com:80/lmis/level4/acs.html.

 AIMSS.   AIMSS (Advanced Integrated Maintenance Support System) is a tool for constructing and authoring IETM databases, maintaining the databases, and using the databases for the delivery of information to a user. The AIMSS authoring environment provides the tools used to create, delete, modify, and maintain all aspects of an IETM database development project. More information on AIMSS can be found at http://www.htsc.com/AIMSS/AIMSS.HTML.

11. Teams

Several teams have been defined to work on the STARS prototype. A coach has been assigned to each of these teams to guide them during the development. The initial definition of responsibilities for each team is shown below.

11.1 Authoring (Coach: Grace Ritter)
- Create and annotate IETMs
- Provide web-based display tools for IETMs
- Investigate   tools that can derive a DTD (Data technical documentation) from a UML object model and vice versa.
- Interface to ACS   and AIMSS
- Become familiar with IETM-based authoring and viewing based on SGML and XML

11.2 Workflow (Coach: Grace Ritter)
- Provide a review and quality control process for IETM documents
- Submit IETM documents to a IETM database
- Detect changes/annotations in IETM documents and notify the author
- Create a repair work order and notify subscriber for this type of repair
- Provide synchronous and asynchronus notification for the inspection/repair scenarios
- Investigate tools and products for the automatic creation of workflows such as IETMs and work orders.

11.3 Modeling Team (Coach: David Garmire)
- Create a "real airplane" (Provide a physical model of an airplane)
- Provide a UML model of an airplane
- Provide a wireframe view
- Provide a web-based navigation through a 3-D model of the airplane
- Investigate web-based CAD modeling tools

11.4 Augmented Reality (Coach: Eric Stein)
- Provide location information for the airplane (Where is the airplane and how is it oriented with respect to a 3-D coordinate system?)
- Provide location information for the mechanic performing maintenance (where do the mechanics stand, and where do they look at?)
- Provide an overlay of the wireframe view onto the "real" airplane from the position of the mechanic.
- Investigate technologies for location identification such as GPS.

11.5 Inspection Team (Coaches: Zia Syed and Tom Hawley)
- Perform an inspection based on an IETM document
- Create an annotation ("virtual sticky") by pointing to a specific location at the airplane, indicating the discovered discrepancy and type of repair
- Add this annotation to a workorder.
- Investigate multimodal input devices such as datagloves and identification devices such as component tags.

11.6 Repair Team (Coaches: Pooja Saksena, Tom Hawley)
- Perform maintenance procedures described in a work order
- Locate the virtual stickies associated with an airplane
- Provide capabilities to perform the maintenance procedure interactively without traditional input/output means (no keyboards, no mouse....)
- Investigate speech synthesis/recognition technologies for the interactive performance of repairs at the repair site.

11.7 Architecture (Coach: Bernd Bruegge, Bill Scherlis)
- Model the STARS System as a set of services provided by each of the subsystem.
- Evaluate existing event services and recommend one to be used for the notification

subsystem.
- Develop notification subsystem
- Define a configuration management scheme to be used with CVS during the project.
- Design a plan for integration testing and system testing of STARS.
- Integrate the documentation produced by the team.
- Publish all deliverables on the project portal so they can be viewed online by the client.
- Copy all documents and the STARS prototype onto a CD-ROM, to be delivered to the client during the client acceptance test.

12. People Contacts

The clients for the project are Lt. Matt Herl from the F-18 program office, Mark Kramer and Raymond LeBeau from the Navy Carderock Lab. The client liaison is Tom Hawley from Carnegie Mellon University. Consultants for some of the problems associated with the subsystems and development tools are also available. The consultants are:
- XML/SGML: Stephan Schoenig , schoenig@cs.cmu.edu
- CSCW: Jane Siegel, jals@cs.cmu.edu
- User Interface: Elaine Hyder, ehyder+@cs.cmu.edu; Jack Moffet jmoffet+@cs.cmu.edu
- Speech recognition: Alex Waibel (ahw@cs.cmu.edu)
- Together-J: David Garmire, garmire+@andrew.cmu.edu
- CVS: Eric Stein, essf+@andrew.cmu.edu
- Lotus Notes: Joyce Johnstone, jdarej@cs.cmu.edu

13. Client Acceptance Test

This is a broad problem statement, and as such, all the functionality that has been alluded to is not expected to be delivered in one semester. The client is willing to discuss any of the requirements specified in this document. During the requirements analysis phase of the project, the functional and nonfunctional requirements of an acceptable prototype will be established. An initial prototype of the STARS system is expected six weeks after the functional requirements have been established. The delivery of the second prototype of the STARS system is expected at the end of the semester.

14. Deliverables

The client expects a successful demonstration of the STARS prototype on December 9, 1999 in the Software Engineering Lab at CMU with remote observers around the world viewing the demonstration in real time over the Internet.

A set of documents on a CD-ROM describing the requirements analysis (RAD), the system design (SDD), object design (ODD), testing procedures (TM) and a user manual of the STARS system will accompany the demonstration.