

Online Job Assistance for Procedural Tasks in Mission Operations

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Military and commercial sectors are increasing their use of low earth orbit satellite constellations. However, low orbit constellations significantly increase the burden for ground-based system management because more satellites must be managed, and each satellite is in view for only brief periods of time. Therefore, ground station and satellite operators must be well-trained and supported by job-aids to exploit every contact opportunity. Stottler Henke is addressing this need through development of the TaskGuide™ online job-aid system. The TaskGuide software suite enables organizations to rapidly develop intelligent, electronic job aids that help users carry out complex procedural tasks quickly and accurately. A procedural task is one that can be carried out by following a procedure comprised of step-by-step instructions. For example, TaskGuide can help satellite operators execute command plans to prepare for and conduct satellite contacts. TaskGuide is designed to facilitate rapid development of job-aids by non-programmers, and to enable the gradual introduction of increased automation. Rapid development is achieved by employing easily manipulated task representations and by providing a graphical user interface to edit this representation that facilitates development by operations experts with little outside support. The capability for sophisticated decision aiding and automation is enabled by the ability to incorporate externally-defined Java classes.

I. Introduction

INCREASINGLY, military and commercial satellite systems are employing constellations of satellites in low earth orbit (LEO) for communications and remote sensing. Satellite system management is complicated by the large number of satellites to be managed and the brief time windows when each satellite is visible to ground communication sites during which communication can take place. It is essential that ground systems and personnel are fully prepared to make the best use of every opportunity to communicate with each satellite each time it comes into view. This can be achieved through online job aids that help ensure correct execution of complex procedures, extensive training that exposes trainees to a wide range of situations and provides instructional feedback, and task automation.

This paper describes a suite of software tools designed to enable organizations to provide effective, low-cost online job aids for procedural tasks. The system, called TaskGuide™, directly addresses the need for both online job aids and task automation, and provides a path for gradually shifting from completely manual operation to increased use of automation. It also addresses the need for extensive training by interfacing with two other systems developed at Stottler Henke: a system for rapid development of software simulations to support simulation-based training, called TaskSim, and an intelligent tutoring system for scenario-based tutoring called Task Tutor Toolkit™. These two systems were reported on in an earlier paper¹.

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II. Online Job Aiding for Procedural Tasks

Currently, document-based procedures or command plans guide satellite and ground station operators through the execution of satellite contacts. The main advantage of this approach is that the documents can be produced by non-programmers using familiar word processing software. A limitation of this approach is that the documents can only provide advice to the operator. The operator is responsible for operating the mission operations software, by navigating its screens, requesting and interpreting information, constructing and issuing commands; and determining the appropriate next step in the document to execute.

Electronic job-aids have the potential for reducing operator errors and increasing execution speed. Three levels of automation are possible. In manual execution mode, the job-aid reduces operator workload by determining the appropriate step to carry out and by presenting instructions for the current step to the operator. Dynamically-generated instructions can further reduce operator workload by presenting succinct instructions that are specific to the current situation, in contrast with canned-instructions that must cover all possible situations. The operator executes the action and then indicates to the job-aid when execution has completed.

The second mode is manual review and override. In this mode, the job-aid describes to the operator the action it is prepared to perform, and the operator can accept or modify the action before it is executed. The third mode is automatic. In this mode the job-aid automatically performs the action required by the step without interaction with the operator. Automated actions can include simple calculations based on data recorded by the operator or retrieved automatically from other components of the mission operations software, automated decision support (such as resource replanning to contend with contingencies), and automated operation of the mission operations software.

The level of automation that is appropriate for a particular operation depends on several factors. First, automation of an operation requires that a reliable algorithm can be designed that correctly retrieves and interprets relevant information, makes decisions based on that information, and executes those decisions in all situations. Automation is inappropriate if the job-aiding system cannot access some of the relevant data. For example, accessing some of the relevant information might require verbal communications. Or, some data that is ordinarily accessible to a person via user interface might not be available via inter-systems communication. For some operations, even if an algorithm can perform well in nominal cases, human judgment and experience may be required to perform the operation correctly in exceptional cases, so reliable automation might not be possible in all situations. For these reasons, it may be desirable to automate some operations in a procedure and rely on manual execution or manual review/override for others. In addition, over time, it may be possible to automate more and more of the operations within a procedure as reliable automation algorithms are developed and become trusted. Thus, is it highly desirable that any electronic job aid system for satellite operations be able to incorporate various levels of automation in the same procedure and enable automation to be introduced gradually into a procedure to provide complete control over the degree of automation.

III. TaskGuide Intelligent Job Aid

We designed a cost-effective high-quality automated on-line job-aid for procedural tasks, called TaskGuide™. By *procedural tasks*, we mean any process to be carried out (or supervised) by a person, where that process calls for a reasonably well-specified sequence of operations. The task may be highly context-dependent, and require iteration actions. The TaskGuide software suite enables organizations to rapidly develop intelligent electronic job aids that help users carry out complex procedural tasks quickly and accurately.

TaskGuide guides users by:

- 1) Presenting each step's instructions using formatted text, graphics, input controls, and other media
- 2) Presenting a graphical summary of the procedure's steps and their organization to help users and authors to quickly understand the procedure as a whole and to maintain context
- 3) Making additional information easily available on demand to augment each step's instructions.
- 4) Executing branching and looping logic to determine the appropriate next step
- 5) Accepting and storing data, decisions, and other information entered by the user, and
- 6) Automatically computing data values, recommending actions, and generating and sending commands based on information entered by the user or received from external systems and databases.

TaskGuide presents instructions for each step of a complex procedure using HyperText Markup Language (HTML) text, graphics, input controls and hyperlinks. The HTML language and renderer are extended to enable the inclusion of arbitrary interactive graphical user interface components defined by imported Java classes. Input controls prompt the operator for data, decisions, and requests. TaskGuide also presents a graphical summary of the procedure's steps and their hierarchical organization to help users and authors quickly understand the procedure as a whole and maintain context. Hyperlinks make additional information easily available on demand to augment each

step's instructions. At each step, TaskGuide can automatically compute and interpret data, recommend actions, and generate and send commands based on information entered by the user or received from external systems and databases. The expression language for calculations can be extended by importing Java classes, enabling complex decision support and interoperability with other software components. At the end of each step, TaskGuide determines the appropriate next step according to the procedure's branching and looping logic.

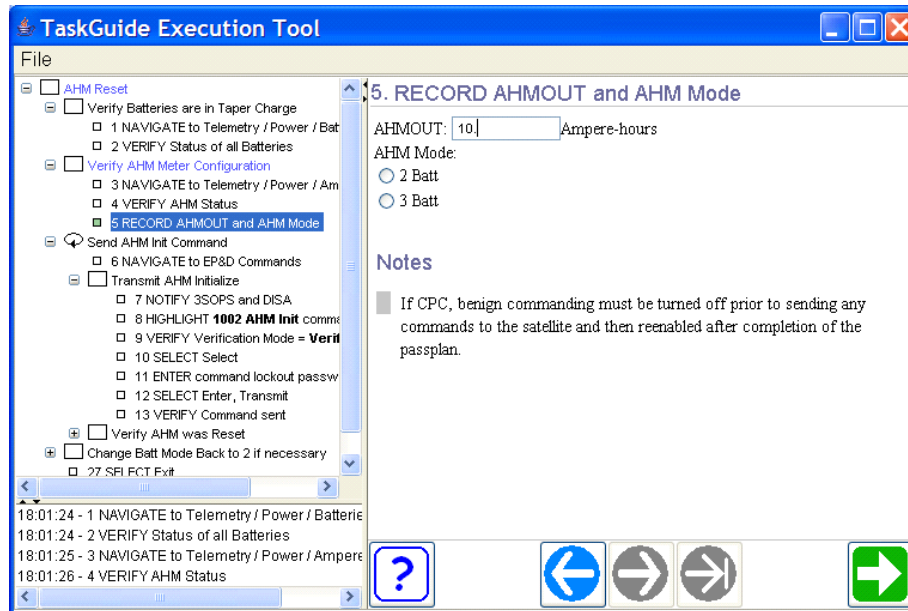


Figure 1. User interface for the procedure execution tool shows formatted instructions for the current step, hierarchical summary of the entire procedure, and time-stamped list of steps that have been executed.

A. TaskGuide Procedure Execution Tool

The TaskGuide Procedure Execution Tool is used to execute procedures. The user interface displays up to three panes. The primary pane, called the “Node Details Pane,” can either display the instructions for the current step (or a step selected by the user browsing through the procedure), or it can display a tabular layout of the instructions for all the steps in the procedure that the user can scroll through. In any case, the user presses one button to indicate that execution of the current step has completed. TaskGuide then determines and displays or highlights the instructions for the next step to be executed. This can be the next step in a sequence, or another step determined by the looping and branching logic of the procedure.

There are two other panes which are optionally displayed at the discretion of either the user or the procedure author. The Procedure Summary pane displays the entire procedure as a hierarchical structure in which simple steps are nested into groups. Different group types signify looping and branching behavior. Branching groups contain steps that are executed only if a test condition is true, and loop groups are executed repeatedly while a test condition is true. A tree control is used so that the user can display or hide the details of the procedure, and easily navigate to any part of the procedure.

Table 1. Icons for Each Type of Step and Group Node in the Procedure Summary Pane

	Interactive	Automated		
Simple Step			Simple Group	
Exit Step			Branching Group	
			Loop Group	

The Execution Log pane displays a list of the steps that have been executed, with timestamps. Selecting an element of the list displays the details of the step in the Node Details pane, showing any inputs that the user entered.

Each simple step in a TaskGuide procedure presents instructions or other information and optionally prompts the user for input with input controls such as text fields, check boxes, radio buttons and selection lists. The instructions are formatted using the standard HyperText Markup Language (HTML). Behind the scenes, TaskGuide steps can incorporate calculations that evaluate expressions containing constants, variables and function calls, and save the results to variables. These variable values can be used within calculations in downstream steps to send/receive data to/from other systems and databases, analyze and interpret this data, recommend actions to be taken by the user, or select and execute actions automatically. Pre-calculations execute at the beginning of each step, before instructions are presented to the user. This is useful for retrieving and computing data or text strings so they can be embedded within dynamically-generated instructions. Post-calculations execute at the end of the step, after the user has followed the step's instructions, entered data, and indicated completion. This is useful for interpreting, processing, saving, or acting upon the user's inputs.

TaskGuide's extensible architecture enables integration with general purpose and application-specific software libraries that provide functions that are invoked by calculations. This architecture enables TaskGuide procedure specifications to incorporate arbitrarily complex automated data retrieval, interpretation, reasoning and decision-making algorithms.

TaskGuide supports incremental automation. Each step in a TaskGuide procedure can be interactive, meaning the user must indicate execution of the step, or automatic, meaning that the TaskGuide system will execute the step (using its ability to perform calculations) without user intervention. The procedure author can incrementally convert any part of a procedure from interactive to automatic, including an intermediate stage in which the user can accept or modify conclusions made automatically and displayed as default values for input controls.

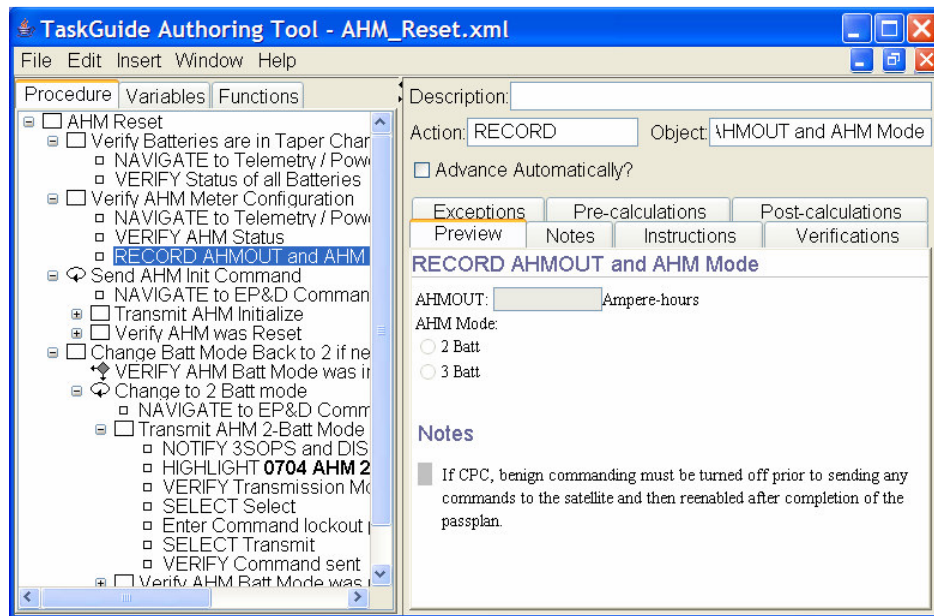


Figure 2. TaskGuide Procedure Editor provides editable display of the procedure specification that mimics the layout of the procedure execution tool.

B. TaskGuide Procedure Editor

A TaskGuide procedure specification encodes step-by-step instructions and execution logic as a list of steps, organized within a hierarchy. Each step presents instructions to the user using formatted text and graphics specified using the HyperText Markup Language (HTML). Instructions can contain hyperlinks to web pages that present additional information on demand in a web browser using text, graphics, and other media.

The TaskGuide Procedure Editor enables procedure authors to create procedure specifications that are executed by the TaskGuide Procedure Execution Tool. The left pane contains tabbed windows that display the procedure's steps and groups, along with the variables and functions that can be used within the procedure. The right pane enables authors to edit the step or group that has been selected in the left pane.

Each step's instructions and verifications can either be static (canned) or it can be generated dynamically. A procedure specification can contain a mix of static and dynamically-generated instructions. In general, however,

most instructions in a procedure specification are static. Static instructions present the same information each time the procedure specification is executed. Procedure specification authors specify the content and format of static instructions as text and HTML tags. The authoring tool provides wizards that help authors create lists, tables, text fields, input controls, and other types of HTML tags.

The author can specify dynamically-generated instructions by embedding expressions within the instruction's HTML text. During execution, TaskGuide generates the instruction by evaluating each embedded expression and replacing the expression with its value. Expressions often contain references to variables whose values can be entered by the user, received from external systems and databases during procedure execution, or computed from mathematical, Boolean, or string expressions that refer to other variables. Compared to static instructions, dynamically-generated instructions can filter information to present instructions that are more succinct and targeted to the situation. They can also compute default values for input parameters or generate recommended actions.

The functions provided for use in calculations include a general mechanism for performing arbitrarily complex validation of user inputs. These functions provide feedback and prevent completion of a step if a validation function fails.

IV. Additional Applications

TaskGuide is being developed for the Air Force to support operators making satellite contacts. However, it has broader application for the rapid development of online job-aiding and decision support tools for other areas requiring operators to perform procedural tasks. For example, TaskGuide can provide online assistance to maintenance technicians to diagnose and repair equipment, and it can help people operate equipment, use software applications, or follow organizational procedures. We have already made a preliminary demonstration of TaskGuide's utility for providing online assistance during helicopter maintenance.

TaskGuide can report the execution of each step in a procedure to a *listener* application. This enables TaskGuide to interface with an intelligent tutoring system that wants to track every action taken by a trainee during simulation-based training. This facility could also be used to support recording operator actions in a persistent store for after action review.

TaskGuide's ability to accept inputs from the user, generate instructions dynamically, and perform branching and looping enables it to be used for training in another manner. Rather than providing online job assistance, these capabilities can be used to provide interactive tutoring dialog during training. We have had preliminary investigations of this capability for training astronauts to use a systems approach to deal with problems in life support systems and in managing autonomous robots.

V. Related Work

TaskGuide's intended function is similar that provided by OPIS². However, TaskGuide's hierarchical presentation of procedures and graphical authoring system facilitates authoring and management of procedures by non-programmers. Taskguide provides graphical editing of flow of control logic, similar to that afforded by flow-chart presentations³, without the inconvenience of requiring two-dimensional layout of flow-charts. It also facilitates browsing of deeply nested hierarchies of steps. TaskGuide can provide the checklist functionality of an Interactive Electronic Technical Manual (IETM)⁴. However, its ability to perform calculations and to handle complex branching logic goes beyond the IETM checklist, and TaskGuide's ability to include hyperlinks to other media enable it to link with other HTML-Based IETM systems. Busa⁵ discusses an approach to automating procedures on the International Space Station. TaskGuide provides seamless integration of manual and automated procedures, and enables a gradual shift toward increased automation.

VI. Conclusion

TaskGuide is a cost-effective high-quality automated online job aid for procedural tasks. It is designed to employ easily understood task representations and to provide sophisticated editing assistance so that the tool can be easily maintained onsite by Air Force personnel with little or no background in artificial intelligence or computer science and little or no outside support. It affords complete control over formatting of step instructions using a standard markup protocol, its capabilities can be extended by importing externally defined class libraries, and it provides a path for the gradual introduction of automation that includes the ability to mix manual and automated modes of operation in a single procedure.

Acknowledgments

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References

- ¹Mohammed, J.L., Ong, J.C., Li, J. and Sorensen, H.B., "Rapid Development of Scenario-Based Simulations and Tutoring Systems," *AIAA Modeling and Simulation Technologies Conference*, AIAA, Washington, DC, 2005.
- ²Illmer, N., Mies, L., Schön, A. and Jain, A., "Development and Use of an Operational Procedure Information System (OPIS) for Future Space Missions," *SpaceOps 94 Conference Proceedings*.
- ³Abendroth T.W. and Greenes R.A., "A clinical algorithm processor: Enabling flowcharts to organize a variety of physician tasks." *Thirteenth Annual Symposium on Computer Applications in Medical Care (SCAMC)*, IEEE Computer Society Press, Los Alamitos, CA, 1989; pp983-984.
- ⁴*Interactive Electronic Training Manual (IETM) Guide – First Edition*, Defense Systems Management College Press, Ft. Belvoir, VA 1999.
- ⁵Busa, J., Braunstein, E., Brunet, R., Grace, R., Vu, T. and Brown, R., "Timeliner: Automating Procedures on the ISS," *SpaceOps*, 2002.