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An Event Logging, Analysis, and Reporting System (ELARS) as a Knowledge Management Technology

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ABSTRACT

The Space-Based Infrared Systems (SBIRS) program represents a "system of systems," that is a critical part in the United States Intelligence, Surveillance, and Reconnaissance (ISR) capability. SBIRS is managed by a large multi-dimensional team. In addition to their other duties, the team is faced with a daunting logging challenge. The extensive required logging places significant demands on the SBIRS team and can at times siphon resources from the task at hand. Moreover, once logged, events are essentially "locked" into the logbooks. Extracting data from the books is an arduous and seldom performed process. The result is that valuable knowledge remains inert. Here, we describe the Event Logging, Analysis, and Reporting System (ELARS) as an enabling technology for knowledge management. ELARS simplifies the process of entering log data and producing a range of associated knowledge products that support state and trend analysis across varied timescales to improve operational efficiency. In doing so, it activates the previously inert knowledge.

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14. ABSTRACT
The Space-Based Infrared Systems (SBIRS) program represents a ?system of systems,? that is a critical part in the United States Intelligence, Surveillance, and Reconnaissance (ISR) capability. SBIRS is managed by a large multi-dimensional team. In addition to their other duties, the team is faced with a daunting logging challenge. The extensive required logging places significant demands on the SBIRS team and can at times siphon resources from the task at hand. Moreover, once logged, events are essentially ?locked? into the logbooks. Extracting data from the books is an arduous and seldom performed process. The result is that valuable knowledge remains inert. Here, we describe the Event Logging, Analysis, and Reporting System (ELARS) as an enabling technology for knowledge management. ELARS simplifies the process of entering log data and producing a range of associated knowledge products that support state and trend analysis across varied timescales to improve operational efficiency. In doing so, it activates the previously inert knowledge.

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Introduction

The Space-Based Infrared Systems (SBIRS) program represents a "system of systems," combining the power of geosynchronous orbit (GEO), highly elliptical orbit (HEO), and low earth orbit (LEO) satellites with a state-of-the-art ground station to provide near real-time strategic and tactical data to national and regional command authorities.

SBIRS is planned for incremental development. During the first increment, the SBIRS ground station functionality was stood up and is replacing the ground station portions of the *Defense Support Program* (DSP) and *Attack Launch and Early Reporting to Theater* (ALERT) early warning systems. During the second increment, HEO and GEO satellites will join the constellation (in 2002 and 2004, respectively). The sensor package aboard these satellites will have both better sensitivity and flexibility. During the third increment, still in competitive procurement, LEO satellites will be added to the mix. These satellites will track long-range tactical and strategic missiles and represent a cornerstone technology for the National Missile Defense Program. The LEO satellites have the potential to provide a wealth of tactical data, culminating in advanced battlespace characterization (BSC) and the "sensor-to-shooter" concept.

All of these diverse vehicles and payloads will be managed at the SBIRS Mission Control Station (MCS) at Buckley AFB, Colorado. SBIRS operations will be guided in the Space Operations Center (SOC) within the MCS. Sonalysts, Inc. and the United States Air Force Research Laboratory have partnered to conduct research to determine how the efficiency of the SOC could be improved. These discussions quickly lead us to realize that an automated logging backbone could be leveraged to support many of the other need areas (see Figure 1).

Logging provides a rich data set on which to build an array of performance support processes. For example, certain events, when logged, might signal increased or decreased system capability. An appropriately structured logging system could recognize this change and alert mission operators within the SOC, improving crew coordination. Similarly, cues/alerts generated by the logging system could represent a significant performance-monitoring tool. Clearly, collecting log data in an organized and searchable manner makes it possible to generate a range of periodic and episodic reports. Closely related to this is the ability to look for, spot, and report trends that appear across log entries. Although not immediately obvious, a centralized logging system could be leveraged to provide important training data. For example, if an operator has not experienced a certain type of event for a long period of time (as indicated by a lack of log entries for that event type), it might be useful to arrange refresher training on that event. Similarly, if the logs indicate that the mean time to respond to a given event is X, and we note that a given operator consistently takes 2X to respond to that type of event, we can assume that training on that class of event may be beneficial.

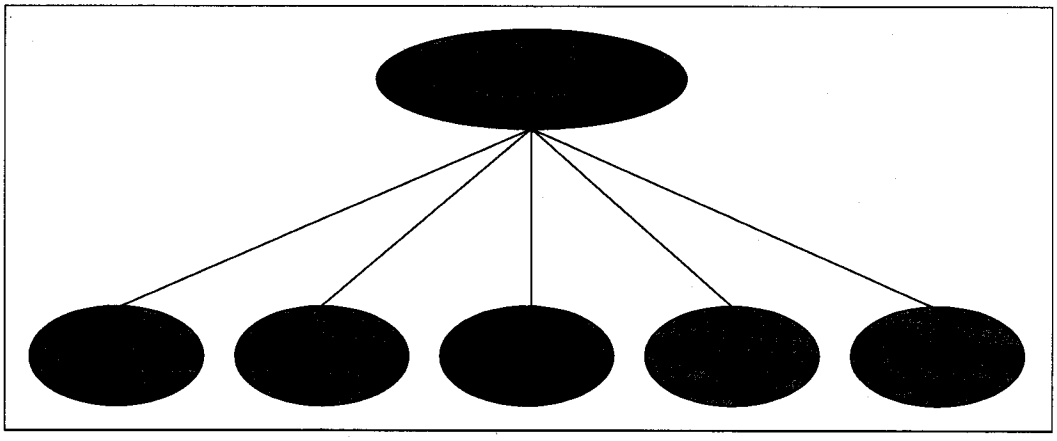

Figure 1. Logging as an Enabling Technology

An Event Logging System

Today, all SBIRS activities are manually logged in green logbooks maintained by the SBIRS staff. The logbooks include documentation for all aspects of the SBIRS mission. The crew commander must log all mission events, tasking requirements, crew changeovers, operational capabilities (OPSCAP) changes, and the activation of emergency procedures/checklists.

Satellite and ground station personnel must log information about satellite communications, commands sent to the satellite, the outcome of the commands, satellite or ground station anomalies and their resolution.

The intelligence team maintains a log that provides the intelligence overview. They will log events such as changes to the posted pending launch list, tip-off information, period of interest start and stop times as well as location and current intelligence indicators, tactical flight operations start and stop times and any significant intelligence activity occurring in that period, requests for information either initiated or resolved, any other intelligence data that complements the team's situation awareness.

This logging places significant demands on the SBIRS team and can at times siphon resources from the task at hand. Moreover, once logged, events are essentially "locked" into the logbooks. Extracting data from the books is an arduous and seldom performed process. Instead of using the data to improve operations, it is logged and forgotten.

The focus of Sonalysts, Inc. and the Air Force Research Laboratory has been to make the knowledge contained in logs available for more widespread use. Many of the enabling capabilities can be encompassed within a robust Event Logging, Analysis, and Reporting System (ELARS). ELARS will support the SOC staff by aiding the completion and processing of automatically generated event entries; the creation and processing of manual event entries; the generation of *ad-hoc* and standard reports; and through intra-SOC notification of significant events. ELARS will also provide support to groups external to the SOC. Reports and status information based on events can be produced on a periodic and episodic basis.

A gross system schematic is shown in Figure 2. Here we posit that each station in the SOC is equipped with the ability to log events. The log entry, properly tagged, is transferred to some storage area for archiving. Various processes or "business rules" operate on this master log to provide different products to different users in different time frames.

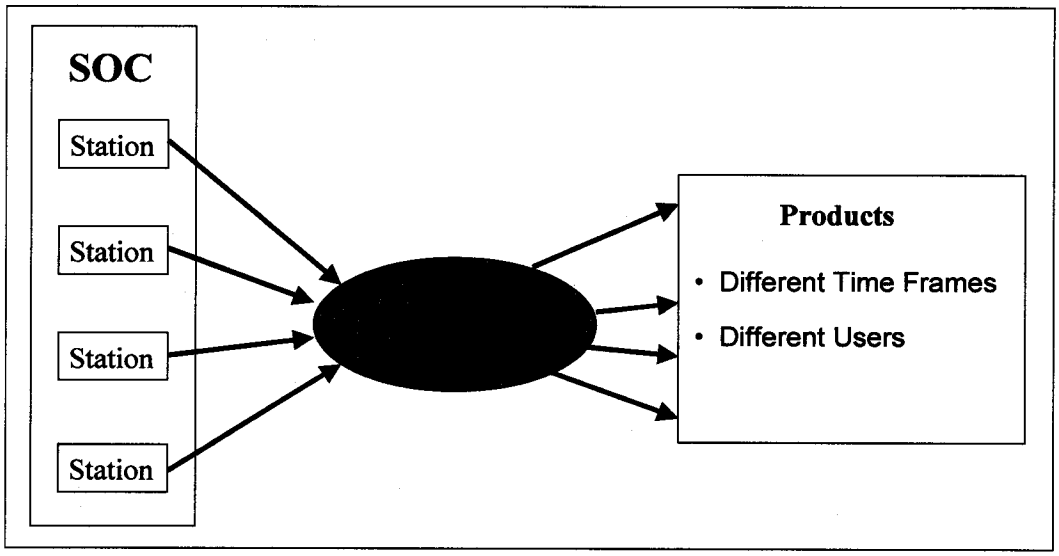

Figure 2. ELARS System Overview

Within this scheme, it is important to account for:

- Data Collection,

- Data Storage,
- Processing, and
- Products.

Supporting data collection over the wide range of required log entries is obviously central to the logging process and represents the most significant technical challenge. A temptation might be to simply re-host the current logging strategy in an electronic format. However, there is ample evidence that simply re-hosting a pencil-and-paper process often *reduces* efficiency (see, for example, Landauer, 1997). Instead, to *gain* efficiencies, the task itself must be fundamentally changed to leverage the capabilities inherent in the electronic medium.

Just as the system can automatically detect some events (launches, system anomalies, *etc.*), it should be able to initiate logging activities. This would represent a significant workload reduction by automatically collecting the subset of the required information derivable from the system itself. Similarly, just as the operator may detect events missed by the automation, he/she should be able to initiate logging independently. Even manually initiated log entries will benefit from the automatic inclusion of identification and time-stamp information.

The monitoring and logging ELARS components can be combined into a powerful Log Entry Notification Sub-system (LENS). The LENS would be responsible for identifying the outstanding "loggable" events/activities for each station, allowing station operators to initiate independent log entries, and providing an interface for completing and managing log entries initiated by the system or the operator.

A notional user interface for the logging portion of LENS is shown in Figure 3. The interface comprises four functional areas. In the upper-lefthand corner of the display is a list of events/activities that the monitoring portion of the LENS has detected for this station and that await operator logging. In the lower-lefthand corner, the list of log entries that can be manually initiated at this station are presented. Clicking on an item contained in either list would launch a form tailored to that type of entry. On the righthand side of the screen, identifying information for the operator at this station and at other positions in the SOC is presented.

Much of the data required by the logs is known to the system; therefore, it should be possible to use this system knowledge to partially complete the log entry form presented by the LENS. Where data is unknown to the system or otherwise unavailable, the LENS will provide the operator with a structured process for providing it. In addition, ELARS will include entirely novel sources of data. For example, summarized log entries from subordinates

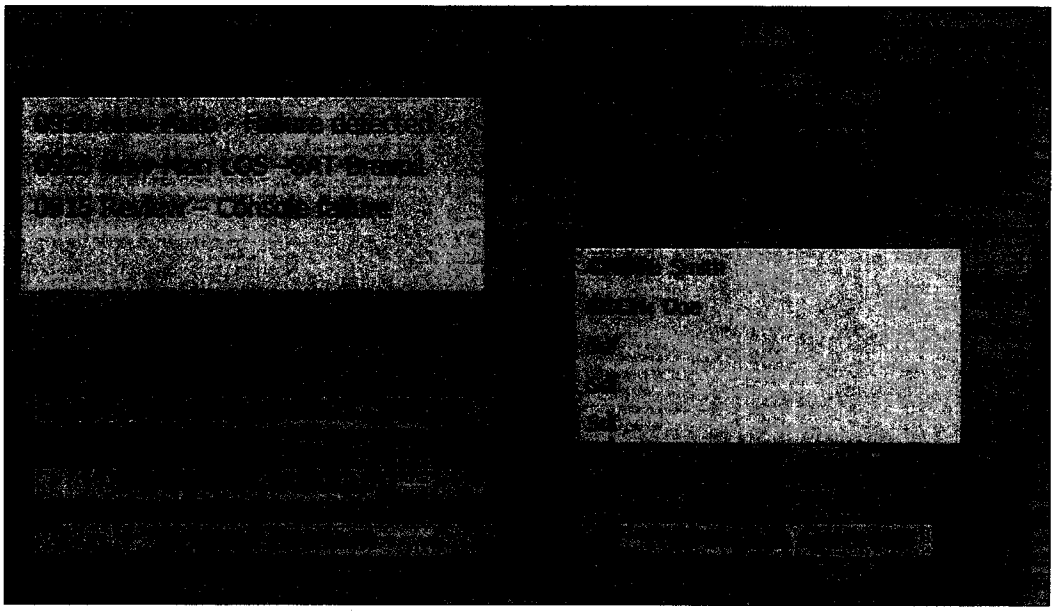

Figure 3. Notional User Interface

might be included in a supervisor's log entry. At the same time, the supervisor might simply augment or annotate an existing log entry, including its contents by reference, not by repetition.

The logging component of the LENS also supports event routing and event modification. Routing paths can be specified by event type. When an individual completes an event log entry that is to be routed, the completed event is recorded and routed as necessary for review or augmentation. The stations to which they are routed must, at a minimum, acknowledge all routed log entries.

Although not necessarily a technical challenge, it is important for ELARS to have a solid repository for the storage of log data. Without a solid repository for the central log, the processes will not able to produce the needed products. The architecture of the central log must be support large-scale, highly reliable storage. At the same time, it must support both real-time access to some data (for cueing/alerting, *etc.*) and data warehousing (for longer term processes/reports).

Log storage and management is the function of the Automatic Repository Management System (ARMS). The ARMS includes both the repository itself as well as the associated management functions.

The repository portion of ARMS represents the actual storage mechanism for the output of the LENS. The management portion of ARMS is responsible for maintaining the integrity of the repository. All event-related storage and retrieval operations are performed through this component, which represents a central point of access control and an independent transaction logging capability for events.

Various tailored businesses processes work on the stored data to produce the required products. Some of these processes, like those to support cueing and alerting must function in real time. Others, for example those that generate internal and external reports, can function at other than real time. Similarly, the analyses can capture the *state* of operations, personnel, or the system or *trends* within these functional areas.

Within ELARS, data processing will become a largely automated function. In general, ELARS will produce draft reports that can be reviewed and modified as required by SOC personnel.

The most compelling feature of the centralized log is the vast array of data products that can be generated from it. Sonalysts envisions a system that is capable of producing data products periodically or on an episodic basis. These products can be made available to other members of the SOC, as well as outside agencies.

By considering these temporal and population dimensions, one can quickly begin to generate a series of useful products. For example, consider the list offered in Table 1. Sample data products that would be used within the SOC and would be classified as "quick reaction" include alerting/cueing notices that would relay news of an event to interested/impacted parties. The central log would also allow drill-down reviewing of logs. As higher authorities review events, they often are required to annotate earlier logs of the event (*e.g.*, validate that the proper procedures were applied or that a piece of faulted equipment is now functioning). With the central log, this can be accomplished by annotating the log entry directly, providing those higher in the chain of command with the ability to review the summarized annotation and, optionally, drill down to the source log entry details.

Remaining within the SOC, but stretching the timescale slightly, allows us to consider periodic reports like changeover briefs and morning standup reports. In addition, we can consider novel reports such as a training analysis or proficiency report. The training analysis would identify events that are missing from or infrequently recorded in the log and suggest the need for refresher training on these events. The proficiency report would note the observed performance for each operator on a series of critical events and compare the observed performance with cross-operator averages.

These same reports might be of interest to those outside the SOC. In addition, the Site Report is a common report that would be greatly facilitated by a central log.

Table 1. Sample Knowledge Products

		Population	
		Inside SOC	**Outside SOC**
Time Frame	**Quick Reaction**	Alerting/Cueing Notices Drill-down Reports	
	Short Term	Changeover Brief Morning Standup Training Analysis Proficiency Report	Site Report Training Analysis Proficiency Report
	Long Term		MTBF Report MTTR Report Checklist Tailoring Event Reconstruction Statistical Mining Custom Reports

We can also consider longer-term reports that might be of particular interest outside the SOC. Obvious examples from systems logs include items such as mean time between failure (MTBF) and mean time to repair (MTTR). Less obvious might be opportunities to tailor checklists as a result of log analysis. Consider troubleshooting checklists. Normally, these checklists manifest some form of a split-half analysis methodology. However, the data within the logs may point to more common causes of failure. Knowledge of these common causes can be used to modify the checklist to direct attention to the most likely failure sources, thereby reducing MTTR and increasing system availability. From time to time, it may be necessary to reconstruct an anomalous event (*e.g.*, the loss of a satellite). The centralized log would greatly facilitate this process. It would also make it easier to mine the data contained in logs to spot statistical trends or to generate custom reports.

As these sample products indicate, a centralized repository will increase operational efficiency by streamlining the production of currently required reports while making it possible to generate a wide range of "value-added" reports.

The ability to produce data products rests on the Query and Report Functions. The Query Component provides the capability to perform interactive queries of the event repository. The information is formatted as appropriate for the query and is displayed or printed as desired by the user.

The Report Component provides the capability to define and produce formatted reports. These reports can be scheduled for automatic generation and distribution or used on an as-needed basis. These are web-based interfaces to permit intranet access, as desired. This also minimizes impact on SOC computing resources by restricting significant database related processing to non-SOC station resources.

Summary

The ELARS represents a knowledge management enabling technology. By increasing the ease with which operators can

record and subsequently access knowledge contained within logs, the ELARS takes the inert knowledge and makes it active. The active knowledge can improve the efficiency of SOC coordination, report generation, training, and maintenance.

About the Authors

Mr. John J. Morris has a Bachelor's Degree from the University of Michigan, a Master of Business Administration Degree from the University of Rhode Island, and more than 26 years of active and reserve Naval service in Surface Warfare and Intelligence, respectively. He has 23 years with Sonalysts in military operations research, training, and advanced training technology development. He leads Sonalysts efforts in advanced training technology transfer and also is program manager for several Army, Navy, and Air Force research and training programs.

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