Part 1 – The Search Intelligence Process Using Artificial Intelligence

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Abstract

Intelligence is a process by which certain types of information/data are aquired or requested by those directing a missing person incident. The process continues by rallying teams of resources to collect, process and exploit, analyze and produce useful information that can then be disseminated and integrated into actionable plans.

Traditionally the collection, processing, exploitation, analysis, and production has been done by hand on paper and sorted by experienced search leaders and training of the human brain. However, what if this work could be done by computers and artificial intelligence? This is the hypothesis we are exploring through a privately funded university effort. The "Artificial Intelligence for Search and Rescue" is a project with goals to use AI and related computational methods and tools to support Search and Rescue (SAR) missions. This project is a collaboration with California Polytechnic State University (Cal Poly) Computer Science and Software Engineer Department Dr. Franz Kurfess, undergraduate and graduate students in alliance with alumnus Gary Bloom and Christopher Young both experienced search and rescue incident managers. The project began in the summer of 2021 through privately funded research, senior projects, and class projects.

This paper is Part 1 and will describe the initial work included the collecting and consolidating the pertinent mechanisms for storing and processing data and the research of the potential artificial intelligence options. Part 2 will describe the final product after lab/field testing and refinements.

KEY WORDS: *Intelligence Gathering, Missing Person, Interviewing.*

Introduction

The Search for Missing Persons:

When someone is reported missing, generally to a law enforcement agency, a set of tactics and processes begin to locate the subject. With the receipt of the first call and response to a missing person incident, details start to emerge about the missing subject. Initial information is vague and unclear but as more investigational intelligence becomes available a clearer picture becomes apparent which allows searchers and search managers to accomplish their respective duties to find the subject. However, there is still the need to look closer at the subject's attributes for more detail and nuances that make up the sum of their experiences and connections to others that make them who they are. Further, there is more data and information developed from the active search effort. The processing of all this data has traditional been done by hand and on paper that eventually gets analyzed and processed by a human brain into something actionable.

What is Intelligence:

This paper is a natural follow up to the 2018 Syrotuck Symposium presentation and subsequent journal article "The Search Intelligent Process" by Young (2018). This was followed up by the publication of Young's (2022) book *Intelligent Search – Managing the Intelligence Process in the Search for Missing Persons.* In these documents intelligence is described as a process and can be thought of as the means by which certain types of information are acquired or requested, collected, analyzed and disseminated, and as the way in which certain types of actions are conceived, conducted and/or executed.

Graphically the process looks like Figure 1:

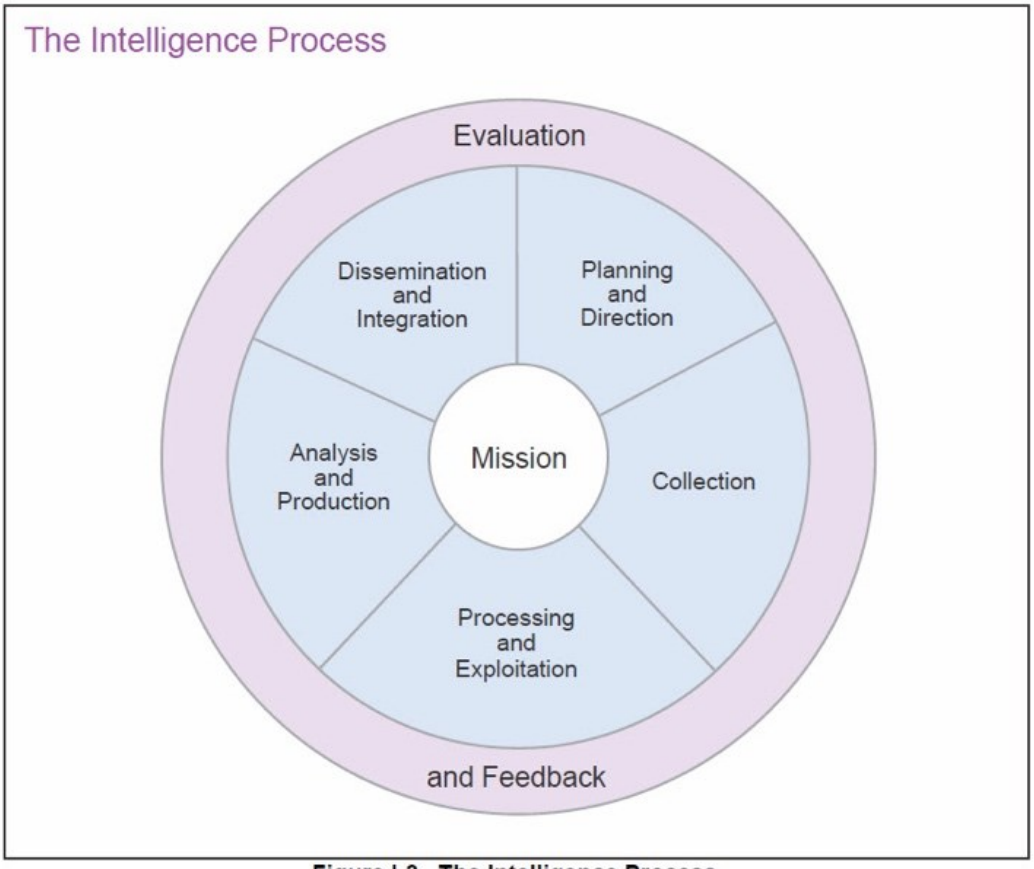


Figure I-3. The Intelligence Process

Figure 1: The Intelligence Process Source: (Joint Chiefs of Staff, 2013)

Defining each stage of the process from Young (2022)

Planning and Direction: the determination of intelligence requirements, development of appropriate intelligence architecture, preparation of a collection plan, issuance of orders and requests to information collection agencies. This may also include sets of established checklists and questionnaires for recurring events and missing person incidents (MPI).

Collection: those activities related to the active acquisition of data [information] required to satisfy the requirements specified in the collection strategy.

Processing and Exploitation: raw collected data is converted into forms that can be readily used by commanders, decision makers at all levels, intelligence analysts and other consumers.

Analysis and Production: all available processed information is integrated, evaluated, analyzed, and interpreted to create products that will satisfy the end user. The analysis would also include filtering out redundant information as well as false positives or negatives. Intelligence products can be presented in many

forms including oral presentations, hard copy publications, or electronic media.

Dissemination and Integration: intelligence is delivered to and used by the consumer and used to make decisions and take action.

Evaluation and Feedback: occur continuously throughout the intelligence process and as an assessment of the intelligence process.

Further there are the analogies of **Tactical intelligence, Strategic intelligence, and Operational intelligence** defined as:

Tactical intelligence is focused on support of the operations at the tactical level and includes field searchers. Briefings are delivered to teams prior to leaving on assignment and include descriptions of the missing subject, items to look for, potential hazards, and other information that would aid the field searcher in identifying and locating the missing subject. This is classified as **Searching Data**. The teams are debriefed at the end of their assignment to elicit additional information for analysis and communication through the reporting chain.

Tactical intelligence can vary in its intensity based on the environment the missing person is in. If we are looking for an 80-year-old male missing in a wilderness environment the amount of data necessary may be minimal. It would be expected that there is only one 80-year-old male and a complete description or even a photograph of the subject is not necessary to send searchers out in the field. However, if we are looking for the same 80-year-old male in an urban retirement community, there could be several subjects that will need be sorted out by physical description and photograph.

Strategic intelligence is concerned with broad issues such as the number and type of resources to apply to the search effort. Such intelligence may be scientific (e.g., weather forecasts), technical, tactical, or diplomatic (e.g., pressures from the family, local politics, or other authorities having jurisdiction). But these changes are analyzed in combination with known facts about the area in question, such as geography or demographics, which may be related to safety issues as well as statistical lost-person behavior. In search management, this is referred to as more long-term value as **planning data**.

Operational intelligence is focused on support or denial of data at the operational level. In search management, this means managing clues and information as they become available and applying that information to affirm or refute the various scenarios being developed. This is the function of the **Clue Unit Leader**, sometimes referred to as the “Clue Meister” or “Clue Frog”—that is, the person to “jump on it” and take action.

The Paper Version of Data Collection

Throughout the law enforcement and search and rescue communities in the United States the standard for management of any emergency incident, including missing persons comes from the National Incident Management System (NIMS) guidelines under The Federal Emergency Management Agency (FEMA) which dictates the use of the Incident Command System (ICS).

The Incident Command System has developed standard forms that are used in most missing person incidents. In addition, there are search and rescue specific forms (SAR 1##) developed in the early 1990's by the (San Francisco) Bay Area Search and Rescue Council (BASARC) (Young & James, 1995) and have been widely adopted throughout California, the United States, Canada, and other parts of the world. Most importantly these data collection methods have been field tested, work well, and are easily trainable to less experienced management staff.

Further, the Missing Person Questionnaire (MPQ) is considered the most valuable source of information to paint a picture of who is the missing subject, the circumstances of their disappearance, and the best source in determining what the subject might do in a particular situation (e.g.: weather turns bad, night fall, rugged terrain).

For a list of all the forms used to collect data during a missing person incident both ICS and SAR 1##, see **Appendix A**

The Human Model of Processing, Exploitation, Analysis, and Production of Intelligence

Consider the initial collection of data from a traditional paper Missing Person Questionnaire (MPQ):

> Question: "Can he dress himself?"
>
> Response: "I have to lay out his clothes for him and help him with his socks."

This could be construed to be an innocent and innocuous response. However, in context of a missing person incident, the experienced human interviewer would recognize that there is more data to be collected and would follow up with:

> Follow up question: "Why does he need help with his socks?"
>
> Possible response: "He can't bend over to reach his feet."

Again, another innocuous response, but can further be explored by another follow up question:

> "Why does he have trouble reaching his feet?"
>
> Possible responses could be:
>
> 1. "He has a physical back/spinal movement issue limiting movement and/or is painful."
> 2. "He is overweight making it difficult to reach his feet."

3. "He has cognitive issues related to dementia/Alzheimer's."

Each of these final responses creates further human brain processing and analysis. An example of the further exploitation of the spinal issue would be:

1. "Is the limited spinal movement related to a chronic or acute back condition?" (Analysis: if this is chronic due to a disease what other limitations are there? If this is acute, due to an accident, where are they in the healing process?)
2. "Is the pain and limited motion relieved with medication and/or physical therapy/exercise?" (Analysis: what is the medication, side effects, potential overdose/underdose problems that could occur? What happens after several hours if they don't take their medications?)
3. "Does this condition limit their mobility?" (Analysis: how far can they physically travel by foot? Can they sit is a vehicle for only a limited time without having to stop and stretch?)
4. "Does this condition limit their survivability?" (Analysis: what other limitations are they experiencing that will limit their ability to stand up if they fall? Do they need a cane or walker (also related to mobility)?)

Based on the further tangent[1] questioning and analysis the human brain would surmise that there is a lot of intelligence to be compiled into actionable products to be used by the searchers in the field and the planners in the command post.

The Components of Artificial Intelligence

The research regarding Artificial Intelligence, started with the five basic components of learning, reasoning, problem solving, perception, and language understanding (CaseGuard, 2022). CaseGuard defines these components as:

Learning

As with human intelligence, the first step is the learning stage. There will be a trial-and-error process making mistakes and gradually learning the rules and techniques that are needed to effectively handle a task. In the context of artificial intelligence, the learning process requires the memorization of individual items including different solutions to problems, vocabulary, and foreign languages, among others. Through this learning process, programs that utilize artificial intelligence are able to keep notes of all actions or moves that led to positive results, allowing the program to leverage this knowledge within its data should similar problems arise in the future.

Reasoning

[1] With every question there is a response. Responses to the original question will trigger an additional related question. Again, depending on the response, this may lead into a specific direction or set up a different line of questioning. These related questions are referred to as tangent questions.

Mental reasoning is something that has been limited to the human mind throughout history. Artificial intelligence centers on software programs that are able to draw conclusions and inferences from a situation, without the need for human interference, whether inductive and deductive reasoning. To this point, the use of inductive reasoning has allowed computer programmers and software developers to create products and systems that achieve consistent results when faced with a particular problem or issue.

Problem-solving

The creation of computer software programs and systems that solve problems in a manner similar to that of human beings and is one of the most essential components in the development of AI. AI's problem-solving skill is based on the application and manipulation of data, where the solution needs to be x. Conversely, in advanced applications, problem-solving techniques can include the development of efficient algorithms, performing root cause analysis with the goal of discovering a desirable solution, and heuristics.

Perception

In comparisons to the function of the human mind, the way in which individuals perceive the world around them is critical to the way they solve problems in their respective lives. AI perception is achieved through the utilization of different sense-organs, whether they be real or artificial. Human perception is extremely complicated. It can prove to be extremely challenging for AI programs to perceive certain inputs and information. A self-driving car is a classic example of perception of the outside world in order to function safely.

Language understanding

The understanding of language is the last component that makes up AI. Language understanding in AI can be defined as a system of signs having meaning using standard conventions (Copeland, 2023). Most AI programs and systems are developed within the English-speaking world and understand the English language. Through this language understanding, software developers can ensure that computer programs are able to efficiently execute their respective functions and operations.

Using the application of these components, AI systems can work effectively without the need for human inputs, as software programs that make use of artificial intelligence are able to govern themselves in conjunction with the codes or rules that are provided to them by software engineers and developers.

Literature Review:

The contexts related to individuals reported missing is complex and involve many factors. Factors include the various attributes of the missing subject including but not limited to age, the physical and mental health as well as physical appearance. The literature review focuses on the attitudes (data), applying one or more methods (tools) to extract the data, and then analyzing the information collected using one of several approaches (AI) to produce actionable intelligence. All the literature review expresses the goal of improving the outcome of the

missing person incident. The literature can be consolidated into one of the following

- Focused on technologies in facial recognition.
- Looking at narrow demographics (E.g.: Missing adults with dementia, children with autism unaccompanied immigrating minors in Europe).
- Websites and applications dedicated to locating missing persons.

Facial Recognition:

Some published articles discuss the use of artificial intelligence ability to use biometric-based technology that mathematically maps a particular person's or individuals facial features and stores all that data as a face print. Face recognition models in these systems look for a match of the missing subject in the database. If a match is found it will be notified to the authorities who have jurisdiction for follow up investigation (Pawar, et.al, 2021), (Michalitsi-Psarrou, et.al, 2020), (Solaiman, et.al., 2022). Facial recognition technologies have gone so far as to allow developers to apply for United States patents for the deep learning technology (United States Patent No. US 10,163,042 B2, 2018).as well as develop mobile phone applications (Pawar, et.al., 2022).

Demographics

One published study discusses the use of machine learning methods to infer the reasons a person may go missing to assist law enforcement (Pierzchala, et.al., 2020(2)). Another study sought to identify individual and environmental factors that might predict where an older adult reported missing would be found (Ruiz-Rizzo, et.al., 2022). The latter study stated "…identified the individual factors that predict whether a missing older adult will be found, using a supervised machine learning model based on ensembles. The present findings suggest that there are intrinsic and extrinsic factors at play, all of which can influence the outcome prediction of older adults."

Websites and applications

A study published in 2021 *SaRNet: A Dataset for Deep Learning Assisted Search and Rescue with Satellite* Imagery (Thoreau & Wilson, 2021), looks at high resolution satellite imagery with dramatically improved resolution for humanitarian relief and Search and Rescue (SAR). The proposal uses a novel remote sensing object detection dataset for deep learning assisted SAR.

Closely aligned with our research

Most of the publications reviewed were not focused or aligned with our research and project goals. However,

an older study *Data Mining of Missing Persons Data* (Blackmore, et.al., 2005), presented the results of analysis to evaluate the effectiveness of data mining techniques to predict the outcome for missing persons cases. A rule-based system was used to derive augmentations to supplement the missing person incident manager's intuition. The results indicate that rule-based systems can effectively identify variables for prediction. Another article *Knowledge representation for missing persons investigations* (Taylor & Reilly, 2017), looked at knowledge collections in missing person investigations and applying situation calculus to provide a "more relevant than an expert systems approach that would typically suggest a particular given action". This decision support approach aims to provide a set of relevant actions from which the officers or search leaders concerned in a missing persons case might choose or might combine as appropriate.

And still another article *Machine Learning-Based Method for Recommendation of Missing Person's "Search Level"* (Pierzchala, et.al, 2020), presented the use of various algorithm methods, decision trees, random forests, naïve Bayesian classifier multi-layer perceptron, and support vector machine to model and classify search levels to support decision-making problems concerning the actions of the Police (in this case in Poland) in the search of missing persons.

Discussion

The "Artificial Intelligence for Search and Rescue" is a project with goals to use AI and related computational methods to support Search and Rescue (SAR) missions. The project was developed in collaboration with California Polytechnic State University (Cal Poly) Computer Science and Software Engineer Department Dr. Franz Kurfess, undergraduate and graduate students in alliance with alumnus Gary Bloom and Christopher Young both experienced search and rescue incident managers. The project began in the summer of 2021 through private funding research, senior projects, and class projects. Initial work included the collecting and consolidating of the pertinent mechanisms for storing and processing data.

The first step was to collect the data electronically so that data can be enhanced and analyzed be software technologies. This required converting the paper forms into a collaborative data base that can be analyzed and processed by software either already developed or modified as required.[2]

Artificial Intelligence Methods Explored:

The team moved to the second step to evaluate the most appropriate technologies, methods, and tools

[2] Disclaimer: this is a rough outline and not necessarily the final user interface (UI). This is largely built and is now moving to system level testing. Component and the UI will be modified as usability testing requires.

available. The project is looking at the practical application for artificial intelligence and not trying to present in this paper a very theoretical description of all these advanced technologies.

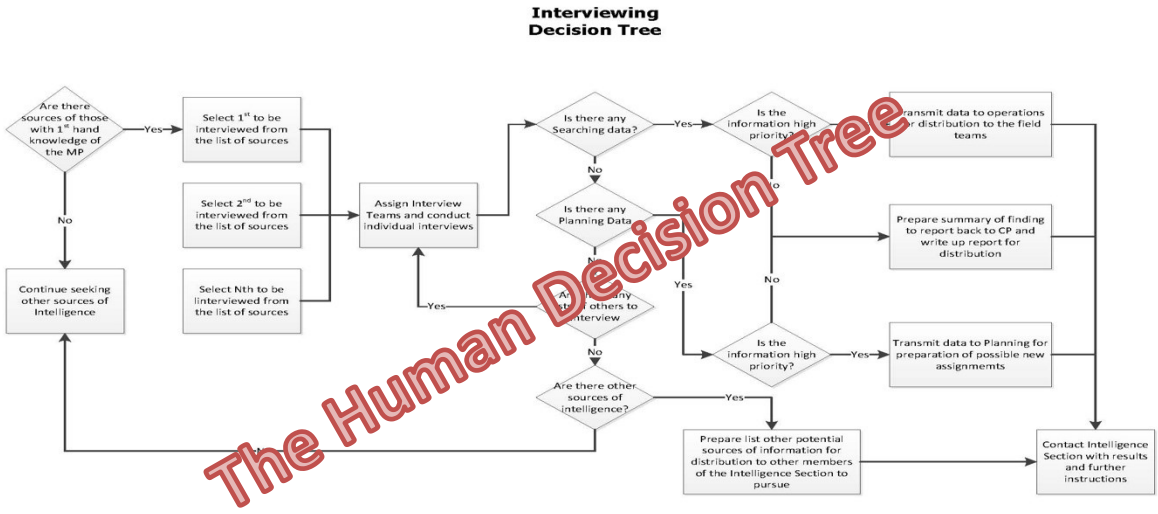
The Semantic Web: (Wikipedia, 2022)
With an ontology as the structural backbone of a knowledge repository, sematic web technologies are used for knowledge retrieval and reasoning over a wide range of digital documents. Ideally, documents should be described through metadata, but methods and tools are available to generate metadata from plain documents such as text files, databases, images, diagrams, and other formats. [Deductive reasoning and inference]

Some of the challenges with the semantic web (Wikipedia, 2022)

- Vastness – There are billions of pages of existing ontological knowledge to search through.
- Vagueness – The imprecise concepts like “young” and “tall”. (so called “fuzzy logic”)
- Uncertainty – There are too many variables – e.g.: medical symptom there are many different diagnoses. These can be partially resolved using Probabilistic Reasoning
- Inconsistency – The logical contradictions between combined ontologies
- Deceit – Data intentionally misleading requires the need to confirm and verify the knowledge [data] by human intervention.

Probabilistic Reasoning (Demartini, et.al., 2013)
This approach using probabilities can be used to explore relationships in data sets, predict the outcomes of actions and evaluate possible causes of events. The outcome could generate possible missing person scenarios. This is used in predicting lost person behavior (Koester, 2008)

Machine Learning: (Wikipedia, 2022)
Using the objectives to classify data based on models which have been developed from training data and to make predictions for future outcomes based on these models. Machine learning training can be supervised or unsupervised. Supervised consists of training data from examples from real incidents supplied by subject matter experts. This would also incorporate the use of decision trees:



Source (Young, 2022)

Unsupervised learning generates actions based on what it has already learned e.g., cluster analysis based on similarities from existing data sources such as the International Search and Rescue Incident Database (ISRID) used to develop Dr. Robert Koester's (2008) Lost Person Behavior book.

Deep Learning: (Wikipedia, 2022)

In this context, the use of Deep Learning in Natural Language Processing is especially relevant. Deep learning is a class of machine learning algorithms that use multiple layers to extract higher levels of features. E.g., lower levels of lines and edges to higher levels to extract digits, letters, or faces.

Hybrid Systems

While hybrid methods combining multiple artificial intelligence approaches have been explored for a long time, recent advances, combined with more easily available and lower cost computer capacity, have led to approaches that combine symbol-oriented methods (like the Semantic Web) with Machine and Deep Learning and Probabilistic Methods.

Evaluation of Technologies and Tools

The above approaches have yielded implementations of varying scopes, ranging from experimental research systems to large- scale commercial applications. The aspects to consider are capabilities, availability (e.g.: licensing, cost), reliability, scalability, and performance.

Computing Requirements:

The Initial requirements are cloud level of computing capacity to set up the models where incredibly large

amounts of data capacity can be crunched. The cloud can handle this very economically, but will require evaluation of:

- What the connectivity is required whether intermittent, on demand, or 100 percent of the time. If constant connectivity to the cloud is required, then it may be necessary to consider satellite/cloud connections.
- Consider using virtual management from lessons learned during the COVID outbreak.
- Connectivity from field personnel to command post.

Once the model is developed, applying the model could potentially be done on a laptop given today's computing capacity.

System Architecture & Database Organization:

There are two parts to the system architecture and data base organization referred to as front and back-end development. To date the front-end uses JavaScript and Node.js to develop and manage the system and Redux to handle predictable state. The back end uses JSON to develop schemas and security rules for the digital forms as data is entered.

Experiments

The project team has and is continuing to identify interesting tools and conducting experiments to assess their suitability and performance in a missing person incident environment. This will include the use of available data sets in the search and rescue area, in particular data about past search missions. (e.g.: Lost Person Behavior ISRID database (Koester, 2008)). Based on the outcomes of the experiments, the project team will examine the practical aspects of a particular tool or technology to determine if it is a suitable candidate to be incorporated into the larger system This includes compatibility with other tools, licensing terms and conditions, financial aspects, and other factors.

Project Milestones Completed to Date:

By the end of the academic year 2021-2022, the project team successfully converted the BASARC and ICS forms into the Firebase database which required creating schema, security rules and integrating a search engine within the database. The front-end teams have established and are testing the connections between front end forms and submissions stored in the database that allows users to enter data on laptops, tablets and smart phones. An initial dashboard has also been created, evaluated, and modified as testing progresses. One of the challenges still to be resolved is to present everything in such a way that the end users do not have to learn database technology and to improve the navigation of the forms for searchers using the technology in the field. This foundational development work is largely completed and supports real-time collection of search data, improved distribution of the data and electronic storage of search information.

Future Research to be Present in Part 2 of this Paper:

This Part 1 paper has set the foundational data collection and management components for the further development of the use of artificial intelligence for search and rescue (which has now been abbreviated "AI4SaR") and missing person incidents. The next exciting part is how to analyze and apply some of the newest technologies to improve search outcomes with real-time analysis of the data as it is collected and stored electronically in the database. There will be extensive testing using past missing person search data as well as mock tabletop and, in the field, real time practical events.

Beyond the implementation and the research work around AI4SaR there is also the need for commercialization of the system which means looking for partners that are interested taking this from a professor/student lead effort to a commercial enterprise

Acronyms

AI	Artificial Intelligence
AI4SaR	Artificial Intelligence for Search and Rescue
BASARC	Bay Area Search and Rescue Council
Cal Poly	California Polytechnic State University
FEMA	The Federal Emergency Management Agency
ICS	Incident Command System
ISRID	International Search and Rescue Incident Database
MPI	Missing person incidents
MPQ	Missing person questionnaire
NIMS	National Incident Management System
SAR	Search and Rescue

Glossary

Firebase (Wikipedia, 2023)
Firebase is a set of backend cloud computing services and application development platforms provided by Google. It hosts databases, services, authentication, and integration for a variety of applications, including Android, iOS, JavaScript, Node.js, Java, Unity, PHP, and C++.

JavaScipt: (Wikipedia, 2023)
JavaScript is a software programing language and is one of the standards used by the World Wide Web.

JSON (JavaScript Object Notation) **(Wikipedia, 2023)**

JSON is an open standard file format encoding schema for data and data interchange ability with human-readable text.

Node.js (Wikipedia, 2023)
Node.js is a cross platform, open-source server environment and is used as the library in JavaScript to write commands.

React (Wikipedia, 2023)
React (also known as React.js or ReactJS) is a free and open-source front end JavaScript library for building user interfaces based on defined components.

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Appendix A

List of digitized forms for data collection:

Incident Command System:

ICS Form #:	Form Title:	Typically Prepared by:
ICS 201	**Incident Briefing**	Initial Incident Commander
ICS 202	**Incident Objectives**	Planning Section Chief
ICS 203	**Organization Assignment List**	Resources Unit Leader
ICS 204	**Assignment List**	Resources Unit Leader and Operations Section Chief
ICS 205	**Incident Radio Communications Plan**	Communications Unit Leader
ICS 205A	**Communications List**	Communications Unit Leader
ICS 206	**Medical Plan**	Medical Unit Leader (reviewed by Safety Officer)
ICS 207	**Incident Organization Chart** *(wall-mount size*	*optional 8½" x 14")* Resources Unit Leader
ICS 208	**Safety Message/Plan**	Safety Officer
ICS 209	**Incident Status Summary**	Situation Unit Leader
ICS 210	**Resource Status Change**	Communications Unit Leader
ICS 211	**Incident Check-In List** *(optional 8½" x 14" and 11" x 17")*	Resources Unit/Check-In Recorder
ICS 213	**General Message** *(3-part form)*	Any Message Originator
ICS 214	**Activity Log** *(optional 2-sided form)*	All Sections and Units
ICS 215	**Operational Planning Worksheet** *(optional 8½" x 14" and 11" x 17")*	Operations Section Chief
ICS 215A	**Incident Action Plan Safety Analysis**	Safety Officer
ICS 218	**Support Vehicle/Equipment Inventory** *(optional 8½" x 14" and 11" x 17")*	Ground Support Unit
ICS 219-1 to ICS 219-8	**ICS 219-10** ***(Cards)***	**Resource Status Card (T-Card)** *(may be printed on cardstock)* Resources Unit
ICS 220	**Air Operations Summary Worksheet**	Operations Section Chief or Air Branch Director
ICS 221	**Demobilization Check-Out**	Demobilization Unit Leader
ICS 225	**Incident Personnel Performance Rating**	Supervisor at the incident

Search and Rescue specific forms developed by the Bay Area Search and Rescue Council (BASARC)

SAR 100	**General Briefing**	
SAR 100A	**General Briefing Missing Person**	
SAR 104	**Team Assignment**	
SAR 110	**Team Debriefing**	
SAR 111	**Team Debriefing – Dog Team Supplement**	
SAR 112	**Team Debriefing – Area Search Supplement**	
SAR 113	**Team Debriefing – Equestrian Supplement**	
SAR 115	**Team Debriefing – Tracking Team Supplement**	
SAR 116	**Team Debriefing – Hasty Search Supplement**	
SAR 119	**Team Debriefing – Supplement**	
SAR131	**Individual Availability Assessment**	
SAR132	**Urban Interview Log**	
SAR133	**Radio Log**	
SAR134	**Clue Log**	
SAR132	**Clue Report**	
SAR139	**Event Missing/Found Person Report Form**	
	Missing Person Questionnaire (MPQ)	
	Backcountry Interview Log	