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Decision-Acquisition System Based on a Common Decision-Exchange Protocol

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Decision-Acquisition System Based on a Common Decision-Exchange Protocol

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Abstract**—***This paper describes design considerations for the implementation of a decision-support system based on a Common Decision Exchange Protocol (CDEP), which is an XML-, REST-based protocol for representing generic human decisions in a simple, interoperable format. The paper also describes characteristics of decisions that should be expressed using CDEP and specifies a proposed XML format. The CDEP will enable war fighters to track and manage the decision-making process better, to enable improved information-flow metrics in networks, to maintain an archive of the decisions and the decision-making process, to enable semi-automation of certain decision-making processes, to improve information sharing across networks, and ultimately, to support better and faster decision making. The CDEP format should provide concise, generic, structured assessments and decisions that enable "drill down," support pedigree and confidence, enable approvals and vetting, define options considered, link to previous decisions, and support flexible structuring. The format recommended here is a first step toward such a CDEP.*

Keywords-Decision making, command and control, applications, resource allocation and management, network services, standards, training

I. INTRODUCTION

This paper describes the need and recommends a format for a Common Decision Exchange Protocol (CDEP) [21]. CDEP is an XML, Representational state transfer (REST)-based protocol for representing generic human decisions in an interoperable format. It describes characteristics of decisions that should be expressed using CDEP and specifies a proposed eXtensible-Markup-Language (XML) format. The goal is to integrate humans into computer systems to track and manage the decision-making process better, to enable improved information-flow metrics, to maintain an archive of decisions and the decision-making process, to enable semi-automation of certain decision-making processes, to improve information sharing, and ultimately, to support better and faster decision making. CDEP format should provide concise, generic, structured assessments and decisions that enable information "drill down," support pedigree and confidence, enable approvals and vetting, define options considered, link to previous decisions, and support flexible structuring.

The time and effort to convert decisions into products (e.g. briefs, papers, proposals) and communicate our decisions (e.g. meetings, teleconferences, conversations, emails) might be recaptured if we had a standard concise format for representing and sharing decisions. CDEP tools could be instrumented to generate decisions in a format that could be shared. CDEP tools also can be used to track the state of the decision in the decision-making process. Instrumentation could support the development of a metric of decision flow and help us understand and optimize our decision processes across our organization or enterprise. Visibility of the decisions in their formation and evolution would enable proactive management and assistance from others.

For these reasons, we should consider a networked open-standard format for representing decisions efficiently for information exchange and for situational awareness. Such a standard does not exist, although previous research has suggested effective techniques and frameworks for representing arguments and decisions [1], [2]. This paper builds on this significant prior work to propose a Common Decision Exchange Protocol (CDEP) for enabling effective sharing and managing of decisions across an enterprise. The Common Alert Protocol (CAP) [9] is an example of the type and style of information exchange format recommended in this paper. What CAP did for alerts, a common decision exchange protocol should do for decisions.

Due to the use of networks, a CDEP is possible to implement and use efficiently. The network enables decisions to be captured in greater detail at a higher level of fidelity because information can come from any node on the network and the decision capture is not limited to a single command center. The network amplifies the utility of the CDEP by making its results available to many users. The CDEP contributes to the evolution of computer science technology in general. Moreover, the CDEP represents a significant advance in the evolution of decision support and training in particular.

The motivation for this effort is to support networked information sharing and making better decisions. The research

approach is to explore the use of XML code to document and transmit on the network pros and cons as well as other characteristics of decisions. This paper recommends a CDEP and a concept for how it can be utilized. This work implies that we need an open-standard body similar to OMG in the object-oriented world. This would help to make decisions and their explanations more interoperable across a wide variety of organizations. The value of this work will be realized in military and other types of command and intelligence centers where decision tracking serves training and analysis purposes with to preserve lessons learned. The authors welcome suggestions and would like to collaborate with others on this effort. This work supports a global interoperability test bed, which anyone reading this paper is welcome to join.

This paper is organized as follows. Section II explains characteristics of decisions and the decision-making process. Section III provides examples of CDEP XML representations. Section IV describes the design and concepts of operation of a decision-acquisition system. Section V provides a way forward in terms of future standards, research, development and applications. Section VI concludes the paper.

II. CHARACTERISTICS OF DECISIONS AND THE DECISION-MAKING PROCESS

Use cases are important to explore and define the purpose for which we are developing an information model. Without a well-defined purpose, we cannot determine what to include in the model. The notion of a Common Decision Exchange Protocol (CDEP) suggests that we are striving for an information model that contains the "common" types of things most people would like to know regarding a decision that may be of interest to them. The information model is intended for this type of "exchange," so it won't be highly specific or too detailed. We do not target a specific domain for the format per se, but we are most immediately interested in applying the model to the military domain. Health care and emergency management are other domains to which the model could be applied. Ultimately, we would like our format to be usable across all domains. A good start is the "who, what, where, when, how and why" that journalists consider the basic components of any story [8]. However, decisions differ from other types of stories. The decision process includes balancing and assessment of pros and cons based on criteria in an attempt to answer a question or to select a course of action, often from among several alternatives. A decision always has context, a purpose or goal, and some constraints (e.g. time, cost, etc.). The following questions pertain to the basic situational awareness regarding any type of decision:

(a) What was the decision?
(b) Who made the decision and when?
(c) Who was consulted and brought into the decision-making process?
(d) What options were considered?
(e) On what criteria was the selection based?
(f) What were the pros and cons?
(g) Why was the selected option chosen?
(h) How was the decision made, e.g. individual decision, majority vote, consensus, expert opinion?
(i) What is or was the context for this decision?
(j) What is or was the state of the decision-making process? For example:

- Not yet started,
- Gathering information,
- Evaluating and analyzing and fusing information,
- Listing of alternatives
- Paring down the list
- Selecting an alternative,
- Preparing decision product,
- Communicating the decision,
- Gathering feedback regarding the decision,
- Finished.

(k) How much time and effort went into making this decision?
(l) What was the confidence level at various stages?
(m) Where can I find more information? For example, what are the links to

- "Drill-down" background information
- Detailed metadata regarding the reliability of data sources and data-processing methods?

Although the questions above were phrased as though the decision had already been made, the same questions could be rephrased to describe decisions underway or yet to be considered. Representing decisions under consideration in a sharable format is important to allow others to understand the options being considered and potentially contribute or prepare in advance. (See, for example, [2].) Another key reason to represent decisions underway is that circumstances change and a decision may need to be made before the original assigned deadline. A continual representation of the current state of the decisions under consideration would enable making more agile decisions and perhaps allow optimization through dynamic management of the ongoing decision processes.

The goal of the proposed CDEP is to capture the essence of the decision for information exchange to enhance situational awareness. For example, the information obtained through a CDEP might be the equivalent of receiving a 60-second overview from a knowledgeable participant in the decision process. For example, a summary of our decision to propose a CDEP could read as follows: "We decided to propose a Common Decision Exchange Protocol on July 15, 2008 after having considered other information exchange protocols, such as CAP; Really Simple Syndication (RSS) (a dialect of XML); the National Information Exchange Model (NIEM); and domain-specific models like the Chemical Biological Radiological Nuclear (CBRN) data model."

The CDEP is needed because representing the basics of decisions requires a unique combination of information that requires more than some of the existing formats and less than some of the others. However, the goal is to reuse tags from other formats. The decision evolved after about a half-time effort over six months. We have a draft schema in an "open-

standard-like" format for those who want to learn more. We made the decision by consensus among the authors because during our research on an information-flow metric, we identified the need to represent and instrument the decision process. The essence of the format is to support information exchange for situational awareness and to answer questions about decisions, such as 'who, what, where, when, why, options considered, criteria used, confidence level, decision style, and context. The format enables a hierarchical representation of a decision and its sub-decisions." The proposed CDEP should be able to represent this type of decision information.

We define "decision making" as "the act of reaching a conclusion, a judgment, or the selection of a course of action after considering information that supports various options" [11]. The output of a decision can be an action or an opinion. For the purpose of this paper, a decision might be considered best in this broader context, incorporating judgments, opinions, assessments and recommendations. The ultimate question of concern in this paper is how to represent and share these judgments efficiently and, how to manage them to improve our organizations and our decision-making processes. Although a CDEP could apply to many domains, this paper concerns the military domain.

Decision making, situational awareness, and the communication of both are closely linked. Situational awareness is necessary for sound, reliable command decisions, and information regarding decisions constitutes a portion of situational awareness that is communicated to subordinate units. (See, for example, [17].) Situational awareness is known as "level-two data fusion." Sometimes situational awareness is focused on a Common-Operating Picture (COP) based on information collected at level one, namely, platform detection, localization, classification, identification, and track correlation. In situational awareness, the position and disposition of friendly forces and their relationship to other forces, both hostile and neutral, is important. Pedigree metadata are becoming increasingly more in demand to reduce uncertainty, now that the technology has evolved to a point where it can support situational awareness and decision making [3]. All of this information contributes to the COP, which then becomes an important decision aid, if not the primary decision aid.

As listed above, the decision-making process includes gathering and analyzing information, developing alternatives, selecting one or more alternative courses of action, and issuing a command with enough detail so that a subordinate commander can execute it. Information acquisition and analysis often will center around the fusion of sensor data in the COP, as well as other data from first-hand observations and verbal reports. In contrast, the product of the decision process will be an order to implement a course of action, usually written in the case of a decision that consists of multiple parts and/or contingent alternatives. A CDEP can support both the decision-making process and the products of the decision. A CDEP supports storage and retrieval of past decisions. Therefore, it can help a commander analyze these past decisions in light of the current situation as described in the COP. For maximum utility, the CDEP-formatted decisions should be available from the COP software. Moreover, a CDEP can support the archiving of current decision products and the reasoning behind them to make this information available for future consideration.

Most decision makers rely on the assessments of others, rather than on raw data. This may be a consequence of selecting intuitive rather than equally valid non-intuitive alternatives [19]. Assessments of others that are written in plain language or expressed verbally can seem more intuitive than raw data, which may require detailed analysis to understand. Moreover, decision makers often mistake someone's assessment for "raw" data. An assessment is a person's opinion of something, often based on previous fusion or analysis of that topic or related topics, incorporating the person's experience, expertise, confidence, and current knowledge, all of which is stored mentally as patterns [4]. Perhaps the definition of an assessment could also include opinions generated by computer systems if those systems were based on human knowledge.

Many organizations consider their employees, their people, as their most valuable resource [23]. If this is true, the manner in which we represent and share our assessments is crucial to the success of our efforts. In spite of the value of employees, time is a valuable resource that is squandered inefficiently by most traditional forms of sharing assessments, such as briefs and meetings [14]. For example, often assessments are represented and shared in inefficient, time-consuming, and unproductive ways that do not scale well, such as e-mails, briefs, white papers, phone calls, video teleconferencing, and many other forms. Even blogs, which scale well in terms of visibility, do not scale well in terms of time. The goal in sharing assessments should be to share as widely as possible, but as quickly and efficiently as possible. Most decision makers do not have time for much beyond a concise statement of the main points.

For assessments to be widely usable for situational awareness, they must be as generic and scalable as possible [10]. If a person's experience is considered, none of us is likely to be an expert in each other's domain of knowledge. Yet, what we know may be important to others, and something we know that we think is important should be available efficiently for others. Non-experts may need to understand details about the thought process that led to experts' assessments and decisions. Similarly, the assessments should be tiered to be useful [13]. High-level decision makers need high-level assessments. Mid-level decision makers need mid-level assessments. Even high-level decision-maker may want access to mid-level assessments. Therefore, all the supporting knowledge should be visible in similarly tiered assessments for the reasons discussed above.

The protocol recommended here is based on some founding assumptions or principles as follows.

- The vast majority of decision makers base their decisions on the decisions, assessments, and recommendations of others, not on raw data.
- Higher-level knowledge as represented by decisions is necessary to achieve useful knowledge sharing to avoid the information glut of raw data and to arrive at vetted, actionable knowledge.
- Knowledge communication must be concise, generic, hierarchical, and structured to be understood and managed quickly.
- The human component must be integrated into the representation of computer communications systems and processes to achieve the most efficient resource management.
- The protocol should support decentralized, open-standard and open-source technologies, approaches, and tools, thus allowing participant the jurisdiction to manage their own affairs yet participate efficiently in communicating useful knowledge.

III. EXAMPLES

Figures 1, 2 and 3 are example CDEP XML messages illustrating how to represent decisions at various stages of the decision-making process. For readability, in Figure 1, the question to be answered is expressed in **bold.** In Figure 2, the options are expressed in **bold.** In Figure 3, the advantages and disadvantages of selecting the USS Valley Forge or the USS Sentry are shown in **bold**.

Figure 1 is an example of a CDEP XML message that communicates a decision that needs to be made. The use of XML has been demonstrated to facilitate consistent, dependable, and interoperable data access, data integration and general information exchange [15], [16]. In this case, RADM Jones needs to decide which platform to send on a search-and-rescue mission. At this point, RADM Jones has just started information gathering on this question, so confidence is low and no options have been defined.

```
<?xml version = "1.0" encoding = "UTF-8"?>
<decisions>
   <decision>
      <guid>http://www.spawar.navy.mil/Code90/decisions/114.xml</guid>
      <question> What is a good base platform for the search and rescue mission?</question>
     <description> RADM Jones needs a ship for search and rescue in the Indian Ocean.</description>
      <decision confidence>Low</decision confidence>
      <state>Gathering Info</state>
      <eventInfo>
         <who>http://www.spawar.navy.mil/code90/people/RADM_Jones.xml</who>
         <when>2008-04-15T13:00-08:00</when>
      </eventInfo>
  </decision>
</decisions>
```

Figure 1. Example 1: CDEP Decision at the Information-Gathering Stage

```
<?xml version = "1.0" encoding = "UTF-8"?>
<decisions>
   <decision>
     <guid>http://www.spawar.navy.mil/code90/decisions/114.xml</guid>
     <question> What is a good of base platform for the search and rescue mission?</question>
     <description> RADM Jones needs a ship for search and rescue in the Indian Ocean.</description>
     <options>
       <option>
         <idea>USS Valley Forge</idea>
         <description> Aegis ship is fully SAR-mission capable.</description>
         <selected>false</selected>
       </option>
       <option>
         <idea>USS Sentry</idea>
         <description> Mine sweeper is partially SAR-mission capable.</description>
         <selected>false</selected>
       </option>
     </options>
     <decision confidence>Medium</decision confidence>
     <state>Analyzing Info</state>
     <eventInfo>
        <who>http://www.spawar.navy.mil/code90/people/RADM_Jones.xml</who>
        <when>2008-04-15T13:00-08:00</when>
     </eventInfo>
  </decision>
</decisions>
```

Figure 2. Example 2: CDEP Decision with Options

```xml
<?xml version = "1.0" encoding = "UTF-8"?>
<decisions>
   <decision>
     <guid>http://www.spawar.navy.mil/code90/decisions/114.xml</guid>
     <question> What is a good of base platform for the search and rescue mission?</question>
     <description> RADM Jones needs a ship for search and rescue in the Indian Ocean.</description>
     <options>
        <option>
           <idea>USS Valley Forge</idea>
           <description>USS Valley Forge could perform search and rescue.</description>
           <selected>false</selected>
           <pros>
             <pro>
               <title>Capable</title>
               <description>USS Valley Forge is a very mission-capable ship</description>
             </pro>
             <pro>
               <title>Available</title>
               <description> USS Valley Forge is available for mission.</description>
             </pro>
           </pros>
           <cons>
              <con>
                <title>Distance</title>
                <description>USS Valley Forge is 50 NM away.</description>
              </con>
            </cons>
        </option>
        <option>
           <idea>USS Sentry</idea>
           <description>USS Sentry is 15 NM from the search area.</description>
           <selected>true</selected>
           <pros>
             <pro>
               <title>Capable</title>
               <description>USS Sentry is a mission-capable ship</description>
             </pro>
             <pro>
               <title>Available</title>
               <description>USS Sentry is available for mission.</description>
             </pro>
             <pro>
               <title>Distance</title>
               <description>USS Sentry is 15 NM from the search area.</description>
             </pro>
           </pros>
        </option>
      </options>
      <decision confidence>High</decision confidence>
      <sub-decisions/>
      <notes/>
      <references/>
      <state>Product</state>
      <pedigree/>
      <eventInfo>
        <who>http://www.spawar.navy.mil/code90/people/RADM_Jones.xml</who>
        <when>2008-04-15T13:00-08:00</when>
      </eventInfo>
    </decision>
</decisions>
```


Figure 3. Example 3: CDEP Decision with Pros, Cons, and Ideas at the Product Stage

The decision components include a unique identifier in a RESTful format [12], a question, description, confidence and state. In addition, every question encapsulates the basic components of an event, namely "who, what, when, where, how, and why." Note that "who" is a link in a RESTful format to another "who" resource, containing the full contact information. The advantages of the RESTful approach are that it is simple, easy to understand, and scalable. The main features of the architecture are: a) Everything is represented as a resource; b) Each resource has a unique URL; c) Resource state is maintained on the server (but not application state); and d) Hyper-Text Transfer Protocol (HTTP) methods (post, get put, delete) are used to create, retrieve, update, and delete a resource.

Figure 2 is a CDEP XML message illustrating how to represent a decision that has progressed to the phase where some options are under consideration. Here, RADM Jones has found two potential ships near the search area, the USS Valley Forge and the USS Sentry. At this point, confidence is medium and the decision-maker, RADM Jones, has entered the information-analysis state but has not yet made a decision.

Figure 3 shows a CDEP XML message illustrating how to represent a decision in which the options have been considered, pros and cons have been listed, and one of the options has been selected. Here RADM Jones has considered the pros and cons of the available options and selected the USS Sentry because it is closer to the search area than the USS Valley Forge, and time is of the essence in search and rescue. At this point, confidence is high and the decision-maker, RADM Jones has started a decision product in the form of a task order.

Figure 3 is only one of many ways to represent the same information using the CDEP format. More complex examples are available from the authors, which include representation of sub-decisions in a recursive style.

IV. DESIGN OF A DECISION-ACQUISITION SYSTEM

This section describes components of the decision-acquisition system, major design considerations, the risks and the most challenging aspects of the design. Such a system will require intelligent software, such as a KASER [18] capable of providing automation that does not irritate the user and the decision maker. This is among the most important human-factors considerations. The main risk is that no one will use it if it is too obtrusive to the decision maker. The system will need to detect topics and fill in the XML format automatically. The human-computer interface must learn what the decision maker is doing and detect the stage(s) of the decision-making process automatically. A CDEP-based system must have the means to communicate the decisions, relate them to other decisions, relate them to current data, and provide useful support to training, planning and other functions. The CDEP will enhance the not only the speed of training and shorten the learning curve, but it also will enhance the content of network communication. The CDEP and any decision-support system based on it must function on a network as a network service.

The protocol does not target a specific domain for the format per se, but the team is most immediately interested in applying the model to the military domain. Applications of CDEP may include the larger context of the users' working environment, users' needs and their expectations. One such environment is the Global Command and Control System and its various service-specific versions.

A network-based tool could be developed, implementing a mixed-initiative paradigm, where the system provides some suggestions to the user and the user provides feedback to verify or correct the system. This decision aid would learn over time to capture the aspects of decisions that are important not only for future training and analysis, but also to an evolving current Common Operating Picture. A CDEP-based system, such as the system depicted in Figure 4, could support training through a user-friendly interface. Such a system could influence how a user approaches making decisions by offering examples of alternate approaches in a single training tool, which is a major advantage of a repository of documented decisions.

Decision styles vary considerably among commanders. Each decision style has its advantages and disadvantages. The one that is best depends on the specific task and the decision deadline. A CDEP tool could capture the users' general decision styles; the information users need to perform their tasks, including the pedigree metadata to reduce uncertainty in situational awareness; the alternatives generated in the decision process; and the reasoning the decision-maker used to arrive at a decision. A system based on the CDEP could enable war fighters in the naval and joint forces to have a new, effective tool to help them in their decision-making, which is such a critical factor in achieving mission goals.

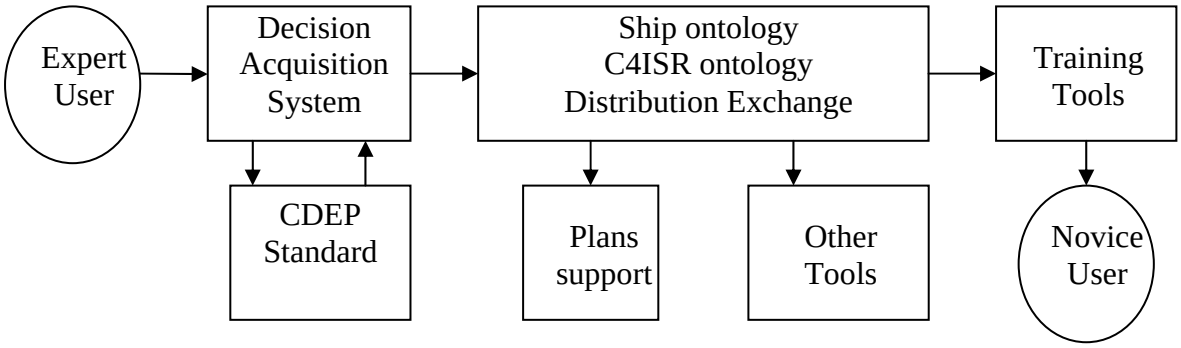

Figure 4. Block diagram of CDEP-based decision –acquisition system with support to training, planning and other functions

V. FUTURE SANDARDIZATION, RESEARCH, DEVELOPMENT AND APPLICATIONS

This paper represents an initial proposal for a Common Decision Exchange Protocol and as implied, much work remains. First, this work should be proposed and promoted under the auspices of an open-standard body. Second, specific details remain to be determined, including the representation of context and the details of the enumerations and sub-formats, for example, the "who" references. Third, the tags should be modified to align with existing data models, such as NIEM, CAP, RSS, and Dublin Core. Fourth, a reworking of key free-text tags, such as <question> and <idea> is desired. The text in these tags is understandable to a human but not to a computer. Free text is not an adequate format for effective knowledge representation. At a minimum, an optional format leveraging the Resource-Description Framework should be provided for these tags so that more expressive knowledge-representation concepts, such as ternary predicates, such as subject-verb-object, can be used. These more expressive formats enable the information to be managed efficiently in computer knowledge bases for inferencing. Another enhancement to the CDEP would be to include the weighted criteria for making the decisions.

Apart from the specific details outlined above on how to enhance and standardize the CDEP itself, applications of CDEP needs to be tested in the larger context of the war fighters' working environment, war fighters' needs and their expectations. One such environment is the Global Command and Control System (GCCS) [20] and its various service-specific versions. To obtain a consensus of acceptance among the user community, any software tool that instantiates a CDEP-based protocol will need to be designed to avoid undue burden on the already overworked users. No user wants a tool that makes an operations-oriented job more labor intensive in return for better decision-data archiving for future training and analysis studies.

Therefore, a software tool based on artificial intelligence, such as an expert system or a system of intelligent agents could be best suited to learn and understand the users' tasks, capture the information about these tasks with minimal user input, and present interim results to the user who then could verify the information through a user-friendly interface. Thus, a tool could be developed based on a mixed-initiative paradigm where the system provides some suggestions to the user and the user provides feedback to verify or correct the system. This decision aid would learn over time to capture the aspects of decisions that are important not only for future training and analysis, but also to an evolving current COP.

Decision styles vary considerably among commanders. For example, some decision makers like to consider a large amount of data and formulate many alternate conclusions and courses of action, whereas some like to consider a smaller data set and arrive at a single course of action. Others prefer to consider many data sets and arrive at a single course of action. Still others like to limit the size of the data sets and generate multiple courses of action. [5], [6], [7]. Each decision style has its advantages and disadvantages. Which one is best depends on the specific task and the decision deadline. For example, the tool could capture the following aspects of the decision process:

- The users' general decision styles,
- The information users need to perform their tasks, including the pedigree metadata to reduce uncertainty in situational awareness [3],
- The alternatives under consideration in the decision process, and ideally,
- The reasoning the decision maker used to arrive at decisions.

A CDEP-based system available to users across the secure network via a user-friendly interface could support operations and training. Such as system could influence how a user approaches making decisions by offering examples of alternate approaches in a single training tool. This is a major advantage of a network-accessible repository of documented decisions, and a major advance in the evolution of command and control.

VI. CONCLUSION

A Common Decision Exchange Protocol (CDEP) has been proposed and recommended in this paper. The purpose is to create a sharable format for capturing and exchanging the essential information underlying decisions. The goal is to allow the decisions of our most valuable resource, our employees, to be represented and managed effectively. The format relies heavily on previous research on how to represent challenging problems. The format includes concepts of decision state, incorporates RESTful concepts for efficiency and visibility, and includes a hierarchical recursive representation of decisions and sub-decisions that enable flexibility and expandability to multiple levels of decision making.

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