Developing a transition path for ARPI technology into the Air Campaign Planning Domain

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Abstract

The ARPA / Rome Laboratory Knowledge Based Planning and Scheduling Initiative (ARPI) has been a major source of support for new and evolving research in planning, scheduling, and related fields ever since its origins in 1989 and Desert Storm / Desert Shield. ISX has been involved in the initiative since those early days and continues to be involved during Phase III (beginning in June of 1995) with the role of identifying and building transition paths for maturing technologies into the domain of Air Campaign Planning (ACP). The primary elements in this transition path are described in this paper and include the following:

- Building, distributing, and supporting ACP domain knowledge and data in ACP "Domain Packages";
- Building and supporting a "Testbed Environment" to support designing, conducting, and evaluating Technology Integration Experiments (TIEs);
- Coordinating and supporting the development of Integrated Feasibility Demonstrations (IFDs) of operational prototypes for key user communities.
- Providing a World Wide Web (WWW) based coordination and information management environment to better serve and support the initiative community.

ARPI Phase III Facilitation Focus

Introduction

As Phase III Facilitation Contractor for the ARPI, ISX is responsible for the identification and facilitation of technology transition from the ARPI community into an operational domain. The Air Campaign Planning domain was selected as the target domain for IFD-4 scheduled for completion in early summer of 1996.

In order to expedite the technology transition process, ISX has identified and is pursuing four primary activities described below.

The first primary support activity is to provide a link from the operational community to the ARPI in the form of key data and knowledge necessary for the ARPI community to refine and hone their individual technologies. The use of this operationally oriented data and knowledge helps to ensure technology applicability to problems of operational concern. As part of this process ISX is providing coordinated and documented access to both internal and external domain experts. The result of this activity will be a detailed Domain Package for use by the ARPI.

The second major activity is to provide a testbed environment that supports the collaborative experimentation within the domain by the research community. The basis for this testbed will be the existing, operationally relevant and accepted Air Campaign Planning Tool (ACPT).

The ACPT testbed will further provide the basis for the integration of the results from several Technology Integration Experiments (TIEs) to produce an Integrated Feasibility Demonstration with operational significance to the user community.

Lastly, ISX will be providing a World Wide Web (WWW) based collaboration and information management environment for the ARPI participants and management. The goals of this environment include improving general visibility and understanding of the goals and activities within the initiative, fostering easy information archive and interchange, aiding in the identification of common areas of interest and/or concern, helping in identifying and supporting collaboration opportunities, and providing an improved management environment for the ARPI management team as well.

A primary driver for the development of the Phase III plan were the lessons learned from the earlier phases of the ARPI. These lessons included:

- The need to provide the ARPI participants direct access to a broad range of domain experts, leveraging the results of these activities back to the initiative as a whole.
- The need to let the community drive the requirements and thus, to a large extent, the design for the collaboration environment.
- The need to formally identify, support, and evaluate Technology Integration Experiments as a primary, scheduled aspect of the initiative.
- The need to identify and dynamically manage the "balance point" between the desire for technology insertion and the user community interest in a robust, focused solution to an operationally significant problem.

The work described in this paper represents the planned activities for ISX during Phase III of the ARPI and the first 4 months of that implementation. As such, much of the described plan has not been executed and thus, the plan and its implementation will evolve over the course of the ARPI.

Domain Package Support

Because of prior experience in the Air Campaign Planning (ACP) domain, ISX Corporation is providing the ARPI community with an accumulation of years of experience in this domain. Over the past three years, ISX has established relationships with experts in the field and augmented our own staff with ACP domain experts. These experts are now being provided as domain expert resources to the community. In addition, we are providing the ARPI with the Air Campaign Planning Tool (ACPT), scenarios, source material, and data sets.

ISX's Knowledge Acquisition (KA) goal for the ARPI project is to expand the ACP domain expertise of those participating in the initiative through direct and focused interaction between ACP experts and the ARPI community. We are leveraging time with experts by encouraging joint KA along common themes and providing access to information and models summarizing sessions.

Knowledge Acquisition Process

The KA process is illustrated in Figure 1. To initiate the process, ARPI participants have submitted their KA requirements to the KA coordinator. Because the knowledge and data requirements of the groups within the initiative are different, it is important to build a requirements profile for each member. Once these requirements have been identified and prioritized, a schedule is proposed. As the requirements change, the schedule is adjusted to accommodate new needs of the researchers.

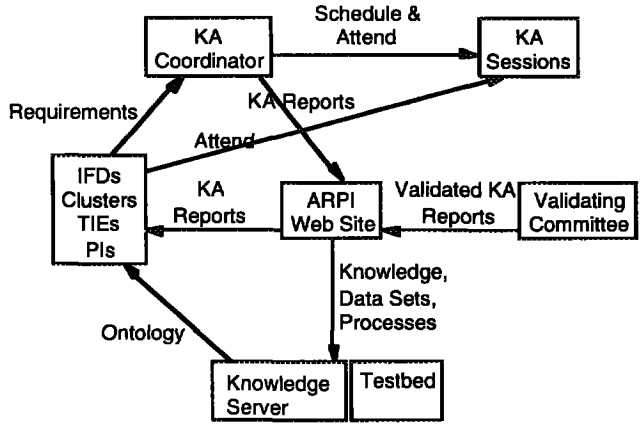

Figure 1: ARPI KA Process

Scheduled sessions have been attended by individual Principal Investigators (PIs) and key developers. Those who can not attend the session but are interested in the results find detailed session reports and products in the ARPI web site (discussed in a later section).

The session reports and models are later validated by the experts involved in the KA sessions to assure accuracy.

The session reports, models and data sets resulting from these sessions will contribute to the knowledge server. The knowledge server will be accessible through the testbed and by the PIs through the ontology which is being developed by the Plan Ontology Construction Group and refined by IFD-4 participants.

Data / Information Repository

The KA repository (Figure 2) is accessible from the Domain Packages topic on the ARPI home page (http://arpi.isx.com).

The repository includes KA information about:

- Schedules
- Plans
- Meeting/interview summaries
- TIE requirements
- IFD requirements
- Cluster requirements
- Domain and related documents
- KA Requirements Summary Matrix.

Dotted lines in Figure 2 indicate features which are still under development at the time of this article.

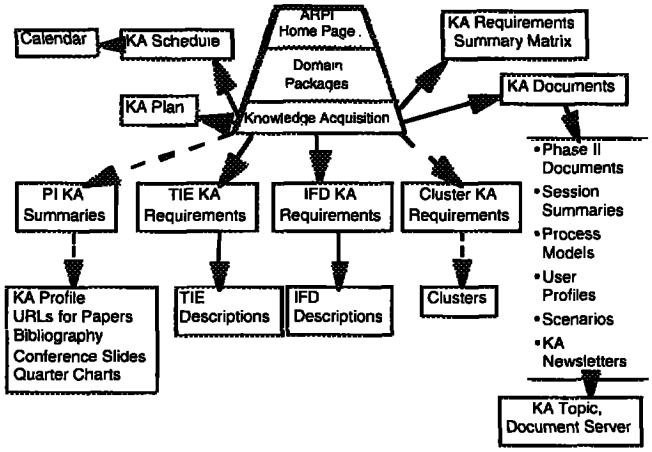

Figure 2: ARPI KA Repository

The Calendar is a mechanism for communicating the KA schedule. An additional mechanism for communicating the schedule high-level summary information is the ACP KA newsletter. The newsletter, published bi-monthly, summarizes the past two weeks and the next two weeks of related activities.

The KA Plan is also accessible from the repository. For a detailed description of the KA process, refer to this document through the ARPI home page.

In order to make the individual PIs research topics more accessible, each PI will have a location for their project information requirements, Quad Charts, conference slides, research summaries, bibliographies and pointers to their project or personnel home pages.

Along with the individual PI requirements, KA requirements generated from TIEs, IFDs and Clusters is also captured and addressed in the repository.

The KA Summary Matrix lists the PIs, their requirements, the priority of the requirements, and the results which satisfied those requirements. The matrix is a mechanism for quickly viewing the status of the knowledge acquisition process and is dynamically generated from database entries and displayed using an HTML/WWW interface.

The KA topic within the initiative Document Server organizes session reports, ACP models, ACPT literature, related ACP documents, scenarios, user profiles, and KA newsletters as well as all Phase I & II documents.

ACPT Testbed

To facilitate the demonstration and evaluation of the advanced planning technology being developed under the ARPI program, ISX is developing a software testbed based upon their Air Campaign Planning Tool (ACPT). The development will be done in three distinct phases.

The product of the first phase testbed development phase will be a World-Wide Web accessible Air Campaign Browser which will support the domain familiarization process. The researchers will be able to remotely access examples of air campaigns that were developed using the existing ACPT software.

The next phase in the development of the testbed will be to distribute the ACPT testbed to the research sites. This will allow the researchers to continue their familiarization with the Air Campaign Planning process and also allow them to begin experimenting with how their advanced planning systems could be applied to that process. Initially, ISX will distribute the software agents of ACPT with the exception of the plan object repository and the air target database which will be maintained at one or more central locations. Finally, ISX will provide a low-cost, low-maintenance versions of the plan object repository and air target databases that can be run locally at each researcher's site.

Phase 1: Air Campaign Plan Browser

As stated above, the goal of the first development phase of the testbed is to provide the researchers with a facility that will allow them to remotely browse Air Campaign Plans that were developed

using ACPT. In addition to aiding the researchers in their familiarization of the Air Campaign Planning domain and process, it will also prove to be useful in the future as a mechanism enabling researchers to share plan results with others at remote sites, thus enabling joint experimentation and collaboration.

ISX will take advantage of the capabilities of the World-Wide Web as a distribution method for viewing Air Campaign Plans. By using one of the publicly available Web browsers, the researchers will be able to browse the Air Campaign Plans stored at a remote site. A set of tools will reside at that remote site which will be responsible for accessing the plan object repository, formatting the plan elements for display, and returning the requested information to the user. Initially, these tools will reside only at one or more ISX sites but ultimately will be available for distribution to each researcher .

Phase 2: Local ACPT Agents with Remote Repositories

In the second phase of development, it is ISX's goal to provide each research site with a local copy of ACPT to allow them to continue their familiarization process and also to begin integrating their planning technology with ACPT. Unfortunately, the software environment that is required to support an installation of ACPT includes several COTS products that are prohibitively expensive in terms of both cost and their local maintenance and support. In an effort to relieve the research sites from this burden, ISX will extend the agent-based architecture of ACPT in order to allow the agents to be distributed over a wide-area network. This would allow the majority of the agents to operate locally at the research sites while the agents requiring the costly software could be run at one or more ISX sites and be accessible to the research community. Both the plan object manager/repository and the target mediator/ database will be among the agents operating at the central ISX site(s). In addition to the cost/maintenance benefits, this centralization will also enable sharing of plan elements among the researchers facilitating better collaboration. A possible drawback to this agent distribution could be in the area of performance when accessing plans or targets remotely. During this phase, ISX will work to reduce any performance degradation. For extreme cases, Phase III of our plan will support our very high bandwidth user community. Figure 3 illustrates a prototype version of the ACPT client running through a WWW interface.

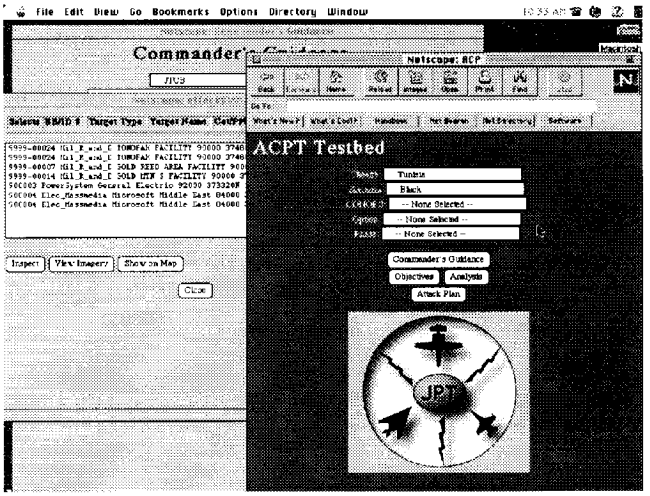

Figure 3: ACPT WWW Client

Additionally, ISX will provide the researchers with the tools necessary to integrate their advanced technology into the testbed. Part of this effort will require collaboration between the IFD-4 development group, the Plan Ontology Construction Group (POCG), and rest of the researchers in order to define a common plan representation that will allow their advanced planning systems to share plans between themselves and with the ACPT testbed. To facilitate the communication within the testbed, ISX will develop and distribute both C++ and Lisp versions of the underlying software interfaces to the plan object manager.

Phase 3: Local Low-Cost ACPT

This final development phase of the testbed will add low-cost versions of previously remotely accessed agents allowing the testbed to be run entirely at the researchers' sites. In particular, ISX will modify the plan object manager to use several optional object repositories including a low-cost object-oriented database and will also enhance the target mediator to allow access to a low cost relational database.

The phasing and focus of this last development phase will be driven by the success of the

previous two as well as the specific and evolving needs of our user community.

It is the author's belief that the successful use of the ACPT testbed during the ARPI as a web-based collaborative integration and testing substrate for functional components or agents could indicate a paradigm shift in the way that distributed, collaborative, system development will be done in the future.

Integrated Feasibility Demonstrations (IFDs)

Integrated Feasibility Demonstration should be seen as the Initiative's opportunity to demonstrate progress toward transitioning advanced technology into operational systems. The primary objectives are:

1. To demonstrate advanced technology transfer from the ARPI into an operational domain.
2. To address key operational bottlenecks or hurdles with those technologies - up to and including facilitating operational paradigm shifts.
3. To measure various technologies against complex, demanding, real-world applications.
4. To demonstrate a pipeline of technologies at various levels of maturity that can be used to excite and engage the operational community in planning follow-on.

Technology Transfer Process

The process of Technology Transfer is key to the goals and activities of ISX in Phase III of the ARPI. In short, the concept is to aid in the operationally oriented development of technologies by providing key data and knowledge in the form of a "Domain Package." Technologies that demonstrate a level of maturity and relevance to operational domain problems through TIEs may be selected to support an IFD. If an IFD is successful in addressing a key operational problem and the user community is willing to endorse and support the activity further, the IFD or its contained functionality may transition into user developed and user supported prototypes. This span of activities defines the transition of technology from Tier 1 to Tier 3 as depicted in Figure 4.

Integrated Feasibility Demonstration 4

At the time of this article, IFD-4 is in the design phase and thus, the description provided below is subject to change but represents our best view of that activity at that time.

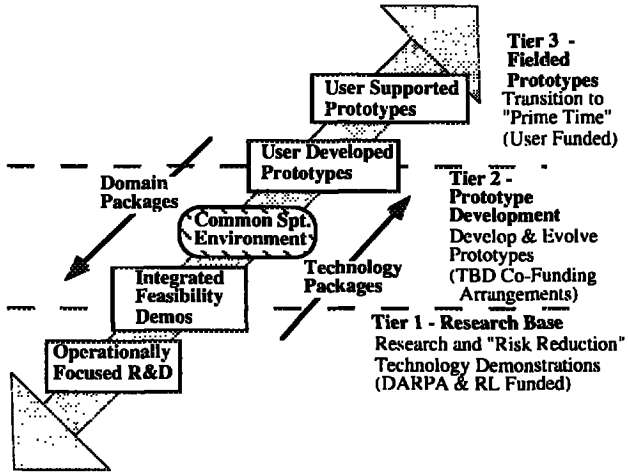

Figure 4: Technology Transition Process

IFD-4 is being built around three levels of demonstration. The Core Demonstration will be the centerpiece of the IFD, and will utilize the SOCAP Generative Planner from SRI to plan objectives decomposition within ACPT. In constructing the IFD Core Demonstration, SRI, ISX, and Checkmate staff are engaging in a user-centered "mini application development" project. By building the demonstration around a fairly complex real-world problem, and by building that application in a manner that allows the planning process to be open and inspectable, we will be able to demonstrate that SOCAP has both significantly advanced the state of the art in planning, and that it is "ready for prime time."

The second tier of the IFD demonstrations involves a small set of "critical experiment TIEs." These TIEs represent technology components that appear to be very close to "Core Demo" capability. The Critical Experiment TIE is serving as the first application of these technology components in a real user's work process. While these demonstrations will be similar in nature to the Core Demo, the level of investment will be less than a full scale "mini-application," and the demonstrations will be correspondingly smaller in scope. Those involved in the second tier currently include the EXPECT system from ISI and TACHYON components from GE. We are also considering evaluating the SAGE briefing generation tool from the ARPA Human Computer Interactions

(HCI) initiative as a Critical Experiment TIE for this IFD.

The third level of IFD demonstration is a "Technology Sidebar" that provides an opportunity for a wide range of technology providers in the initiative to showcase their wares to operational users. Each participant of the Technology Sidebar will provide 1) a clear example of the technology's application to a real-world, domain-oriented problem and 2) a clear roadmap describing when the technology is expected to provide useful products. The Tech Fair demos will include demonstration outside the ACP domain. The Kestrel work in transportation scheduler synthesis and the MITRE FORMAT in case-based force module application will likely be centerpiece demonstrations in the Technology Sidebar.

WWW Infrastructure

The ARPI World Wide Web Server currently under refinement at ISX provides facilities for both information distribution as well as information collection. Users are free to not only browse documents and data, but are also encouraged to expand the repository by uploading or revising documents and HTML pages. On-line tools such as the distributed calendar server, roadmapping server and mailing list archive facilitate collaboration between initiative participants while providing a repository for these interactions. The current repository contains items such as Technology Descriptions, Domain Documents and Knowledge Acquisition Session Reports.

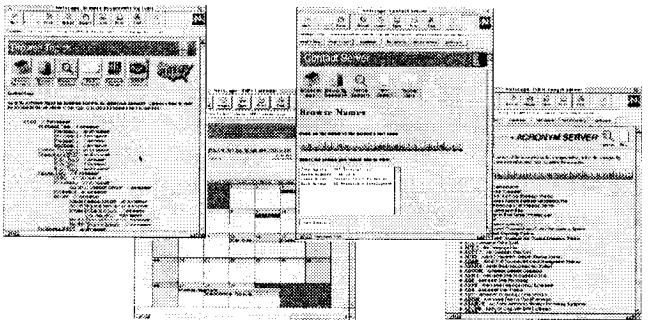

Figure 5: Sample WWW Server Screens

All services of the infrastructure are accessible from standard WWW browsers on multiple platforms. Some sample screens from this set of servers are illustrated in Figure 5 and is described in the remainder of this section.

Document Server

The Document Server acts as a repository for all initiative related documents, data files and pointers to both distributed internet resources and off-line hard copy resources. Entrees are organized in a hierarchical structure and can be located by either traversing the hierarchy or performing a search on the entree's description or keyword fields.

Initiative participants can publish items on the repository by uploading the source (Word, Powerpoint, Postscript, etc.), HTML, or data files; choosing where in the hierarchy the item goes; and entering the description. Documents can be restricted to a specific class of users (public, participant, government, etc.) and are protected with user ID's and passwords.

Calendar Server

The Calendar Server provides functionality for entering and viewing meetings and events. A graphical monthly calendar page displays all entrees for that month, and selecting one provides all pertinent information, such as location, agenda, sponsoring group and pointers relevant items in the document server. Events can be found by either scanning each month or searching on keyword fields.

Contact Server

Initiative participants are registered in the Contact Server database. This service provides search capabilities and holds all contact information for the ARPI participants.

All ARPI mailing lists are currently administered through the contact server as well as supporting direct user subscription email group subscription.

Roadmap Server

The Roadmap Server provides a means for both researchers and sponsors to define realizable paths for promising technologies to affect solutions to critical problems. This facility lets users define experiments and TIEs as they relate to IFDs and other downstream technology transition opportunities. The technology push/domain pull relationship is graphically

depicted in the technology transition process, Figure 4.

Subscription Facility (Push, not just Pull)

The Subscription Facility provides a capability for users to "subscribe" to any item in the Web Server. By declaring an interest in a document, document classification, event or roadmap entree, a user will automatically be notified when an item is added or modified. For example, if a user is interested in KA Session reports, he would go to that topic in the document server hierarchy and select the SUBSCRIBE button. From then on, whenever a document is added to that topic area, or a child area, the user will be notified. This facility will keep users up to date on additions without forcing them to browse the web on a regular basis.

Events in the Calendar Server can be subscribed too as well, and users can be notified, for example, when meeting dates change. Roadmap entrees can also be subscribed too, so downstream participants can be immediately informed when dates on contributing TIEs or IFDs change.

URL

The current version of the ARPI WWW Server is http://arpi.isx.com. The ARPI home page is depicted in Figure 6.

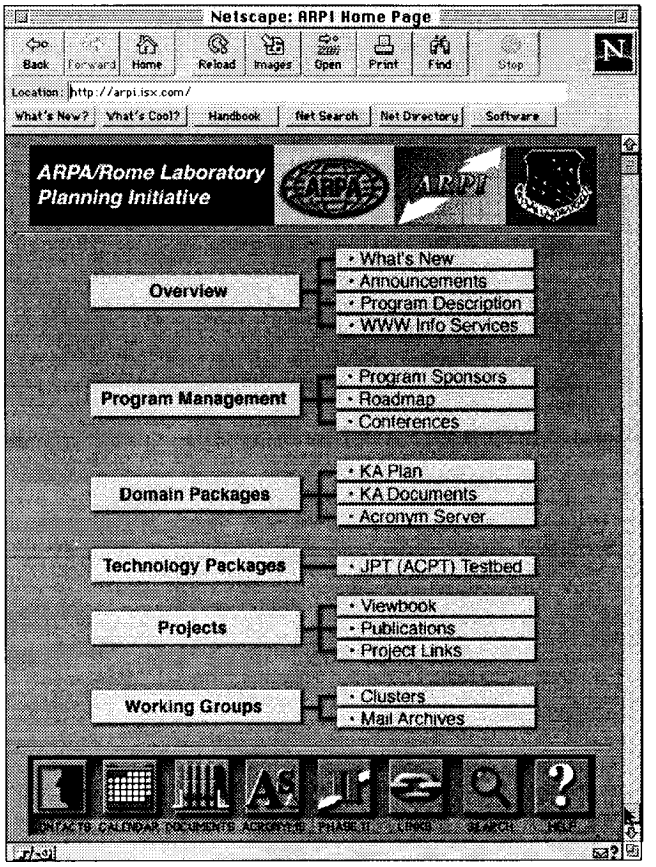

Figure 6: ARPI Home Page

Summary

This paper has described the role of ISX Corp. as facilitation contractor for Phase III of the ARPI. It describes the primary tasks being pursued, their goals, the relations to the ARPI community, and their current status. As a final point, it is worth noting that ISX firmly subscribes to the philosophies of rapid prototyping and user-centered engineering. Our customer within this program is the ARPI research community and as such, our goals, activities, and focus will be driven by that community and will evolve over the life of the program.