# ISLE: Intelligent Selection of Loop Electronics A CLIPS/C++/INGRES Integrated Application

*Lynn Fischer, U S WEST Advanced Technologies*
*Judson Cary, U S WEST Advanced Technologies*
*Andrew Currie, Bolder Heuristics*

## 1.0 Abstract

The Intelligent Selection of Loop Electronics (ISLE) system is an integrated knowledge-based system that is used to configure, evaluate, and rank possible network carrier equipment known as Digital Loop Carrier (DLC), which will be used to meet the demands of forecasted telephone services. Determining the best carrier systems and carrier architectures, while minimizing the cost, meeting corporate policies and addressing area service demands, has become a formidable task. Network planners and engineers use the ISLE system to assist them in this task of selecting and configuring the appropriate loop electronics equipment for future telephone services.

The ISLE application is an integrated system consisting of a knowledge base, implemented in CLIPS; a planner application, implemented in C++, and an object database created from existing INGRES database information. The embedibility, performance, and portability of CLIPS provided us with a tool with which to capture, clarify, and refine corporate knowledge and distribute this knowledge within a larger functional system to network planners and engineers throughout U S WEST.

## 2.0 Overview

The selection of Digital Loop Carrier equipment has a significant impact on network operations and business costs. In today's environment, the network planner faces a growing number of DLC equipment vendors and potential carrier systems. Perhaps more significantly, new carrier architectures (such as dynamic concentration and integration) have been introduced. Each system has different features, functions, capacities, and costs. Determining the best carrier system and architecture, while minimizing the cost, has become a formidable task. The planner must consider all possible choices, screen out incompatible solutions, and then rank the remaining contenders in a manner that optimizes functionality, minimizes cost, and meets corporate objectives. In addition, corporate policies set forth as guidelines for equipment selection need to be included in the planning process.

The ISLE system was developed to bring the appropriate knowledge to the network engineer and support the evaluation of many more DLC equipment options than previously possible. U S WEST network planners and engineers currently use ISLE to assist them in choosing the appropriate DLC electronics equipment and architectures when configuring equipment within a specific geographic area for future telephone services. The ISLE program assures that corporate policies are implemented and provides a thorough analysis of all applicable systems.

The ISLE system is an integrated knowledge-based system which is currently deployed on UNIX workstations in U S WEST Communications. The knowledge-base module of the system was developed using CLIPS, an OPS-like, rule-based language implemented in C. The control module was written in C++ with interfaces to INGRES/SQL databases.

## 3.0 The ISLE system

The major functionality of the ISLE system is to evaluate telephone service requirements and produce recommendations about DLC equipment which has optimal price and performance to meet those requirements. The ISLE system generates all potential DLCs or sets of various DLCs, evaluates those solutions, ranks the solutions, and determines the housing required for each equipment solution.

ISLE provides planners with the following information:

-A cost summary of all equipment/architectures and housing technically capable of providing the forecasted service for the geographic area.
-A configured parts listing for the recommended DLC system(s).
-Economic comparison graphs for potential DLCs.
-Comments on corporate strategies related to DLC equipment.
-Service capabilities of a given DLC system.
-Engineering information and assumptions used to configure DLCs.

Some of the benefits derived from the ISLE system are:

- improved decision-making in the planning process with the result of more effective and cost-efficient DLC installations
- consistent application of corporate guidelines
- increased productivity for planners
- superior training for planners with an accelerated learning curve for the design process.

By developing a uniform process for carrier design, planners throughout U S WEST benefit from the knowledge of the company's expert engineers coupled with the assimilation of large amounts of data collected over many years and stored in the U S WEST engineering databases. Planners can more thoroughly and quickly evaluate equipment configurations, ultimately arriving at a better solution. The previous manual approach to planning required the planner to complete many computations and search the databases for information. Even after that time-consuming process, the planner still did not have the benefit of the knowledge collected and delivered by ISLE. Delivering that expertise on an on-going basis shortens the learning curve for planners, both new and experienced, by systematically increasing their awareness of new solutions and corporate polices in the planning process.

## 4.0 ISLE Architecture

ISLE is an integrated system which uses the CLIPS rule-based system, C++, and information from INGRES/SQL databases, all running under a UNIX* operating system. Currently ISLE contains over 200 CLIPS rules, consists of 20 C++ modules, and uses data from two INGRES databases. The major components of the system are shown in Figure 1.

*UNIX is a registered trademark of American Telephone and Telegraph Co.

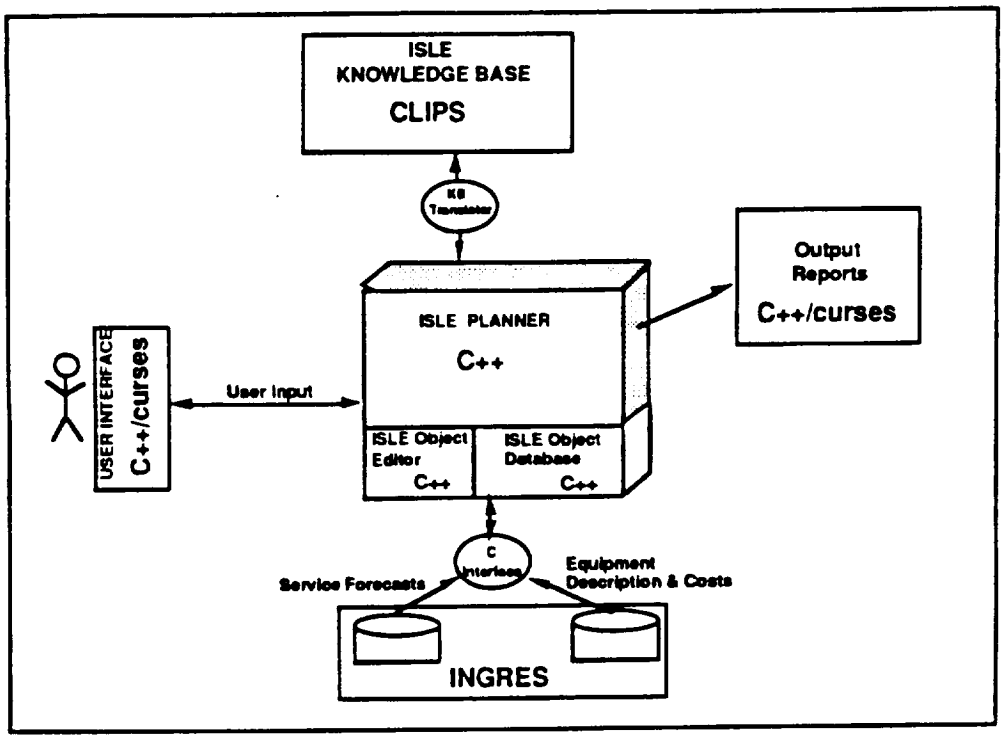


**Figure 1. Integrated Components the ISLE system**

The high-level program control is maintained by the C++ modules which call CLIPS for rule-based constraint satisfaction and equipment configuration. INGRES/SQL databases provide service forecast information, equipment descriptions, and costs. All DLC equipment, parts, and housings are represented as objects in C++. The user provides additional information concerning characteristics of the geographic area. ISLE then begins generating possible DLC solutions which can meet the forecasted service demand in the area. During the generation/evaluation process, various sets of CLIPS rules are invoked to eliminate or comment on various DLCs. Figure 2 is a high-level data flow which depicts the high degree of integration between the the C++ processes and the CLIPS rules.

ISLE relies on two INGRES databases which contain data related to the various equipment models, (eg. part ids, costs, modes) and telephone service forecasts for various geographic areas. ISLE uses SQL queries to several tables in these databases to retrieve information that is referenced by CLIPS rules. The data from the database query is fetched into a structure, then used to construct new C++ objects. When this information is needed by a ruleset that is about to be run, an assert method is called on one or more of these C++ data objects. This two step process also allows us to translate the data from the format and structure found in the INGRES tables to one more useful for the ISLE systems. In the course of rules firing, the CLIPS rules also generate information that must be returned to the C++ environment. For this task, ISLE has a special interface ruleset whose sole task is to pass back certain types of information (costs, comments, etc.) and create new C++ objects or revise that information in existing C++ objects.

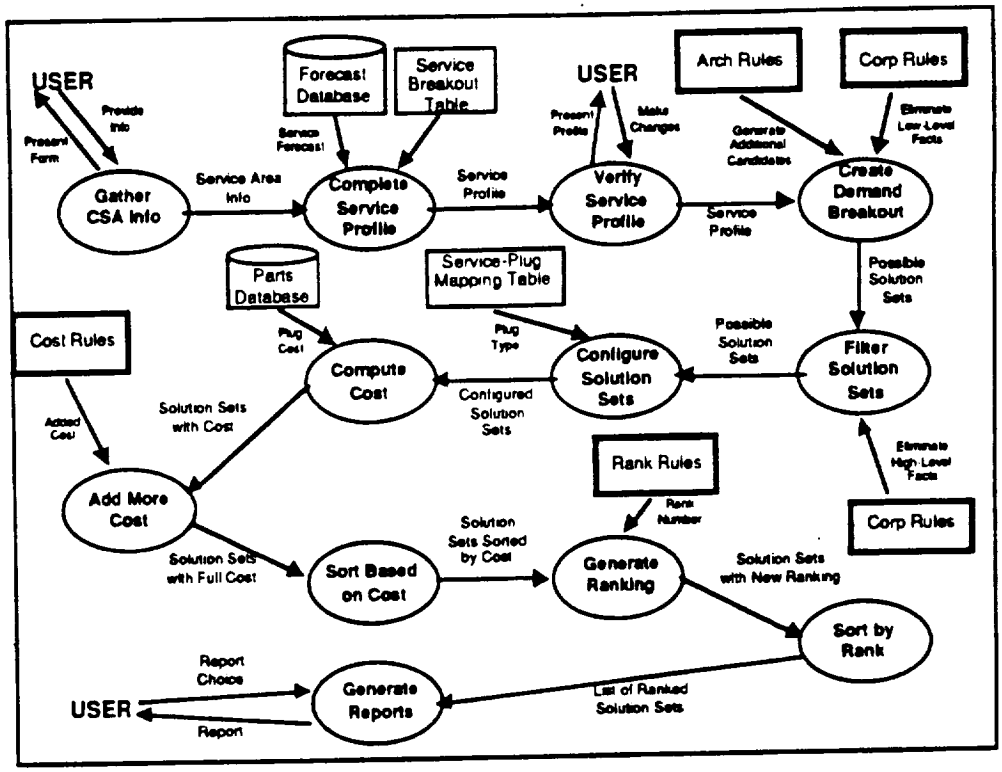


**Figure 2. High-level Data Flow of the ISLE System**

ISLE also contains some information that is not stored in databases, but is information necessary for the generation of solution sets of DLC equipment which can meet the telephone service forecast. Most of this information is a kind of "engineering expert common knowledge" that is best represented as association lists. An example of this information is the mapping of specific types of telephone services to the appropriate hardware components which support each service.

Most of the information that is required by the rules, but not available in U S WEST databases is obtained from the user through the use of simple menus and forms created using C++ and the curses package in UNIX. Some additional information may be required based on the user input to the ISLE forms. This information is obtained by direct query of the user from the rules themselves via a curses interface function exported to CLIPS. In all cases where ISLE is using data from the databases, or deriving data in some other way, the user is given the opportunity to inspect and change any data that does not seem appropriate for the analysis. The data change task is performed by using object browsers written in C++ or using forms written in curses.

Currently all CLIPS rules remain in working memory during the entire ISLE session and context facts are used to activate the appropriate group of rules as ISLE performs its analysis. With this approach, CLIPS performance (i.e. speed and memory usage) has been acceptable to date, although some rule optimization has been necessary to work within memory constraints and maintain an appropriate total run time. This is especially true when ISLE is used to analyze geographic areas with more than 1000 service lines. Such a scenario can generate over 500 different types of objects which must be evaluated by the CLIPS rules. The likely introduction of new types of DLC or different architectures could significantly increase the number of objects in CLIPS working memory and dramatically impact the system performance.

## 5.0 ISLE Knowledge base

The ISLE knowledge base contains knowledge related to corporate policies, equipment limitations, and qualitative costs. The knowledge represented in ISLE is well-suited to representation in a rule structure. The following is a typical ISLE rule along with the CLIPS representation:

If integration architecture is allowable in this carrier serving area
and the central office switch is a type-a
and the total number of lines forecasted exceeds 600
and no special services are forecasted or specials could be groomed to copper,
then Integration is recommended in this carrier serving area.

```
(defrule csa-integ-type-a-600
    (csa-integration possible)
    (csa-info-object ?idcsa co-switch type-a)
    (csa-service-forecast-object ?sfo total-forecast ?forecast-lines&:(> ?forecast-lines 600))
    (or (not (csa-service-forecast-object ?sfo total-specials  ?no))
       (could-groom-specials-to-copper))
=>
     (assert (csa-info-object ?idcsa arch-comment
     "Integration is recommended within this CSA for the following reasons:
       1. A type-a switch can be integrated.
       2. The service forecast is over 600 lines.
       3. The number of specials (non vf-asgn services) is insignificant."))
     (assert (csa-integration recommended)))
```

A wide variety of knowledge sources were required to obtain all the information necessary for the generate/evaluate task. Figure 3 identifies some of the information sources which were used to generate the ISLE knowledge base.

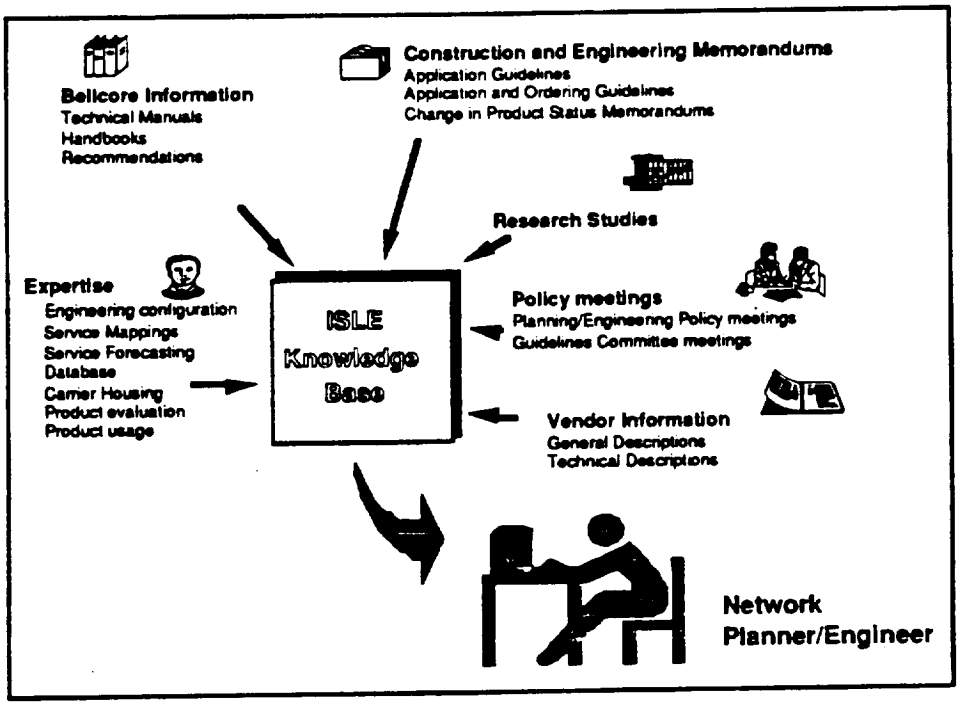


Figure 3. ISLE Knowledge-base Sources

The ISLE knowledge base is divided into five areas which focus on different concerns related to generation and evaluation of DLC equipment and housing. Those knowledge base subject areas are corporate rules, architecture rules, cost rules, housing rules, and rank rules.

**CORPORATE RULES** provide knowledge about which DLC electronics equipment is the most desirable in terms of future cost-effectiveness and viability. These rules focus on overall corporate strategies and also corporate policies on the use of specific carrier systems. This knowledge will encourage planners to explore unfamiliar solutions in planning for geographic areas and adhere to corporate guidelines.

**ARCHITECTURE RULES** help configure DLC candidates by providing knowledge about concentration and integration architectures at the individual DLC level, and identify the most appropriate configuration modes for a given DLC. Recommendations for integration architectures, remote switching units, and fiber use are made based on the general characteristics of a geographic service area.

**COST RULES** provide estimates of costs for factors such as training, installation, the number of T-lines and P-lines, and other expenses. Comments on qualitative costs are also provided.

**HOUSING RULES** define which type of housing can be used with a specific solution set. This cost is then added to the total cost of the solution set.

**RANK RULES** re-rank ISLE solution candidates based on factors other than cost, such as corporate strategies or equipment features.

## 6.0 Summary

In summary, ISLE is a system "that uses human knowledge to attain high levels of performance in solving difficult problems within a narrow problem domain". The U S WEST network planner is aided in the difficult problem of planning for geographic areas by the data and knowledge collected and assimilated within ISLE. The planner becomes more productive and the corporation benefits from higher-quality, lower-cost installations which fulfill corporate strategies and policies.

CLIPS provided an integral component to the overall business solution of the ISLE system. The versatility and portability of CLIPS allowed us to deliver the ISLE system on the user's chosen platform of UNIX. This approach also allowed us to integrate the system with C++ modules and existing INGRES/SQL databases on the delivery machine. In general, we have found that a majority of real-world AI business applications are best delivered as integrated business solutions, rather than stand-alone systems. CLIPS seems to allow for the high portability and integration with external systems necessary for production knowledge-based systems.