Chapter 16

Knowledge Application Systems: Systems that Utilize Knowledge

Chapter Objectives

- Describe knowledge application **mechanisms,** which facilitate *direction* and *routines.*
- Explain knowledge application **technologies,** which support direction and routines including:
  - expert systems
  - decision support
  - advisor systems
  - fault diagnosis (or troubleshooting) systems
  - help desk systems.

Technologies for knowledge application systems

- **Constraint-based Systems**
  - *Constraint-based reasoning*
    - problem solving technique that, when given a set of variables and constraints on these variables, can find a set of values that satisfy all the constraints.
  - *Constraint Satisfaction*
    - Constraint systems reflect what constraints restrict possible solutions.

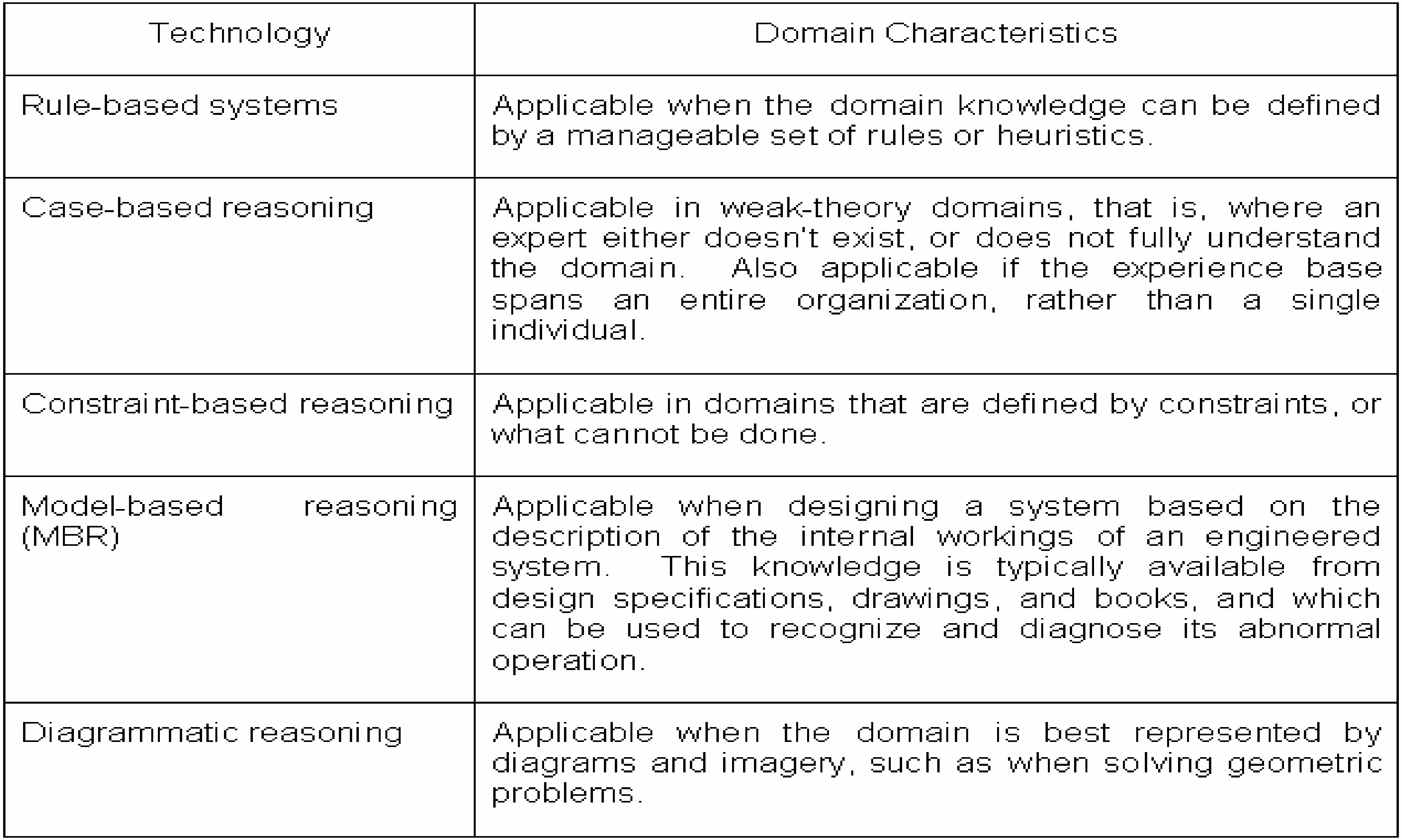
Technologies for knowledge application systems

- **Model-Based Reasoning**
  - knowledge about the internal workings of a *target system* can be used to recognize and diagnose its abnormal operation
  - incorporates generic troubleshooting procedures common to diagnosing many types of systems
  - can help diagnose faults not previously experienced
- **Diagrammatic Reasoning**
  - understanding of concepts and ideas through the use of diagrams and imagery, versus linguistic or algebraic representations
  - instrumental in developing systems such as Gelernter's Geometry Machine

Technologies for knowledge application systems

- **Variations of Case-Based Reasoning**
  - Exemplar-based reasoning: solve problems through classification
  - Instance-based reasoning: large number of instances (or cases) which are defined by a small set of attributes vectors.
  - Analogy-based reasoning: solve new problems based on past cases from a different domain

Summary of Technologies



Technology	Domain Characteristics
Rule-based systems	Applicable when the domain knowledge can be defined by a manageable set of rules or heuristics.
Case-based reasoning	Applicable in weak-theory domains, that is, where an expert either doesn't exist, or does not fully understand the domain. Also applicable if the experience base spans an entire organization, rather than a single individual.
Constraint-based reasoning	Applicable in domains that are defined by constraints, or what cannot be done.
Model-based reasoning (MBR)	Applicable when designing a system based on the description of the internal workings of an engineered system. This knowledge is typically available from design specifications, drawings, and books, and which can be used to recognize and diagnose its abnormal operation.
Diagrammatic reasoning	Applicable when the domain is best represented by diagrams and imagery, such as when solving geometric problems.

Table 16.1 Technologies for Knowledge Application Systems

Developing Knowledge Application Systems

- Typical case-based knowledge application system will consist of the following processes:
  - Search the case library for similar cases.
  - Select and retrieve the most similar case(s).
  - Adapt the solution for the most similar case.
  - Apply the generated solution and obtain feedback.
  - Add the newly solved problem to the case library.

Developing Knowledge Application Systems

- The CASE-Method:
  - System development process
    - to develop a knowledge application system that will store new cases and retrieve relevant cases.
  - Case library development process
    - to develop and maintain a large-scale case library that will adequately support the domain in question.
  - System operation process
    - to define the installation, deployment, and user support of the knowledge application system.

Developing Knowledge Application Systems

- The CASE-Method Cont’d:
  - Database mining process
    - uses rule inference techniques and statistical analysis to analyze the case library.
  - Management process
    - describes how the project task force will be formed and what organizational support will be provided
  - Knowledge transfer process
    - describes the incentive systems to encourage user acceptance and support.

Developing Knowledge Application Systems

- Sub-processes of developing the case library:
  - Case Collection
  - Attribute-Value Extraction and Hierarchy Formation
  - Feedback
- CASE Method in CBR development:
  - significant reduction in system development workload and costs
- Knowledge application systems:
  - apply a solution to a similar problem
  - serve as a framework for *creative reasoning*.

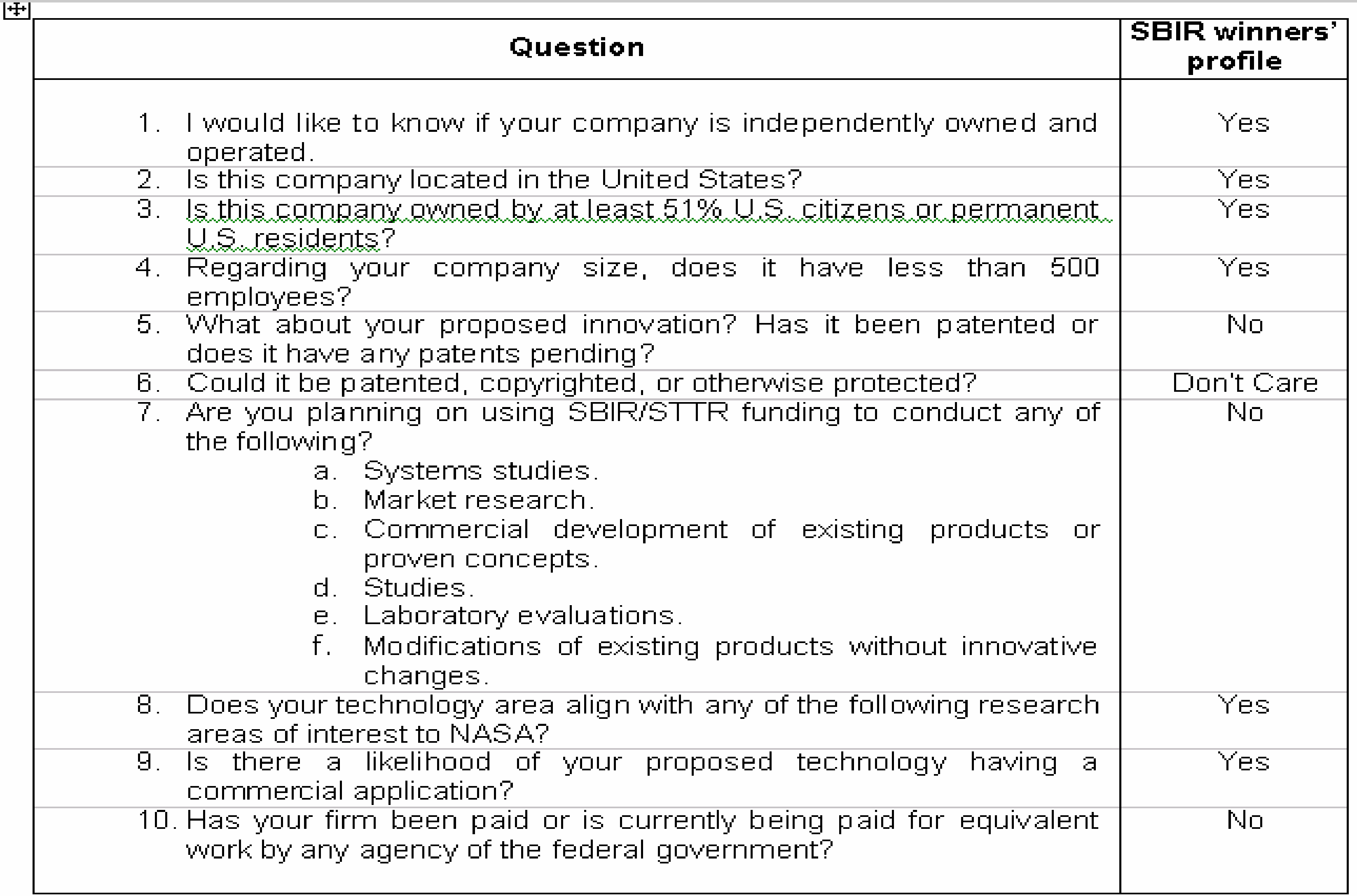
Developing Knowledge Application Systems

- Knowledge application systems enabled the implementation of decision support systems
  - to support design tasks in diverse domains such as architecture, engineering, and lesson planning.
  - *case-based design aids* (CBDA’s) help human designers by making available a broad range of commentated designs.
  - Case libraries accumulate organizational experiences, considered corporate memory.

Case Study: SOS Advisor

- The SBIR/STTR Online System (SOS) Advisor
  - Web-based expert system
  - identify potential applicants to the Small Business Innovation Research (SBIR) and Small Business Technology Transfer Research (STTR) programs
  - optimize the time required to examine the potential eligibility of companies seeking SBIR/STTR funding.

Case Study: SOS Advisor



Question	SBIR winners' profile
1. I would like to know if your company is independently owned and operated.	Yes
2. Is this company located in the United States?	Yes
3. Is this company owned by at least 51% U.S. citizens or permanent U.S. residents?	Yes
4. Regarding your company size, does it have less than 500 employees?	Yes
5. What about your proposed innovation? Has it been patented or does it have any patents pending?	No
6. Could it be patented, copyrighted, or otherwise protected?	Don't Care
7. Are you planning on using SBIR/STTR funding to conduct any of the following? a. Systems studies. b. Market research. c. Commercial development of existing products or proven concepts. d. Studies. e. Laboratory evaluations. f. Modifications of existing products without innovative changes.	No
8. Does your technology area align with any of the following research areas of interest to NASA?	Yes
9. Is there a likelihood of your proposed technology having a commercial application?	Yes
10. Has your firm been paid or is currently being paid for equivalent work by any agency of the federal government?	No

Table 16.2 – SBIR/STTR Profile Framing Questions

Case Study: SOS Advisor

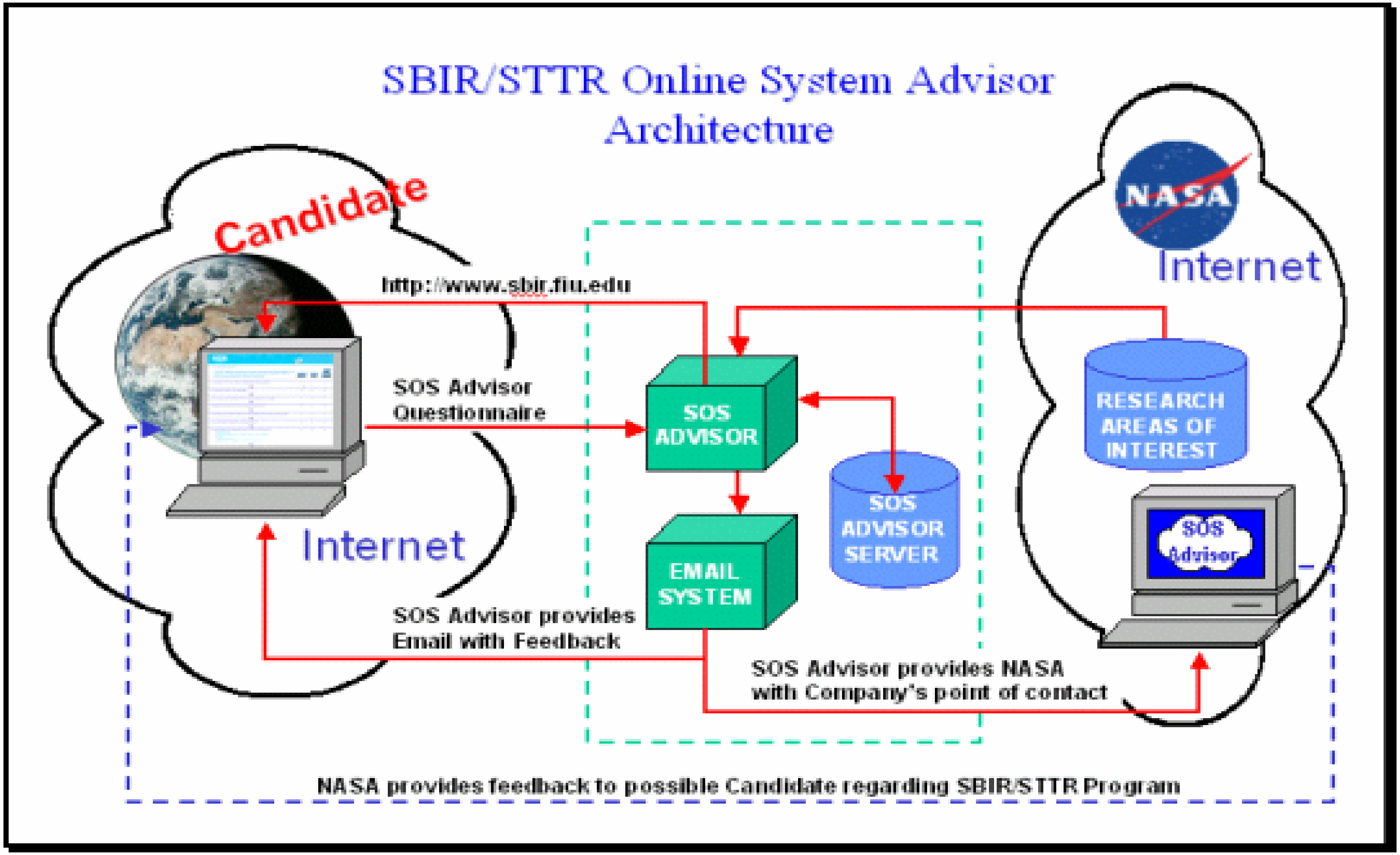
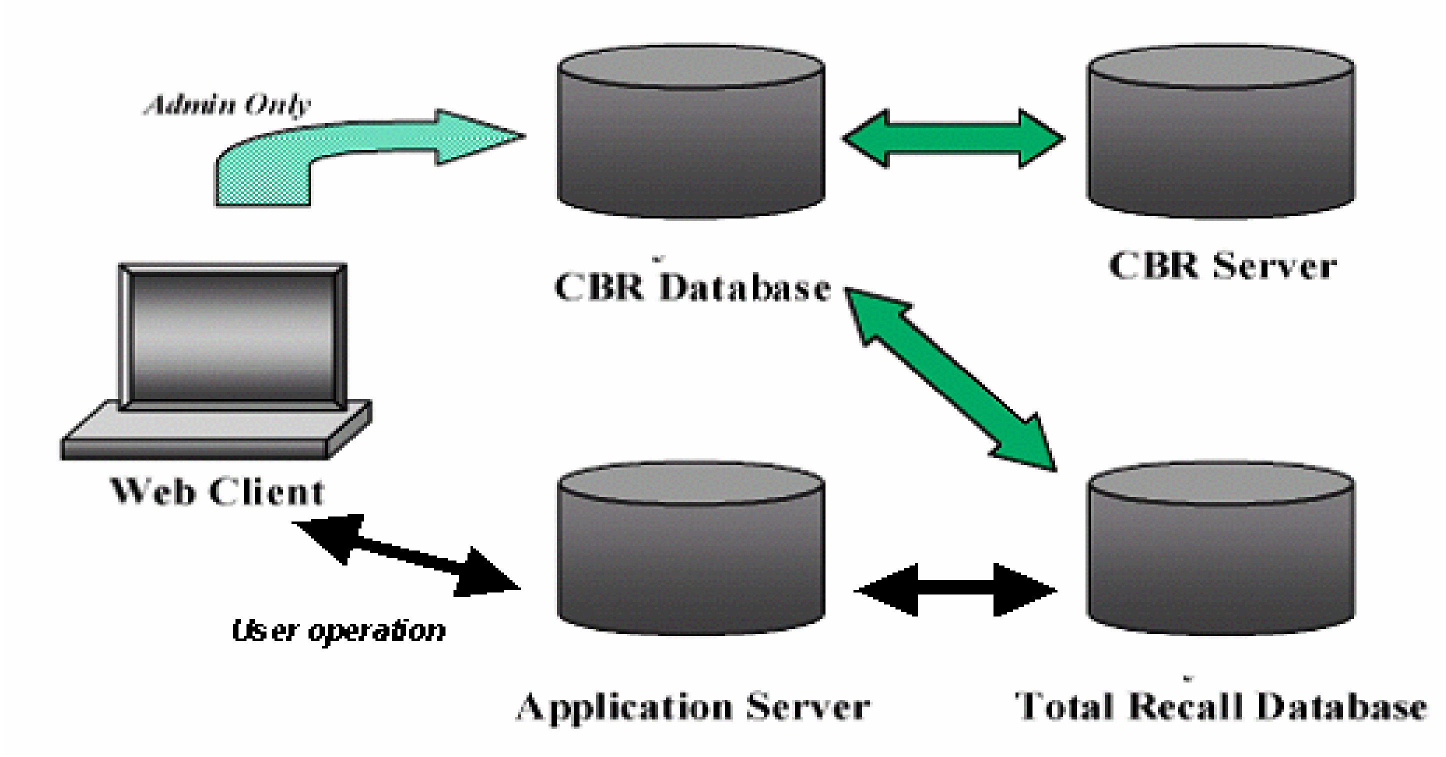


Figure 16.1 SOS Advisor Architecture

Case study: National Semiconductor

- Knowledge application system based on the use of case-based reasoning (CBR) technology for product quality assurance.
- *Total Recall*, can be viewed as consisting of four components and the Web client:
  - **Application Server:** Main server for the Total Recall application. Performs data manipulation and user presentation.
  - **Total Recall Database:** Maintains all the information related to the testing results of the PQA process.
  - **Case Library:** A separate database containing CBR representation of cases.
  - **CBR Server:** The final case library and CBR engine.

Total Recall System Architecture



Total Recall CBR Database

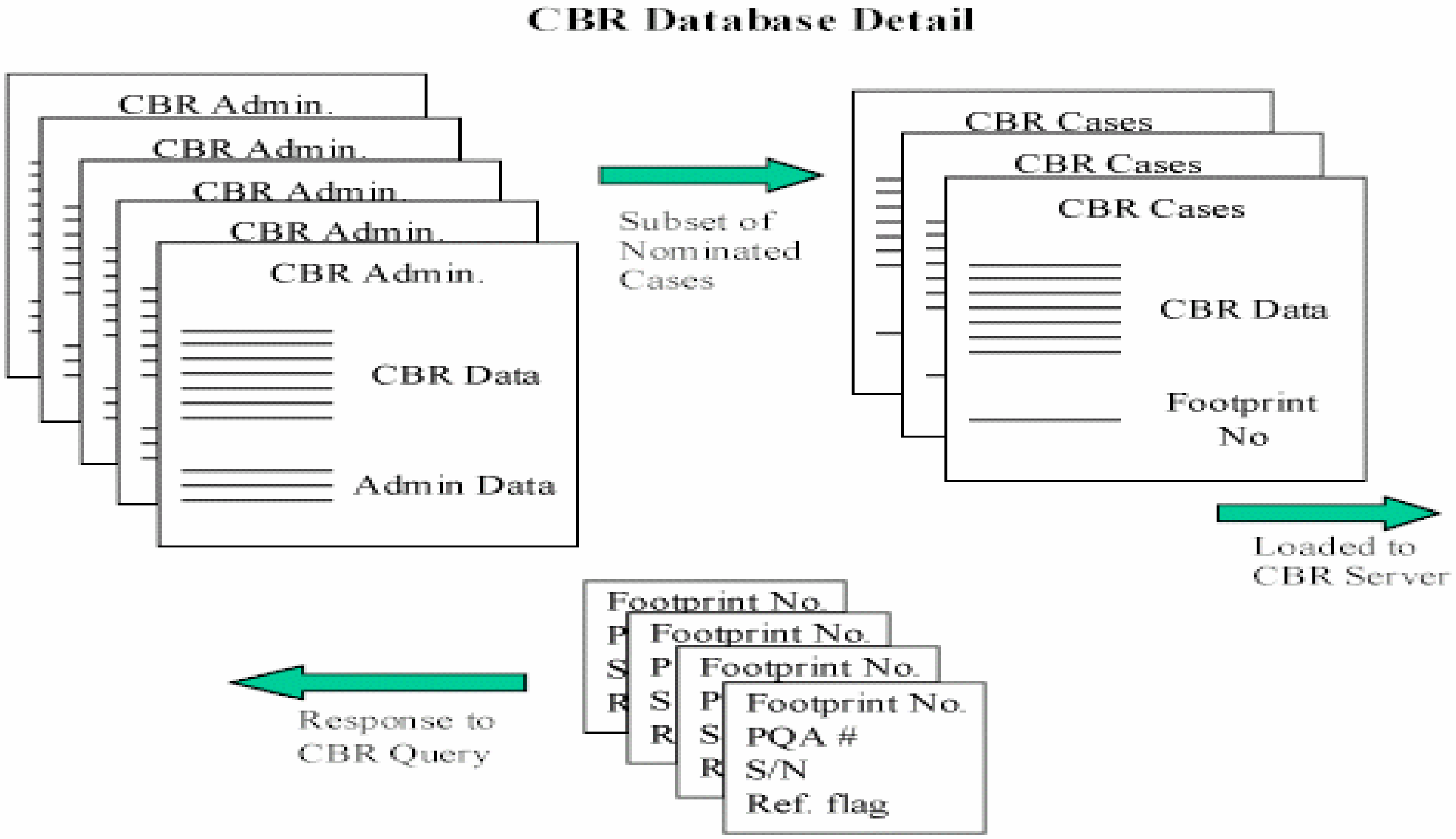


Figure 16.3 Details of the CBR Database [Courtesy National Semiconductor]

Case study: OFD for shuttle processing

- Out-of-family disposition (OFD) process deals with any operation or performance outside the expected range, or which has not been previously experienced.
- Shuttle Processing Directorate of KSC provides pre-flight, launch, landing, and recovery services for KSC

Case study: OFD for shuttle processing

- Creation of the case library:
  - Identify and establish a set of clusters to through analysis of their similarities and differences.
  - Identify a case title, a description, a set of characterizing questions and answers, and a resulting action.
  - Develop a set of descriptive questions for each case.
  - Add permutations of the OFD Problem Reports.

Case study: OFD for shuttle processing

- Case library must be validated to ensure the proper execution of the application:
  - *Disjunctions*: Disjunctive cases must be combined into a single case.
  - *Internal disjunctions*: A single case in a cluster containing multiple questions not answered in any other case in the same cluster.
  - *Subsumed cases*: One case being a logical specialization of another and having the same solution.

Case study: OFD for shuttle processing

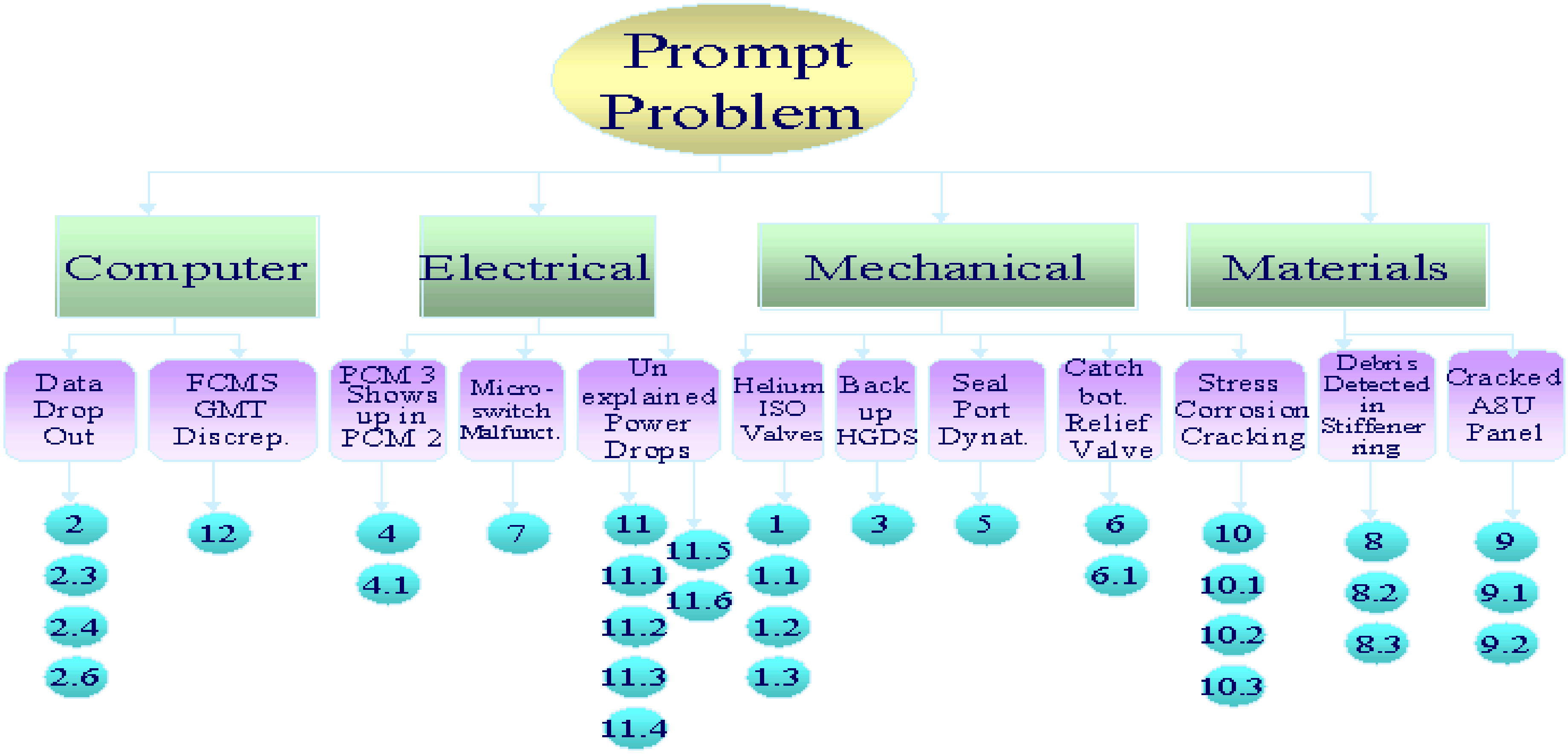
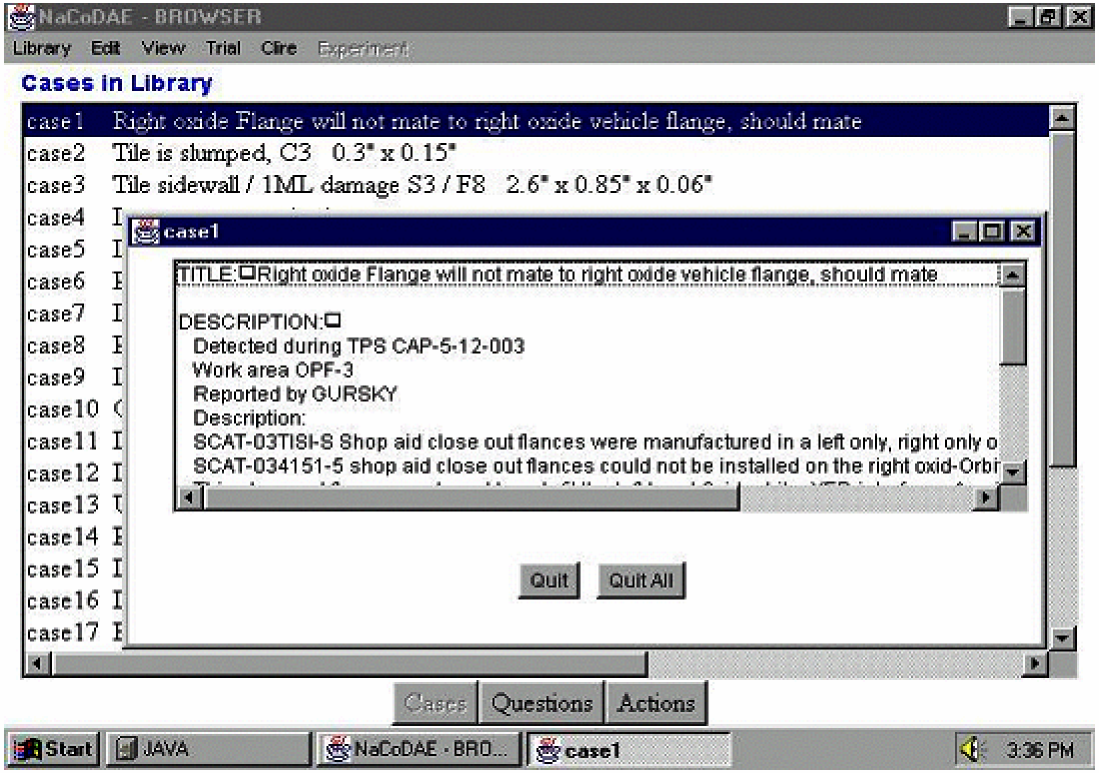


Figure 16.4 - Distribution Order Tree for the OFD Problem Reports

Case study: OFD for shuttle processing



Cases in Library

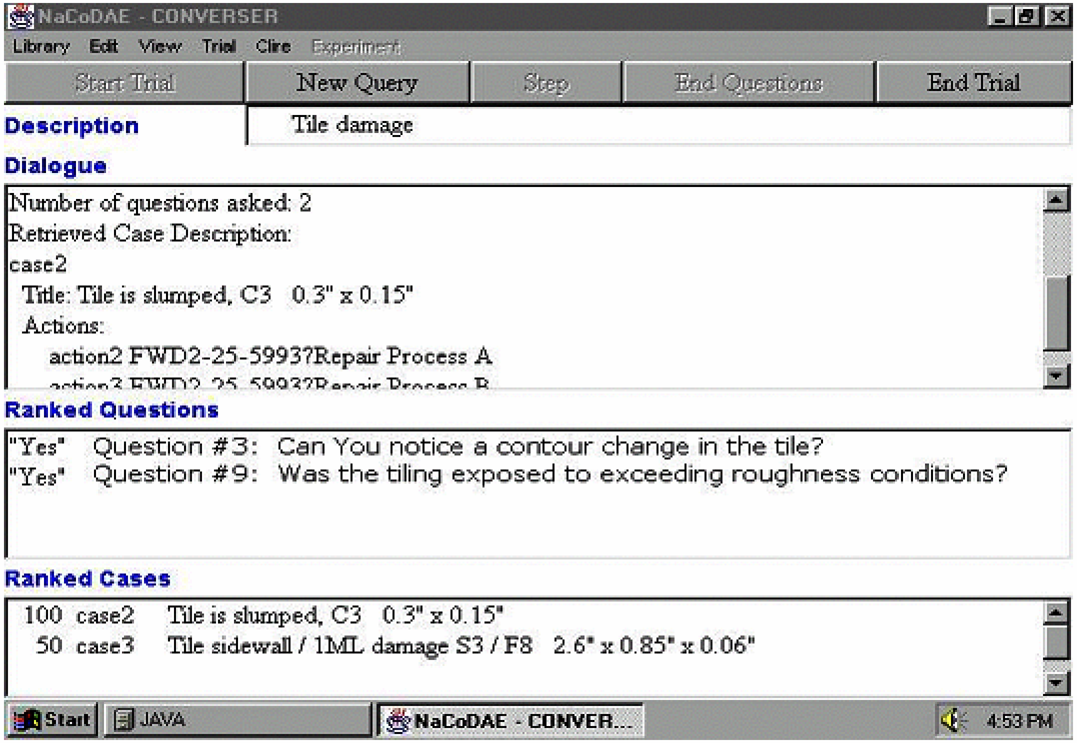
case1 Right oxide Flange will not mate to right oxide vehicle flange, should mate
case2 Tile is slumped, C3 0.3" x 0.15"
case3 Tile sidewall / 1ML damage S3 / F8 2.6" x 0.85" x 0.06"
case4 I
case5 I
case6 E
case7 I
case8 E
case9 I
case10 C
case11 I
case12 I
case13 U
case14 E
case15 I
case16 I
case17 E

TITLE:□Right oxide Flange will not mate to right oxide vehicle flange, should mate

DESCRIPTION:□
Detected during TPS CAP-5-12-003
Work area OPF-3
Reported by GURSKY
Description:
SCAT-03TISI-S Shop aid close out flances were manufactured in a left only, right only o
SCAT-034151-5 shop aid close out flances could not be installed on the right oxid-Orbi

Figure 16.5: OFD Case Database

Case study: OFD for shuttle processing



Description: Tile damage

Dialogue

```
Number of questions asked: 2
Retrieved Case Description:
case2
  Title: Tile is slumped, C3   0.3" x 0.15"
  Actions:
      action2 FWD2-25-5993?Repair Process A
      action3 FWD2-25-5993?Repair Process B
```

Ranked Questions

```
"Yes"   Question #3:  Can You notice a contour change in the tile?
"Yes"   Question #9:  Was the tiling exposed to exceeding roughness conditions?
```

Ranked Cases

```
 100  case2    Tile is slumped, C3   0.3" x 0.15"
  50  case3    Tile sidewall / 1ML damage S3 / F8   2.6" x 0.85" x 0.06"
```

Figure 16.6. Search Results

Case study: OFD for shuttle processing

- The key importance of the OFD system
  - enables one to apply the knowledge gained through solving prior problems
  - helps to apply knowledge to prevent unnecessary work from being performed
  - while promoting learning from prior failures.

Limitations of knowledge application systems

- Typically developed to serve a task-specific domain problem, and not integrated with the organization’s enterprise systems.
- Security: cases may include sensitive information.
- Scalability: must represent a large enough number of cases
- Speed: as the size of the case library grows to a more comprehensive representation of real environments, computing and searching costs will also increase.
- May not be able to solve all the problems that come across, in particular, increasingly complex environments

Conclusions

In this Chapter we:

- Discussed what knowledge application systems and design considerations, including the Case-Method Cycle
- Described the types of knowledge application systems:
  - expert systems
  - help desk systems
  - fault diagnosis systems
- Presented case studies describing details of implementation of knowledge application systems:
  - SOS Advisor
  - Total Recall
  - OFD for Shuttle Processing

Chapter 16

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