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# Design Knowledge Capture for a Corporate Memory Facility

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## Abstract

Currently, much of the information regarding decision alternatives and trade-offs made in the course of a major program development effort is not represented or retained in a way that permits computer-based reasoning over the life cycle of the program. The loss of this information results in problems in tracing design alternatives to requirements, in assessing the impact of change in requirements, and in configuration management.

To address these problems, we are studying the problem of building an intelligent, active *corporate memory facility* which would provide for the capture of the requirements and standards of a program, analyze the design alternatives and trade-offs made over the program's lifetime, and examine relationships between requirements and design trade-offs. Early phases of the work have concentrated on design knowledge capture for the Space Station Freedom. We have demonstrated and are extending tools that helps automate and document engineering trade studies (the topic of this paper), and we are developing another tool to help designers interactively explore design alternatives and constraints.

## 1.0 Introduction - Overall Problem

Under NASA contract NAS2-12108, the Boeing Advanced Technology Center (ATC) is conducting research leading to a corporate memory facility (CMF). A CMF would provide facilities for capturing and using decision history and rationale throughout a major program's life cycle. This effort is jointly funded by OAST's AI Program and the Space Station Freedom Advanced Development Program.

Currently, much of the information regarding alternatives considered and trade-offs made in the course of a major program development effort is not represented or retained in a way that permits computer-based reasoning over the life cycle of the program. The loss of this information results in problems in tracing alternatives to requirements, in assessing the impact of change in requirements, and in configuration management (Boeing Computer Services, 1989a,b).

There is not an integrated set of capabilities to assist in generating and evaluating or reevaluating program alternatives. The lack of this capability results in such problems as belated reaction to changes in requirements and inability to consider a reasonable number of alternatives.

## 2.0 A Corporate Memory Facility

To address these problems, we are studying the problem of building an intelligent, active corporate memory facility which would provide for the capture of the requirements and standards of a program, alternatives considered and trade-offs made over its lifetime, and relationships between these. The CMF would provide for requirements traceability, impact assessment, automation and/or assistance in the generation and evaluation of alternatives, and configuration management.

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The CMF would support interactive problem solving across diverse areas such as the aerospace engineering disciplines (propulsion, weights, and aerodynamics). In operational use, a CMF would reduce life-cycle flow time and cost and improve the quality of program deliverables. Similar benefits could be realized by applying information accumulated in the CMF for one program to other related programs.

In initial phases of this work, the ATC is studying core corporate memory facility ideas, preparing CMF technical reports detailing study results, and building feasibility demonstrations. In conjunction with NASA, the Space Station Freedom Program was selected as a testbed; within this test bed we are concentrating on design knowledge capture. In 1989 the ATC examined aspects of the Power subsystem and the Environmental Control and Life Support (ECLS) subsystem. We also used our tools in a portion of the 1989 Space Station Freedom technical audit to investigate the rationale for a previous design decision.

Through the series of demonstrations, we hope to show a novel integration and extension of design knowledge capture ideas by:

a. Tailoring knowledge acquisition and process control tools for *engineering trade studies*, a significant and feasible part of design knowledge capture.
b. Digitally recording speech as an unobtrusive method of capturing design rationale at the trade study workstation.
c. Developing an interactive design alternative generation aid.

## 3.0 Automating Engineering Trade Studies

We are focusing on trade studies in the design knowledge capture area because -

a. They exhibit a microcosmic path through the full cycle of design information, including requirements linkage, generation and comparison of alternatives, and decision documentation.
b. Many design engineers are familiar with trade studies and are comfortable using them to compare alternatives in quantitative terms.
c. Even though different methodologies for trade studies are available, little has been done to automate them.
d. A trade study tool would be immediately useful in a variety of domains, regardless of the success of the overall design knowledge capture or CMF effort.
e. Existing ATC tools could be extended to help perform portions of trade studies.

Trade studies are performed, in part, to avoid a designer's tendency to go directly to a design based on past experience, rather than trying to find a design that may better satisfy overall program requirements. Trade studies are often performed to help establish overall system configurations, study the detailed design of individual configuration items to provide the most cost-effective solution, and evaluate alternate solutions when the need for change occurs.

There are two general types of trade study criteria: limits which must be satisfied by any candidate system (go/no go criteria or *hard constraints*), and attributes upon which a ranking can be based (*soft constraints*)

Candidates are usually filtered using hard constraints and then ranked for comparison using soft constraints. Trade trees are used to decompose large numbers of candidates into groups for tractability. Paths through the tree show total configurations. Typical trade study criteria include accuracy, lifetime, power output, stability, sensitivity, bandwidth, low weight, low power, minimum dimensions, operational simplicity, electromagnetic compatibility, reliability,

survivability, schedule, cost, safety, and risk. Criteria are usually weighted. The results are usually shown in a *trade study matrix* - a table showing the alternatives, criteria, ratings, and weights.

After candidates are rated and scored, a sensitivity analysis can be performed. This shows the sensitivity of the decision to changes in the value of attributes, weights, costs, and subjective estimates.

In our early work on the CMF we demonstrated the capture of trade study information and rationale (Figure 1). In the future, this information will be available through the Technical and Management Information System (TMIS). We are examining several report formats based on current trade study practices. The information necessary for these reports will provide the foundation for the knowledge capture process.
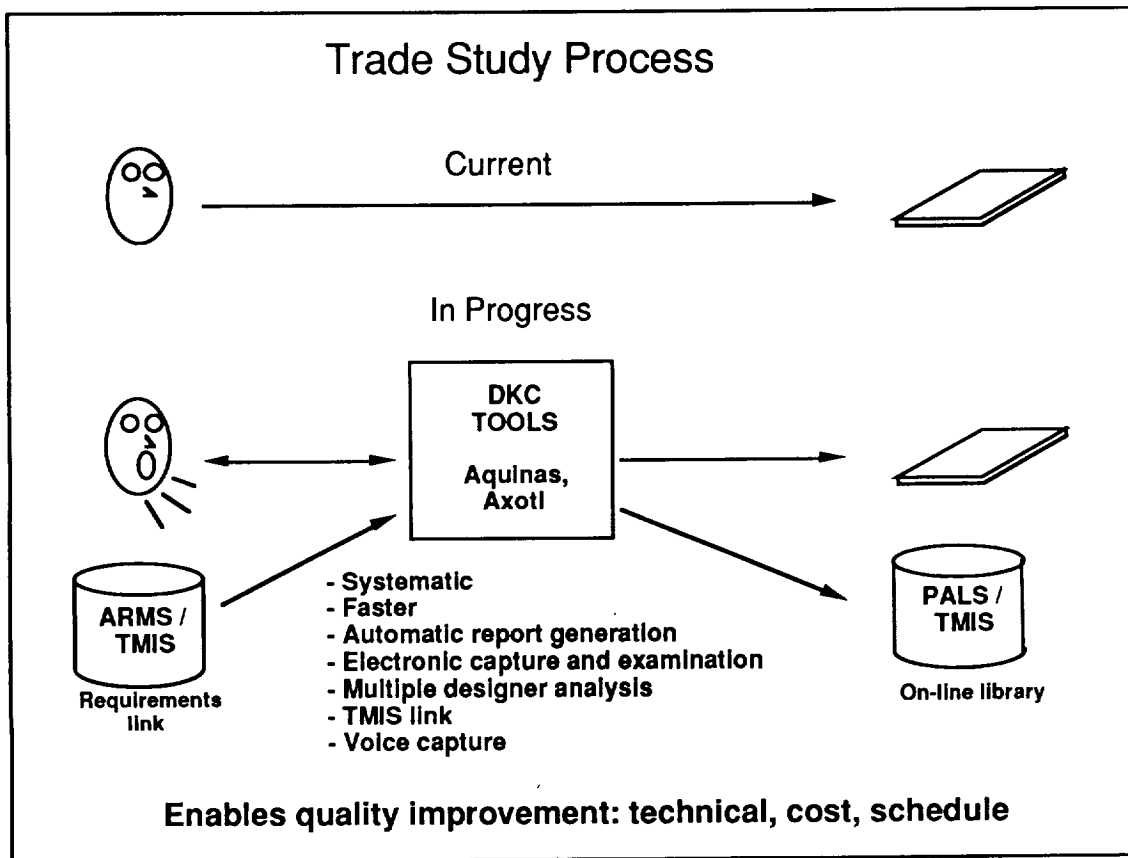


Figure 1. Automating the trade study process.

## 4.0 Design Knowledge Capture Tools

Two tools, Aquinas and Axotl, were used to build the first demonstration. An additional set of tools (MANIAC, HyperCard, and MacRecorder) was used to capture voice rationale and associate it with the Aquinas knowledge base for interactive playback.

### 4.1 Aquinas and Trade Studies

Aquinas interviewed experts in several trade study domains and captured candidate and criteria information leading to rank-ordered candidate selections. In the power domain, additional rationale was captured as voice input. In the ECLSS domain, conflicting opinions from multiple designers were captured, analyzed, and documented.

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**Power subsystem** - Chuck Olson, a design engineer in Boeing Aerospace, used Aquinas to build two separate trade studies for the interface between a computer and automatic circuit breakers. Brian Smith, another Boeing Aerospace design engineer, offered advice on building an electronic trade study process assistant.

**Environmental Control and Life Support subsystem** - Jim Knox, a NASA design engineer at Marshall Space Flight Center, used Aquinas to build a trade study for carbon dioxide removal on Space Station Freedom in the year 2000. Allen Basckay, another NASA design engineer at Marshall Space Flight Center, added additional information to this trade study.

**Technical Audit Item #85** - John Palmer, O'Keefe Sullivan, and Carl Case, Boeing Aerospace, used Aquinas to document a 1986 decision about the placement of the pressurized logistics module.

Aquinas is a workbench developed by the Boeing Advanced Technology Center for acquiring and analyzing expert knowledge for solving diagnostic, structured selection, classification, and other problems (Figure 2). In the CMF context, Aquinas is used to acquire knowledge about requirements and alternatives from individuals or groups of experts, and then assists in merging that knowledge into a single knowledge base. Weights may be assigned to both requirements and their refinements. This knowledge may be merged automatically by Aquinas or by consensus of the program staff using Aquinas as an assistant. Aquinas supports similar capabilities for acquiring compound alternatives.

| Dialog Manager | | | | | | | |
|---|---|---|---|---|---|---|---|
| Repertory Grid Tools | Hierarchical Structure Tools | Uncertainty Tools | Internal Reasoning Engine | Multiple Scale Type Tools | Induction/ Learning Tools | Multiple Expert Tools | Constraints |
| Common knowledge representation and user interface | | | | | | | |

**Figure 2.** Aquinas consists of several tool sets that assist different knowledge acquisition tasks. General advantages of Aquinas include integration of multiple methods and techniques, rapid prototyping and feasibility analysis, generation of expert enthusiasm, multiple mediating representations, embedded testing, and life cycle support for verification, delivery, and maintenance.

Aquinas, an expanded version of the Expertise Transfer System (ETS; Boose, 1984, 1985, 1986a,b), combines ideas from psychology and knowledge-based systems to support knowledge acquisition tasks. These tasks include eliciting distinctions, decomposing problems, combining uncertain information, incremental testing, integration of data types, automatic expansion and refinement of the knowledge base, use of multiple sources of knowledge, use of constraints during inference, and providing process guidance (Boose and Bradshaw, 1987; Boose, Bradshaw, and Shema, 1989). Aquinas interviews experts and helps them analyze, test, and refine knowledge. Expertise from multiple experts or other knowledge sources can be represented and used separately or combined. Results from user consultations are derived from information propagated through hierarchies.

Using Aquinas, rapid prototypes of knowledge-based systems can be built in as little as one hour, even when the expert has little understanding of knowledge-based systems or has no prior training in the use of the tool. The interviewing methods in Aquinas are derived from George Kelly's Personal Construct Theory and related work (Kelly, 1955; Shaw and Gaines, 1987;

Boose, 1988). Kelly's methods and theory provide a rich framework for modeling the qualitative and quantitative distinctions inherent in an expert's problem-solving knowledge.

Aquinas tools mentioned here are explained more fully elsewhere (Boose and Bradshaw, 1987; Boose, 1988; Kitto and Boose, 1988; Shema and Boose, 1988; Bradshaw and Boose, 1989).

Extended repertory grids in Aquinas are a compact and easily understood form of expertise representation for many types of knowledge. Repertory grids can be analyzed, refined, tested, and maintained more easily than a corresponding, larger rule or frame knowledge base. In Aquinas, we have augmented repertory grid structures to include hierarchies, constraints, structures for eliciting and reasoning about knowledge from multiple experts, multiple variable types, and accommodate forms of machine learning. Generally, these analysis capabilities and compact, higher-level *mediating representations* of expert knowledge make knowledge bases easier to inspect, analyze, maintain, test, and improve. We use a test case-based approach within Aquinas for performance measurement, verification, and maintenance, and automatic knowledge base improvement. This method helps find holes and weaknesses in the knowledge base, and provides facilities for verifying knowledge consistency, accuracy, and sanity range.

Refinement methods in Aquinas include implication and similarity analyses, completeness checking, hole filling, cluster analyses, generalization, automatic rule production, internal testing and debugging aids, and graphic representation transformation. Expertise from multiple experts or other knowledge sources can be represented and used separately or combined, giving consensus and dissenting opinions among groups of experts. Recent progress on Aquinas has been in the areas of knowledge base performance measurement, knowledge base maintenance, interacting trait constraints, consultation graphics, and eliciting strategic and procedural knowledge. Experiments show how Aquinas can automatically improve knowledge bases and even suggest new problem-solving information. Forms of interactive and automatic machine learning are also employed by Aquinas (Boose, Bradshaw, and Shema, 1989).

Aquinas exists in several "C"-based versions that run on different microprocessor platforms and a fuller development version that runs on Sun workstations and Xerox Lisp Machines.

## 4.2 Axotl System

In the first demonstration, Chuck Olson used Axotl to elicit an electronically-based model of the trade study process.

Axotl, developed at the Boeing Advanced Technology Center, integrates a set of computer-based decision analysis tools with a knowledge-based system. The decision analysis tools are designed for problems requiring careful consideration of uncertainty and complex tradeoffs. In the context of CMF, alternatives and requirements generated by Aquinas can be analyzed using decision analysis representations to determine the suitability of various alternatives and to gauge the impact of changes in design requirements or circumstances. Influence diagrams are used to represent information, alternatives, and preferences both graphically and mathematically. Our experience has shown that they are an effective way of communicating important issues among participants. Axotl also employs other forms of knowledge representation that may prove useful as part of a CMF. For example, Boeing has extended and generalized an AND/OR graph representation for goals and activities ("activity graphs") that can be used to dynamically construct and evaluate cyclic plans for achieving a set of process requirements.

Axotl is written in the ParkPlace Smalltalk-80 development environment on the Apple Macintosh II. Versions of Smalltalk-80 exist for Sun, Apollo, Hewlett-Packard, IBM, and Apple hardware.

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## 4.3 MANIAC, HyperCard, and MacRecorder

Together, MANIAC, HyperCard, and MacRecorder were used to record and play back voice rationale.

In the first demonstration, design decision rationale was captured on a tape recorder during Aquinas sessions. To demonstrate feasibility, parts of these recordings were processed using MacRecorder on a Macintosh and stored in HyperCard. MANIAC, an ATC shell that controls communication between Axotl, Aquinas, HyperCard, and other application programs, receives commands from Aquinas to play back digitally recorded voice based on particular Aquinas knowledge base objects. Designers and others who later examine the trade study decision rationale can optionally play back this recorded voice information.

In future demonstrations we will link MacRecorder and Aquinas more directly so that designers may enter and edit voice input directly while using Aquinas. This will be a relatively unobtrusive way to enter rationale (as opposed to text entry) in a cost effective manner. Digitally recorded voice information could eventually be stored and played back as design decision rationale in TMIS in a manner similar to many digital phone message systems.

MANIAC is described more fully in (Bradshaw, Covington, Russo, and Boose, 1988).

## 4.4 CANARD

As part of the design process, competing alternatives are generated and evaluated for suitability. The best alternative emerges as the result. Unfortunately, constraints, tradeoffs, and other considerations made during the exploration of the design are usually lost, making it impossible to review or easily modify them at a later time. If a modification to the design is required, the designers may have to redo the entire task.

We started development of CANARD, an automated tool which uses possibility tables, constraints, and knowledge bases to capture significant portions of the design process and assist in the generation of alternative solutions consistent with design goals and design constraints (Shema, Bradshaw, Covington, and Boose, 1989). Using a possibility table, a designer identifies the components of an acceptable design, specifies possibilities for each component, develops criteria reflecting preferences among possibilities, and supplies constraints governing compatibility between components and overall design considerations. The designer next interactively explores design alternatives by selecting possibilities for each component, modifying and/or adding components and possibilities as insight into the solution is gained. He then analyzes and stores the many alternative solutions for later retrieval.

For large problems, an iterative search procedure hypothesizes new constraints based on examples of previously-defined design alternatives, and proposes new design alternatives based on permutations of the constraint space. The tool keeps track of what has been tried and assists the designer in covering important aspects of the possible solution space.

CANARD is written in the ParkPlace Smalltalk-80 development environment on the Apple Macintosh II. Versions of Smalltalk-80 exist for Sun, Apollo, Hewlett-Packard, IBM, and Apple hardware.

## 5.0 Example Trade Study - Technical Audit Item #85

In 1989 a technical audit was performed on the Space Station Freedom for the program's content and implementation planning in relationship to performance, design, and validation

requirements. One concern raised during the technical audit was a 1986 decision about the placement of the pressurized logistics module (PLM). Using Aquinas, we hoped to develop a process for capturing the decision rationale on this topic and similar ones.

First we described our problem and proposed process to a group of designers at Boeing in Huntsville, Alabama, who were or who are involved with the placement of the PLM. We then used Aquinas in two sessions with two teams of designers. One session lasted 1-1/4 hours, one session lasted 1-1/2 hours. We elicited trade study matrices from each team and combined the results, using Aquinas to show the combined rank-ordering. The decisions developed using Aquinas agreed with and documented the current placement of the PLM.

Here we describe the steps that were performed with Aquinas for the technical audit.

**Step 1.** Aquinas elicited nine alternative PLM locations from Team 1 (Node 1 Zenith, Node 1 Nadir, etc.).

**Step 2.** Aquinas elicited a preliminary set of decision criteria by using triadic comparison. Groups of three solutions were compared and designers were asked to give discriminating criteria:

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Think of an important new criterion that two of NODE.1.ZENITH, NODE.1.NADIR, and NODE .2.ZENITH share, but that the
other one does not. What is that trait? (Enter a CR to skip over.)
NEW TRAIT (EXTREME)** BETTER MSC REACH

What is that criterion's opposite as it applies in this case?
NEW TRAIT (OPPOSITE)** WORSE MSC REACH

What is the name of a scale or concept that describes BETTER.MSC.REACH / WORSE.MSC.REACH?
NEW TRAIT (CONCEPT)** MSC REACH

Think of an important new criterion that two of NODE.1.NADIR, NODE.2.ZENITH, and NODE.2.NADIR share, but that the other
one does not. What is that characteristic? (Enter a CR to skip over.)
NEW TRAIT (EXTREME)** CLOSE TO HAB MODULE

What is that criterion's opposite as it applies in this case?
NEW TRAIT (OPPOSITE)** FARTHER FROM HAB MODULE

What is the name of a scale or concept that describes CLOSE.TO.HAB.MODULE / FARTHER.FROM.HAB.MODULE?
NEW TRAIT (CONCEPT)** HAB MODULE PROXIMITY
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**Step 3.** The designers rated each alternative on each criterion. By default, Aquinas supplies ordinal scales from 1 to 5. Designers may change the scale type (to nominal, interval, or ratio) or range for convenience or more precision.

**Step 4.** The designers assigned a relative weight to each criterion. At this point an initial trade study matrix was complete (Figure 3).

## TEAM.1. SOLUTION TRAIT

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 4 | 1 | 4 | 1 | 2 | 3 | 2 | 2 | 1 |
| 2 | 4 | 4 | 1 | 1 | 1 | 4 | 3 | 2 | 2 |
| 3 | 1 | 1 | 1 | 1 | 2 | 4 | 4 | 4 | 4 |
| 4 | 4 | 4 | 1 | 1 | 1 | 5 | 5 | 4 | 4 |
| 5 | 2 | 1 | 2 | 1 | 5 | 4 | 4 | 5 | 4 |
| 6 | 5 | 5 | 5 | 5 | 5 | 3 | 3 | 3 | 1 |
| 7 | 1 | 5 | 1 | 5 | 3 | 1 | 3 | 3 | 5 |

1. (5) MSC.REACH: BETTER.MSC.REACH(1)/ WORSE.MSC.REACH(5) [ORDINAL 1]
2. (1) HAB.MODULE.PROXIMITY: CLOSE.TO.HAB.MODULE(1) / FARTHER.FROM.HAB.MO
3. (3) CG.SHIFT.IMPACT: LESS.CG.SHIFT(1) / GREATER.CG.SHIFT(5) [ORDINAL 1]
4. (1) JAPANESE.MODULE.PROXIMITY: CLOSER.TO.JAPANESE.MODULE(1) / FARTHER.
5. (2) GROWTH./PATH: BETTER.FOR.GROWTH.PATH(1) / WORSE.FOR.GROWTH.PATH(5
6. (5) PAYLOAD.BAY.BLOCKING: BLOCKING.PAYLOAD.BAY(1) / NOT.BLOCKING.PAYLO
7. (4) EXPOSURE.TO.MICRO.METEOROIDS: MORE.EXPOSURE.TO.MICRMETEOROIDS(1

1. NODE.1.ZENITH
2. NODE.1.NADIR
3. NODE.2.ZENITH
4. NODE.2.NADIR
5. NODE.2.PORT
6. NODE.3.ZENITH
7. NODE.3.STARBOARD
8. NODE.4.PORT
9. NODE.4.NADIR
TEAM.1.SOLUTION

**Figure 3.** Initial technical audit trade study matrix from Team 1.

**Step 5.** The designers used several of Aquinas' analysis tools to discover patterns in the collected information. Implication analysis showed logical generalizations that, for this application, provided a sanity check. A cluster analysis and similarity analysis showed the degree of similarity and redundancy between alternatives and between criteria.

**Step 6.** Aquinas scored the alternatives by eliciting preferred criteria values from the designers. For example, the designers said they would prefer alternatives that were *better for the station growth path* and had *less effect on the station center of gravity*. For Team 1, Aquinas produced the following results:

| | | |
|---|---|---|
| 1 : NODE.2.NADIR | ( 1.00 ) |
| 2 : NODE.1.NADIR | ( 0.93 ) |
| 3 : NODE.2.PORT | ( 0.71 ) |
| 4 : NODE.2.ZENITH | ( 0.61 ) |
| 5 : NODE.4.NADIR | ( 0.54 ) |
| 6 : NODE.1.ZENITH | ( 0.54 ) |
| 7 : NODE.4.PORT | ( 0.48 ) |
| 8 : NODE.3.STARBOARD | ( 0.48 ) |
| 9 : NODE.3.ZENITH | ( 0.31 ) |

**Step 7.** The second team used Aquinas to independently develop and analyze their own trade study matrix.

**Step 8.** Both matrices were combined and Aquinas again scored the alternatives, this time showing the *consensus* scores as well as the contributions from both individual teams. The teams are weighted in this example for purposes of illustration (Team 1 has received a weight of 40%, Team 2 a weight of 60%). Teams or individuals may be weighted for technical or other reasons.

**Combined results:**

| | | | | | |
|---|---|---|---|---|---|
| 1 NODE_2_NADIR 0.89 | TEAM_1 | 1.00 | 40% | TEAM_2 | 0.82 | 60% |
| 2 NODE_1_NADIR 0.81 | TEAM_1 | 0.93 | 40% | TEAM_2 | 0.73 | 60% |
| 3 NODE_2_PORT 0.71 | TEAM_1 | 0.71 | 40% | TEAM_2 | 0.70 | 60% |
| 4 NODE_2_ZENITH 0.64 | TEAM_1 | 0.61 | 40% | TEAM_2 | 0.65 | 60% |
| 5 NODE_1_ZENITH 0.55 | TEAM_1 | 0.54 | 40% | TEAM_2 | 0.56 | 60% |
| 6 NODE_4_NADIR 0.48 | TEAM_1 | 0.54 | 40% | TEAM_2 | 0.44 | 60% |
| 7 NODE_4_PORT 0.43 | TEAM_1 | 0.48 | 40% | TEAM_2 | 0.39 | 60% |
| 8 NODE_3_ZENITH 0.40 | TEAM_1 | 0.31 | 40% | TEAM_2 | 0.46 | 60% |
| 9 NODE_3_STARBOARD 0.28 | TEAM_1 | 0.48 | 40% | TEAM_2 | 0.15 | 60% |

Given this information, Aquinas displayed the most dissenting opinion beside the consensus. The dissenting opinion is found by computing a correlation score between each team and the consensus; the team with the lowest correlation score is listed as the dissenting opinion. Dissenting

opinions show the user the range of opinion about a decision, not just the top rated list. In this case, both teams showed a high correlation - both teams were in substantial agreement. This can give the user confidence that the top rated alternatives were sound choices.

Correlation scores for all experts:
TEAM_2     .96
TEAM_1     .90

TEAM_1 has the most dissenting opinion.

| TEAM_1 | / | Consensus |
|---|---|---|
| 1 : NODE_2_NADIR 0.81 | / | NODE_2_NADIR 0.89 |
| 2 : NODE_1_NADIR 0.72 | / | NODE_1_NADIR 0.81 |
| 3 : NODE_2_PORT 0.71 | / | NODE_2_PORT 0.71 |
| 4 : NODE_2_ZENITH 0.66 | / | NODE_2_ZENITH 0.64 |
| 5 : NODE_4_NADIR 0.62 | / | NODE_1_ZENITH 0.55 |
| 6 : NODE_1_ZENITH 0.42 | / | NODE_4_NADIR 0.48 |
| 7 : NODE_3_STARBOARD 0.41 | / | NODE_4_PORT 0.43 |
| 8 : NODE_4_PORT 0.34 | / | NODE_3_ZENITH 0.40 |
| 9 : NODE_3_ZENITH 0.21 | / | NODE_3_STARBOARD 0.28 |

**Near-future capability.** We will be building a TMIS-based menu query mechanism that would be able to answer several types of questions about a trade study:

Q. Why did NODE.2.ZENITH do better than NODE.1.ZENITH?
A. It rated higher on CLOSE.TO.HAB.MODULE (1 vs. 4 on a scale of 1 to 5) and CLOSE.TO.LAB. MODULE (1 vs. 4 on a scale of 1 to 5)

Q. Why did NODE.1.NADIR and NODE.2.NADIR do better than NODE.1.ZENITH and NODE.2.ZENITH?
A. They always rated higher on BETTER.MSC.REACH, BETTER.FOR.GROWTH, and LESS.EXPOSURE.TO.MICROMETEOROIDS.
   They sometimes rated higher on CLOSE.TO.HAB.MODULE and CLOSER.TO.JAPANESE.MODULE.

Q. If LESS.EXPOSURE.TO.MICROMETEOROIDS were the only criterion, how would the alternatives be ranked?
A. 5: NODE.1.NADIR, NODE.2.NADIR, NODE.4.NADIR
   4: -
   3: NODE.3.STARBOARD, NODE.4.PORT
   2: NODE.2.PORT
   1: NODE.1.ZENITH, NODE.2.ZENITH, NODE.3.ZENITH

Q. What are the most critical criteria?
A. (Perform a sensitivity analysis to determine critical criteria; list criteria with high weights.)

**Results.** Boeing and MSFC engineers who used the tool were very enthusiastic about its potential. It was decided to try and use this methodology for other aspects of the station's preliminary design phase.

## 6.0   Conclusions and Future Work

The Boeing Advanced Technology Center (ATC) is conducting research leading to a Corporate Memory Facility (CMF). A CMF would provide facilities for capturing and using decision history and rationale throughout a major program's life cycle.

Initially the ATC is preparing CMF technical reports and building feasibility demonstrations. In conjunction with NASA, The Space Station Freedom Program was selected as an application; within this domain we are concentrating on design knowledge capture. We examined aspects of the Power subsystem and the Environmental Control and Life Support (ECLS) subsystem. We also participated in one aspect of the Space Station Freedom technical audit.

Significant progress was made in helping automate the process of performing engineering trade studies. Other steps in the design knowledge cycle - alternative generation, comparison, evaluation, and documentation - were also demonstrated. In the next phase we will continue to

extend our tools to further automate trade studies, strengthen our links to TMIS, and continue work on CANARD.

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