XML Based Tools for Assessing Potential Impact of Advanced Technology Space Validation[1,2]

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Abstract—A hierarchical XML database and related analysis tools are being developed by the New Millennium Program to provide guidance on the relative impact, to future NASA missions, of advanced technologies under consideration for developmental funding.

An XML dictionary codifies a standardized taxonomy and, in effect, begins to define a set of ontological relationships for space missions, systems, subsystems, and technologies. The use of an XML dictionary and the associated XML database are central to the concept behind the analysis tools. The XML dictionary, and the taxonomies defined therein, may be submitted to NASA as a proposed guideline. The analysis tools are planned for use across a broad range of NASA projects and technology planning activities. In addition, if successful, the products developed under this task may also be submitted for use by the DOD.
This paper describes the motivation for the project, the technical approach, the reasoning behind the selection of XML based tools, the current state of the project, and future plans for this work.

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1. INTRODUCTION

NASA's New Millennium Program [3] is chartered with the task of selecting high value, breakthrough technologies for future NASA science missions, and maturing these technologies from the TRL (Technology Readiness Level) 3-4 (breadboard) stage to TRL 7 (successful use in a flight system) [1,2]. In practice, the NMP technologists work with NASA Code S (Space Science Enterprise) and Code Y (Earth Science Enterprise) technologists to define needed capabilities which can only be provided by advanced, (i.e., beyond state of the art) technologies. These Technology Capability Areas (TCAs) are then used as the basis for open solicitations for technologies promising to provide these capabilities. The selection of technology providers is done through the NASA Research Announcement (NRA) process. The TCA identification and prioritization process, as well as the process used in evaluating individual technologies, has been, for the most part, a qualitative one, without a rigorous quantitative analysis by which relative rankings can be formulated, compared and understood.

To assist in the selection of high payoff TCAs and technologies, a means of providing a quantitative, traceable and defensible evaluation of expected Return on Investment (ROI) was desired. A team was formed to develop a methodology and tool set for performing these ROI evaluations. The team was given two associated, but separate, tasks. The ROI Evaluation Task was the development of a methodology for ROI evaluation and of gathering or generating provably valid data. The Database Task was the development of a database for holding the required data (e.g.: NASA goals; planned future mission goals, approaches and required capabilities; advanced technology, capabilities, TRLs, development costs and projected schedules). In this paper, we discuss the tools and methodologies being developed by the ROI Evaluation Task. A companion paper deals with the database currently under development under the Database Task.

The tools being developed are XML-based and, for the most part, implemented in a spreadsheet. A custom interface to the database allows the spreadsheet tool to request XML identified data. The XML orientation of the tools allows sophisticated interaction between the tools and the database

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and thus, a high degree of automation and intelligence to be built into the tools themselves, rather than into the user interaction.

System Overview

Figure 1-1 shows a high-level system overview. This information system is implemented in a client-server architecture. The server side consists of the Tamino (TM) XML database server and Tomcat, an open-source Java-based web application server. Tamino stores the XML documents and processes XQueries from the client side. Tomcat serves as a container for the Java Server Pages (JSPs), which generate the user interface, and utilizes the Java API objects (NmpDB API) to connect to the database. Tomcat version 5.0 is used to take advantage of the JSP 2.0 specification, especially the Expression Language (EL). The JSP Standard Tag Library (JSTL 1.0) is used extensively. The client side includes a graphical user interface (GUI) accessed through a web browser and an Excel based analysis tool for computing technology valuations.

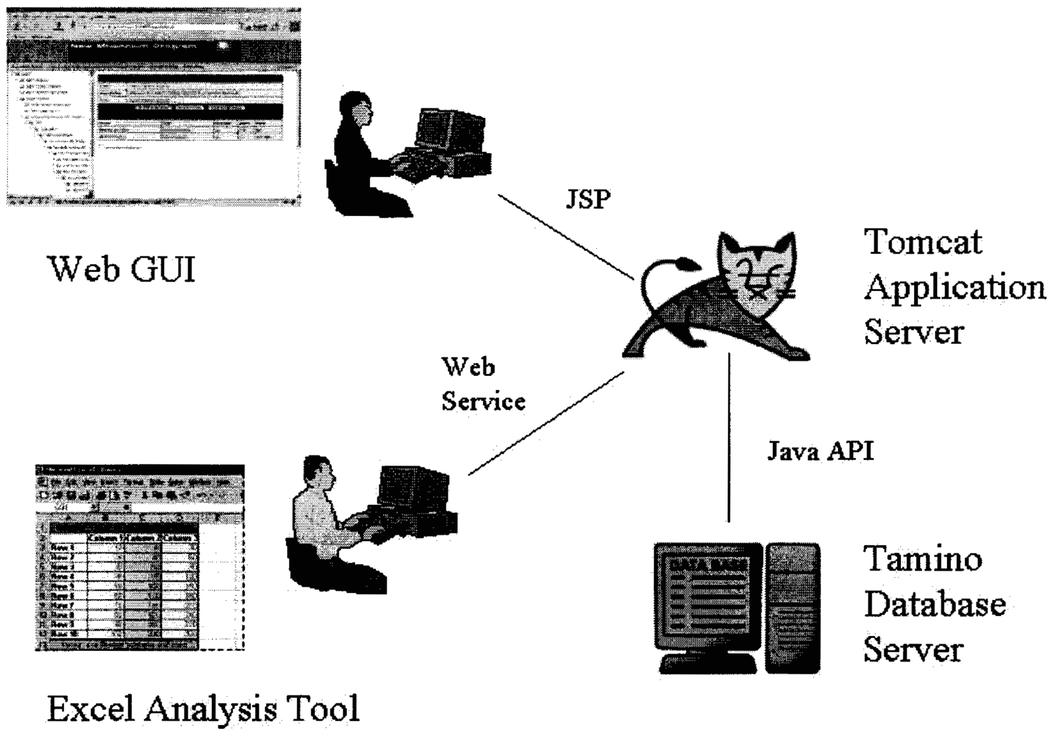

Figure 1-1. System Overview

2. ROI Analysis Overview

Analysis Method

Our overall methodological approach follows that described in references [4, 5].

Though expert decision-makers may be guided by extensive experience and good judgment, they have human limitations. Usually, a decision-maker will consider only a few attributes when comparing competing technologies. Our system's usefulness, as much as anything, is that it induces decision-makers to consider all of the pertinent attributes, and provides a sound method for using them in the decision-making process.

1. Develop a clear, complete statement of the problem to be studied.

State the problem unambiguously, specifying what is to be maximized or minimized, with all pertinent policy, schedule, and budget constraints. For example, a problem statement might be to identify a subsystem technology which requires space validation and which would enable missions providing the highest science return and a cost not to exceed a certain dollar limit. Other examples might be to choose system technologies, or groups of technologies that might constitute a portfolio meeting a specified budgetary limit.

2. Identify top-level goals.

Identify top-level goals and quantify what would constitute satisfying those goals. For NASA work, we draw goals, investigations, and experiments from NASA strategic plans and science working group meeting reports. For example, we might wish to select that technology which enables Codes S and Y longer term missions related to identification of earth-like planets around other stars and/or mapping and predicting the evolution of weather or climate.

3. Develop or select one or more architectures for accomplishing the goals.

Design or select architectures (precise scenarios) for conducting specific subsets of the desired experiment. There might be a number of mission concepts (architectures) which, if developed to fruition, might reach the goal(s) stated in #2. For example, a planet finder mission could take the form of a coronagraph or an interferometer. Each of these architectures might be enabled by a different suite of technologies. We look to Code S and Code Y missions as depicted in their respective roadmaps from 2009 through 2025 in order to identify the relevant mission architectures to be studied.

4. *Identify the capabilities needed for the architecture.*

Decompose the mission or system concepts into specific quantitative capability requirements whose importance is based on their estimated contribution to the objective stated in Step 1 (such as maximizing science return). The mission concept is hierarchically decomposed and capability requirements identified at successively more detailed levels of abstraction until the last level can be readily matched with ongoing technology developments.

5. *Identify technologies that could provide the needed capabilities.*

Assess technology candidates that purport to fulfill or partially fulfill the required capabilities. Capture uncertainties in their capabilities, using performance attributes and their probability distributions. Define each technology development task by at least four critical metrics and their associated uncertainties:

a. performance requirement attributes
b. budget estimate
c. scheduled delivery date
d. risk level

Determine whether the technology tasks under consideration require space validation (e.g. dependent on microgravity or other environmental conditions).

6. *Evaluate and rank the technology candidates with respect to enabling NASA goals*

Rank technologies by calculating their contributions to all relevant capabilities and missions. The analysis is cast in terms of an optimization in which the technology performance metrics are in terms of a ratio relative to the state of the art and are thereby dimensionless so that attributes with dissimilar metrics can easily be combined. Risk may be calculated and considered, both in terms of an individual technology's risk of failure (useful in comparison with competing technologies), and in terms of the impact a technology's failure would have on the entire mission.

In this analysis step, several products are produced:

7. *Products of the end-to-end analysis*

7.1 Quantified objective function and constraints (i.e. overall NASA objective)

7.2 Major science experiments under study

7.3 Mission architectures to fulfill the scientific goals

7.4 Mission capability requirements at several levels of decomposition

7.5 Technology performance characterization and projections

7.6 Specifications of which technologies require space validation

7.8 Assessment of individual technology gaps and impacts

7.9 Recommendation for technologies to be tested by NMP

Example—Formation Flying

The Formation Flying capability area was selected to demonstrate the analysis method. A sample of ten technologies was matched with the capability decomposition in order to test the process (Figure 2-1).

Analysis Method—Step 1: Develop a Clear, Complete Statement of the Problem to be Studied

The point of the analysis was to value technologies to be utilized within selected missions that require formation-flying capability, sum values across the mission set and then to rank/compare technology value. The ranking using technology values assumes that costs to develop are roughly equivalent.

Analysis Method—Step 2: Identify Top Level Goals

The purpose of the analysis was to determine values of a representative set of technologies based on their collective impact on the achievement of mission objectives. The NASA 2000 Strategic Plan [12] established the science goals for this study. We assumed that each science goal would have equal weight and was arbitrarily set to 1000 points thereby establishing a value for each of the 4 selected missions (3000 for TPF, 2000 for LISA, and 1000 each for MMS and MagCon). Note that there is no endorsement or consensus of mission values—these potentially will be different depending on user perspective and needs.

Analysis Method—Step 3: Develop or Select One or More Architectures for Accomplishing the Goals

The sample of missions selected was based primarily on availability of data in order to conduct a meaningful study. Consequently, TPF, LISA, MMS and MagCon were selected.

Analysis Method—Step 4: Identify the Capabilities Needed for the Architecture

Capability areas and values decomposed using the XML taxonomy and total mission values identified in Step 2 were subdivided to the level of technology capability areas and further subdivided as appropriate. Note that the generic analysis method does not require that the decomposition be accomplished using an XML taxonomy. Use of the XML taxonomy is an innovation pioneered by the XML database and the analysis tool to make the analysis task easier for non-specialists.

Table 2-1 shows the functional decomposition for formation flying in the TPF mission. The formation flying function is decomposed into lower-level capabilities (the lowest level of decomposition has been omitted to reduce the table size). The entire TPF mission has been assigned a value of 3000 points. Formation flying, as one of the high-level capabilities required by this mission, has been allocated 294.7 points. Each lower-level capability is allocated a number of points based upon its relative value in accomplishing the higher-level function.

	Mission Value	Inter-S/C Ranging & Alarm System (IRAS)	Autonomous Formation Flying Sensor (AFF)	Control/Sensor/Comm. Architecture & Algorithms	On-the-Fly-Observation Formation Reconfiguration	Distributed Resource Management	Formation Reconfiguration	Collision/Constraint Avoidance	Initialization / Lost Spacecraft Acquisition	Fault Tolerance	Formation State Estimation
TPF	3000	4	66	5	1	7	2	7	9	7	7
LISA	2000	0	0	0	0	0	0	0	0	0	0
MMS	1000	10	0	2	0	7	0	4	0	2	9
MagCon	1000	0	0	1	0	5	0	4	0	0	8
TV(all missions)		14	66	8	1	19	2	15	9	9	24

Figure 2-1. Technology Valuation Results for Formation Flying Technologies Across Four Key Missions

Table 2-1. Capability Value Decomposition for TPF Formation Flying TCA (Total Mission Value Set at 3000 Points)

Functional Decomposition		Capability Value
5.	Formation Flying	294.7
5.1.	Deployment	52.0
5.1.1.	Verify Spacecraft Separation	13.0
5.1.2.	Provide Delta V	13.0
5.1.3.	Collision Avoidance	13.0
5.1.4.	Structural Deployment	13.0
5.2.	Formation Initialization / Lost Spacecraft Acquisition	52.0
5.2.1.	Target Acquisition (4pi steradian)	8.7
5.2.2.	Acquire Relative Position	8.7
5.2.3.	GN&C	8.7
5.2.4.	Positioning	8.7
5.2.5.	Acquire Absolute Attitude	8.7
5.2.6.	S/C to S/C and S/C to Earth Communications	8.7
5.3.	Coarse Formation Maneuvering & Reconfiguration	52.0
5.3.1.	Position Acquisition	13.0
5.3.2.	High Speed S/C-to-S/C Communications	13.0
5.3.3.	GN&C Algorithms	13.0
5.3.4.	Positioning	13.0
5.4.	Fine Formation Flying	52.0
5.4.1.	Sensor Suite Alignment & Cross-Calibration	10.4
5.4.2.	Position Acquisition	10.4
5.4.3.	High Speed S/C-to-S/C Communications	10.4
5.4.4.	GN&C Algorithms	10.4
5.4.5.	Positioning	10.4
5.5.	Stop & Stare Formation Flying	52.0
5.5.1.	Sensor Suite Alignment & Cross-Calibration	10.4
5.5.2.	High Speed S/C-to-S/C Communications	13.0
5.5.3.	GN&C	13.0
5.5.4.	Positioning	13.0
5.6.	On-the-Fly Observation Formation Flying	34.7
5.6.1.	Sensor Suite Alignment & Cross-Calibration	10.4
5.6.2.	High Speed S/C-to-S/C Communications	8.7
5.6.3.	GN&C	8.7
5.6.4.	Positioning	8.7

Analysis Method—Step 5

Technologies were identified and associated to capabilities based on Reference 6. Technologies were also selected on the basis of data availability and verified with the NMP customer. For the representative sample of technologies included in this example, Reference 6 indicates that the following technologies will require space validation:

- Autonomous Formation Flying Sensor
- Collision Avoidance
- Initialization/Lost Spacecraft Acquisition
- Formation State Estimation.

Analysis Method—Step 6

Consequently, the analysis output provides a basis for preliminary ranking of technology value assuming that development costs are relatively equivalent and that the ultimate comparison metric is benefit/cost. Assuming data is available, the tool can also be utilized to analyze and rank technology capability areas.

Conclusions from Analysis

Given the preliminary nature of this study, that the costs are comparably equivalent, and that mission values are a potential point of contention depending on the user, the results suggest that there are two strong candidate technologies that for space validation funding: Autonomous Formation Flying Sensors and Formation State Estimation. Other candidates include Initialization/Lost Spacecraft Acquisition and Collision/Constraint Avoidance. For the other technologies, lower scores coupled with no hard requirement for space validation make the case for a recommended space qualification funding action less clear.

Further analysis of ROI using specific funding data for each technology program, analysis (comparison and ranking) of TCAs, gap analysis, and portfolio assessment/optimization might shed more light on an acceptable integrated strategy for technology investment.

Additional Limitations

In this specific case there was no portfolio analysis or optimization requirement; however, these analyses have been run for the NASA Space Architect. The optimization analysis maximizes technology value for alternate funding levels and thereby generates optimal technology portfolios.

Uncertainty analysis and incorporation of interdependency relationships are not included in this version of tool development but is under consideration for future enhancements.

A complete listing of anticipated products of the end-to-end-analysis for this example are outlined items 7.3, 7.4 and 7.5 of the Analysis Method—Step 7 and Section 5.0 Current Status and Future Plans. These capabilities will be incrementally added to the tool during FY '04.

3. ROI Analysis Tool – How It Works

In this and subsequent sections we discuss: the design of the ROI analysis tool, including: architecture and organization of the data; the computational approach and method of ROI analysis; the XML dictionary as an implementation mechanism for required taxonomies; external interfaces to the user community and to the database. We then discuss the desired characteristics of the tool set, the limitations of traditional (non-XML) tools with respect to achieving these goals, and the advantages, consequences and implications of using XML for data definition, identification, and organization.. We conclude with an explanation of current status and future plans.

Purpose and Goals

The purpose of this ROI analysis tool is to compute technology values across a set of selected missions. Equally important, the goal is to establish an auditable trail that relates the value of a given technology or portfolio of technologies to the values of customer goals (e.g., NASA program goals). The values are uniquely determined by a set of documented assumptions and a formalized procedure. If there is expert disagreement with the valuation, this disagreement can be reduced to identifiable decomposition assumptions, which may then be systematically reviewed, and potentially changed, to study the sensitivity of the valuation.

Analysis Methodology

The analysis tool was developed utilizing work from past JPL ROI studies with minor modifications [6,7,8,9]. Note that the innovation in this analysis tool is not the methodology itself, but in the use of XML to define decompositions and store data. In each case the algorithm expressed below was used to determine technology ROI for a set of missions—either for a selected technology or a portfolio of technologies.

Technology Value =

$$\sum_{\substack{all \\ missions}} \sum_{\substack{all \\ capabilities}} \textbf{CapabilityValue*TechnologyUtility}$$

In past work, ***technology utility*** for a given capability consisted of a ***performance factor*** times a ***completeness factor***. A performance factor indicated whether a mission is enabled or enhanced. It is 0 if the technology does not satisfy requirements or 1 if it does satisfy requirements. A mission is enhanced if there is some percentage of performance achieved that is greater than the enabling metric value. A completeness factor represented one of the following three situations:

- All or nothing
- Probability that remaining technologies will be developed elsewhere, or
- Percentage of resources spent vs. total resources required to develop full capability.

In current and future applications, technology utility may be defined in alternate ways depending on the architecture of the total system (accounting for potential differences in user interface, data structure and content, integration of analysis tool and database, and ability to query).

In any case, mission goals are decomposed to system and in some cases subsystem capabilities, assigned values by technology and mission experts, and then associated with specific enabling or enhancing technologies by the same technologists. Within a mission, and by looking at the applicability of related technologies in each capability area, the capability values for a particular technology can be determined and summed. The composite technology values are summed across selected mission sets (e.g., formation flying, Mars).

Using this basic formula one can rank the most important technologies or capability areas with respect to technology value (or science value), as well as conduct other useful analyses on the data.

Spreadsheet Design

A customized spreadsheet was designed to calculate ROI and could be employed if we assume the cost for all technologies is essentially equivalent or if we are given applicable cost data reported on the same basis. The spreadsheet is based on the methodology described above and follows the work in Reference 1; however, the first version of the model performs a straight value calculation for each technology of interest (Figure 3-1)—in this case it is assumed that all costs are essentially equivalent and thus alternatives can be compared. The portfolio analysis function has not been implemented at this time, but will be a feature added for the next version.

The original method utilized a Monte Carlo simulation to determine (by brute force) typical technology portfolios that maximized technology value for alternate funding levels; this part of the approach will be replaced by an alternate method that is part of the Microsoft Excel analysis tools package. The Excel algorithm also maximizes technology value for given funding levels subject to user defined constraints.

	Inter-S/C Ranging & Alarm System (IRAS)	Autonomous Formation Flying Sensor (AFF)	FF Control/Sensor/Comm. Architecture & Algorithms	On-the-Fly-Observation Formation Reconfiguration	Distributed Resource Management	Formation Reconfiguration	Collision/Constraint Avoidance	Initialization / Lost Spacecraft Acquisition	Fault Tolerance	Formation State Estimation
TPF	4	66	5	1	7	2	7	9	7	7
LISA	0	0	0	0	0	0	0	0	0	0
MMS	10	0	2	0	7	0	4	0	2	9
MagCon	0	0	1	0	5	0	4	0	0	8
TV(all missions)	14	66	8	1	19	2	15	9	9	24
$M to TRL 6 (assume equivalent)	1	1	1	1	1	1	1	1	1	1
B/C by Technology	14	66	8	1	19	2	15	9	9	24

Figure 3-1. ROI Results for Selected Technologies Across Specified Mission Set

User Interface and Tool Utilization Process

Step 1—Connect to Database

The spreadsheet model is set up so that it queries the database. Data is then transferred, parsed and incorporated. The spreadsheet model is an Excel workbook augmented by Visual Basic to automate the analysis and data importing/handling tasks; a front-end user interface has also been added.

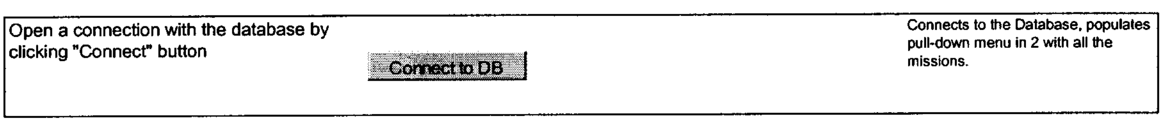

Figure 3-2. **Connection to the XML Database**

Step 2—Selection of Missions and Associated Capabilities

The second step is the selection of missions and computer allocation of capabilities. This step is dynamically generated.

Select mission set that you would like to consider for the ROI portfolio analysis.	Add Mission Get Capability Areas	Mission 1: TPF Mission 2: MagCon Mission 3: MMS Mission 4: LISA Mission 5:	User Selects mission from pull-down menu and clicks "Add Mission", which adds it to the selections column. Up to 5 [TBR] missions.

Figure 3-3. Selection of Missions and Top Level Associations with Capabilities

Step 3—Calculation of Capability Values

The third step is the calculation of capability values that are carried through the analysis. The drop down menu is populated by capability types that have been specified in the list of missions. The user selects only one capability from the pull down menu, and the selected capability is automatically entered in the selections column. All descendants of the selected capability area are automatically included. When the user selects the "Get Capability Data" button, a query returns the tree(s) rooted in every instance "capability area" for each mission. Values are computed for each node in these trees, the data is parsed, and the capability rows in the "Mission 'n'" sheets are populated. This information is also dynamically generated.

Select capability area that you would like to compute value with respect to: Right click on the actions menu, select "ComboBox Object => Edit", and type the name of the capabiltiy and/or scroll through the drop-down list.	Get Capability Values	Capability Area: Formation Flying	Drop down is populated by capability types that have been specified in the list of missions. User selects only one capability area from the pull-down and it is automatically entered in the selections column. All descendents of the selected capability area are automatically included. When the user selects the "Get Capability Data" button, a query returns the tree(s) rooted in every instance "capability area" for each mission. Values are computed for each node in these trees, the data is parsed, and the capability rows in the "Mission n" sheets are populated

Figure 3-4. Selection and Calculation of Capability Values

Step 4—Get Results

By clicking the "Get Results" button, an ROI analysis is generated that displays results in the "Results" sheet.

- A series of "type 1, find technology" queries are done for each mission, starting at the top instance of "capability area" and working down the hierarchy. A type 1 query returns technologies that are related to the selected capability. The technologies returned by these queries are merged into one master technology list, which is used to postulate the "Technology" rows in the "Mission 'n'" sheets. When a technology match occurs for these queries, the row corresponding to the capability, in the column corresponding to the technology, is colored green.
- A second round of "type 3, find technology" queries then follows. A type 3 query returns technologies that have an exact match to the metrics specified in the capability. When a technology match occurs, a "1" is placed in the row corresponding to the capability, in the column corresponding to the technology to indicate to the user that an exact match of requirements has been found.

Perform an ROI analysis by clicking the "Get Results" button. The results will be displayed in the "Results" sheet. Note that the capability area for every mission is given the same value (1000 points) and each technology returned by the query is assumed to be 100% applicable. These values may be modified in the "Mission n" sheets.	Get Results	A series of "type 1, find technology" queries are done for each mission, starting at the top instance of "capability area" and working down the hierarchy. The technologies returned by these queries are merged into one master technology list, which is used to populate the "Technology" rows in the "Mission n" sheets. When a technology match occurs for these queries, the row corresponding to the capability, in t he column corresponding to the technology, is colored green to indicate a technology match has occurred. A second round of "type 3, find technology" queries then follows. When a match occurs for these queries, a "1" is placed in the row corresponding to the capability, in the column corresponding to the technology.

Figure 3-5. ROI Analysis

Total technology values are computed (sum from all missions) and utilized in the ROI and subsequent analyses.

Step 5—Clear Form

The last step includes an optional feature to assist the user in rapidly reconfiguring the spreadsheet.

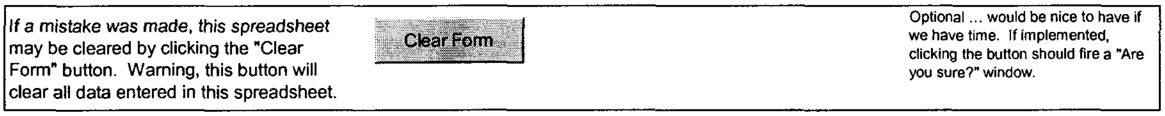

Figure 3-6. Delete All Data to Configure New Analysis

Database Interface

In a previous prototype, we used a Visual Basic API provided by the database vendor to connect the Excel-based analysis tool to the XML database. However, we recently created our own custom Java API to support the web GUI, which is implemented using Java Server Pages technology. The API uses XQuery to search the database and retrieve data. (XQuery is a query language specifically designed for performing searches on XML documents [11]). Our current plan is to expose the Java API methods using Web Services and SOAP XML messaging [10]. In this way, we will have one interface to the database that is available to any Web Services capable application. Having a single interface into the database should simplify connections to future tools and reduce duplicated development effort. Recent versions of Excel support Web Services messaging, so our plan is to use Web Services to connect the analysis tool to the database.

4.0 Advantages, Consequences and Implications of XML

Advantages

There are several advantages that come from using a database to manage data as opposed to managing data directly in a spreadsheet. Data sharing between analysis tasks becomes much easier because the data does not have to be extracted from one spreadsheet and formatted to fit another spreadsheet. This data extraction process is usually manual and labor intensive. In the world of technology planning, data quickly becomes obsolete. Using a database back end greatly facilitates the process of updating and distributing data sets. The use of a database enables analysts to use a standard data set for multiple analysis tasks, as opposed to individually collecting data sets that may not be consistent. The existence of an easily accessible standard data set should greatly reduce data collection time and duplicated effort.

Of course, the advantages just mentioned apply to any database, XML or relational. There are also advantages that come specifically from using XML. The fundamental advantage of XML in this application is that it enables the use of standard hierarchical decompositions, i.e., taxonomies. As mentioned previously, one of the first steps in evaluating a technology is to create a hierarchical decomposition of required mission capabilities. Since our XML database is already organized in a hierarchical fashion, analysts do not have to create new decompositions from scratch for every task. The use of standard taxonomies enables a broader base of users, who are not necessarily specialists in functional decomposition and ROI analysis. Pre-configured decompositions should save time in analysis tasks since they eliminate one of the more time consuming and controversial steps. One of the problems in comparing the results of separate analyses is that the analysts frequently use very different decompositions. The use of standard taxonomies should produce more comparable, i.e., "apples to apples" comparisons over time. Finally, the involvement of more general users in analysis tasks should make the decompositions more familiar to the customer, which will improve communication of results.

Consequences

Although the use of XML offers many advantages, there are some consequences to this approach. For one, standard decompositions mean less flexibility for the experienced analyst. Inevitably, a taxonomy model that is meant to represent broad classes of problems will not be the best description in every case. Furthermore, XML is still a new technology. Excel has had easily configured access to relational databases for several years. Only the latest versions of Excel and Windows enable easy connection to SOAP XML-based messaging via Web Services. This means that people who want to use this analysis tool will most likely have to upgrade their operating system and office software. Staffing is also an issue when working with cutting-edge software technology. The skill set required to develop the analysis tool includes general Excel skills, VBA programming ability, familiarity with XML parsing, and some understanding of Web Services. It can be difficult to find this skill set in a single individual.

Implications

The emergence of XML as a basis for technology planning involves two paradigm shifts, one for analysis and one for data management. In the past, technology ROI analysis was the exclusive domain of specialized analysts who managed infrequent tasks over a period of several months. The use of standard decompositions, enabled by XML, will probably lead to more frequent analysis by both general users and specialists; this is a sort of "democratization" of the process. It is hoped that the expanded use of quantified analysis methods will result in better, more objective decisions on missions and technology planning.

Currently, every analyst is responsible for collecting his own data for his own task. We expect that the use of an XML database will lead to a "centralization" of data collection and management. While we expect that this new infrastructure will improve efficiency across the board, funding to maintain this common data store will have to be arranged with the user community. The very existence of a common database will make the analysis process more visible. We expect that the larger space technology community will insist on conferences and workshops to establish and validate an approved, standardized data set for planning. It is important that no one group has an unfair advantage in securing technology funding. Greater community involvement in setting requirements and technology standards should result in better quality data over time.

Further discussion of the advantages, consequences, and implications of XML, along with the schemas and taxonomies, are detailed in a companion paper in this session dealing with the XML database.

5.0 CURRENT STATUS AND FUTURE PLANS

The database and analysis tool are currently in alpha testing. Taxonomies have been defined for the NASA organization, structural capabilities (bus and electro-optical instruments), functional capabilities (including formation flying), and technologies. In the recent past, a prototype analysis tool established a connection with the XML database, issued XQueries through a vendor-supplied Visual Basic API, parsed the result set, and placed the query results in the analysis tool, which then computed valuations for the formation flying example. The current alpha version of the analysis tool defines a more generic user interface and uses a more transparent analysis method. The user interface allows the user to easily display the data retrieved from the database and make manual modifications if desired. Currently, the analysis tool uses an internal data set for debugging the user interface and analysis computations.

In the near future, we plan to add dynamically sized arrays to the equations in the spreadsheet. Arrays will make it easier to parse and format the XML query results. We will then implement a generic interface to the XML database, probably using Web Services to access our own Java API. Implementing the generic interface will probably require developing and testing new XQueries, in addition to new Visual Basic code for parsing the result set. The results obtained from the internal data set will be used to validate the results obtained using the data supplied by the database.

The taxonomies will be updated to include representations of active electro-optical, passive microwave and active radar instruments, as well as other technology areas of interest to NMP such as precision GNC and high-speed laser crosslinks. This set of functionality will allow the project to proceed into beta testing with NMP users in early 2004. Beta testing is probably the most important part of the future plans providing invaluable feedback on the strengths and weaknesses of the current system design.

During beta testing, we plan to work with NMP to develop a more complete functional taxonomy, possibly with standard "blocks" of mission functions that can be assembled to describe many different missions. We have allocated time and resources to respond to beta user feature requests and bug reports.

At some point, we plan to explore storing valuations in the database and giving the analysis tool access to the valuations, possibly with an update capability. We expect that the database will evolve to store state of the art (SOA) and cost data for technologies; the analysis tool will evolve to use these data types for more sophisticated valuation methods. Eventually, the database will serve as a common repository for several different types of analysis tools covering areas such as schedule and budget planning as well as space mission trade studies.

6.0 CONCLUSIONS

A method for assessing the science benefit of a technology has been developed. This method was then used to define an analytic technique for computing a technologies potential science return on investment. Further extensions to this basic analysis have been defined to encompass return on investment and optimization analyses on technology portfolios. The method has been embodied and validated in an initial spreadsheet based tool, which is now being automated and interfaced to a hierarchical XML database. Use of XML as a basis for both the analysis tool and the database has provided significant advantages to this process, including the establishment of standardized taxonomies, nomenclatures and dictionaries. While the system allows addition of new XML terms and thus accommodates expansion of the taxonomies, care has been taken to ensure that the XML definitions are precise, rigorous, and complete. Rigorous definitions allow precise meanings to be assigned to the XML terms. This, in turn, provides the basis for automated data collection, storage, retrieval and analysis. A pilot system, using these XML taxonomies, a hierarchical XML database and XML-based analysis tools is being implemented for the New Millennium Program to aid in technology portfolio analysis. A beta version will be fielded early in 2004 and a first production version is expected to be released in mid to late 2004.

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