USING SAS FOR THE MANAGEMENT OF RESEARCH RESOURCES.

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1. INTRODUCTION.

The uncertainties associated with carrying out research projects, coupled with the complexities of project management create a situation where systems and tools to support research managers become vital. One major aspect of research management deals with resources and their utilization. Systems that provide information on research resources can help managers responsible for research projects and activities to determine, for example, what resources are required, what resources are available, whether resources are being fully utilized, whether actual resource utilization deviates significantly from the plan, what corrective measures can or should be taken.

At Kuwait Institute for Scientific Research, a SAS-based information system has been implemented to help in the management of research resources, especially manpower and money resources. This paper describes that resource management support system and experiences acquired in using SAS.

The next section presents background information on the system that was developed and the decision to implement in SAS. Then an overview of the system is provided including a discussion of special system requirements facilitated with SAS. The paper concludes with post-implementation considerations and a discussion of activities related to the use of SAS at the Institute.

II. BACKGROUND.

2.1. The Research Environment.

Kuwait Institute for Scientific Research (KISR) is a non-profit public institution entrusted with the mission of promoting scientific and applied research for national economic and social development. Founded in 1967, there are currently about 1000 employees, including some 100 Ph.D.’s employed at the Institute.

The life stream operation of KISR is the execution of research projects which broadly fall in the domains of the five research division: Engineering; Environmental and Earth Sciences; Food Resources; Petroleum; Petrochemicals and Materials; and Technoeconomics. However, the Institute is organized and operated in such a way that interdisciplinary projects can be undertaken by means of matrix organization where research program/project management hierarchies are superimposed across the research functional areas and organizational lines of the Institute.

2.2. The Need for Resource Management Support.

Organizational requirements for information processing have been studied and correlated with several factors (ref. 1, 2) which exist at KISR. These include three particular characteristics of research management which underscored the need for information processing support:

1. Information required to manage research resources originates from and is processed in several distinct but interrelated organizational units. This information needed to be combined and reported on in an integrated way, in order to be most effective for research management.

2. Hierarchies for reporting resource management information needed to be both vertical and lateral in order to accommodate functional area managers responsible for resources housed or attached to that unit, as well as program or project managers responsible for resources that may be attached to several organizational units depending on the matrix organizational requirements of the project.

3. In general, the higher the uncertainty associated with tasks, the more information required for effective management so that replanning and rescheduling can take place early if required. Since research projects, by nature, involve uncertainty, full detailed and timely reporting at the project management level was needed.

Considering these characteristics, an initial set of system requirements was specified identifying the need for a resource management support system aimed at enhancing the effectiveness of managers responsible for planning and controlling resource utilization. In the context of research projects and activities, the system needed to maintain:

1. planned resource utilization information as represented by budgets and committed amounts, manpower requirements, and staff assignments;

2. actual resource utilization information as represented by actual expenditures of funds, actual income from services, actual manhours reported.

The system needed to provide:

1. Monthly reports on actual and planned resource utilization in relation to project/programs, and functional organizational unit activities, at several levels of detail;

2. Facilities for ad-hoc reporting on information maintained.

In addition, the system needed to be:
These alternatives were evaluated according to the following criteria:

1. Expandable, to incorporate new functions and requirements with system evolution;
2. Flexible, to facilitate modifications and changing requirements;
3. Implemented quickly, due to the growing number of projects and pressing needs for information.

2.3. The Preliminary Investigation.

In order to develop a system to meet these general requirements, a preliminary investigation was carried out to consider alternative methodologies for implementing the resource management support system (soon to be known as RMS). These included:

1. Implementation using a high-level programming language (such as PL/I).
2. Acquisition of an application – specific package.
3. Use of a general data retrieval package with report writing capability (such as SAS).
4. Implementation using a generalized data base management system.

These alternatives were evaluated according to the following criteria:

- Time to implement (the system was required to be operational as soon as possible).
- Cost (for implementation and operation).
- Expandability (the ease with which new functions could be added).
- Intangible benefits (associated for example with staff growth, productivity of developers and users).
- Risk level (uncertainty about the successful use of a methodology especially if a new software product is involved; uncertainty about product reliability, performance, documentation, and vendor support, important risk related factors in a developing country such as Kuwait).
- Flexibility (ease of system modification in responding to change).

Before discussing the recommendation and results of this investigation, it is appropriate to overview KISR's computing environment at the time of the investigation. KISR was then about to acquire its own major computing facility, an IBM 4341, operating with VM/SP and Conversational Monitor System (CMS). KISR had been previously processing scientific computer applications via remote linkage to a local computer center, and in addition, some administrative applications (Personnel, and Purchase and Stores systems), were run on an in-house IV Phase minicomputer. The new 4341 facility was intended to meet the institute's research computing needs, as well as house new applications to support the operations of the Institute. An initial selection of software products was to be installed in phases, including several programming languages and general utilities, numerical libraries and simulation software products, plus SAS for statistical analysis.

Returning to the results of the preliminary investigation now considered in the context of KISR's computing environment, the initial recommendation was to proceed with RMS implementation using a high-level programming language. This recommendation was made mainly due to the extended time-frame and higher-risk levels associated with the other approaches.

2.4. Decision to Implement Using SAS.

The RMS project thus commenced and proceeded through the definition and design phases. During RMS design, a solution to the information processing problem was formulated which was independent of the language of implementation. But it was in the implementation phase that the issues regarding language became significant. For RMS, implementation was commencing on data entry modules, coded in PL/I, for on-line data entry and initial field verification. Some preliminary implementation work on RMS file maintenance modules was also beginning, in PL/I. Meanwhile SAS had just been installed for operation under CMS, and an instructor from SAS Institute came to Kuwait and delivered the short courses SAS Basics and SAS Statistics.

With SAS now installed and operational, a parallel effort was initiated to investigate the potentialities of SAS for developing an information system such as RMS.

After an experimentation period of a few weeks, it became evident that SAS would be an excellent tool for implementation of RMS. Thus, although no one on the RMS project team had ever used SAS before, it was decided that all file maintenance and reporting modules would be developed using SAS instead of PL/I. The major features of SAS that led to this decision were:

1. Ease of learning – It was not difficult to become versatile in the SAS programming language.
2. Enhancement of programmer productivity – Data management and report programs could be developed more quickly using SAS. In fact, most of the required RMS report programs were implemented during the experimentation period.
3. Plotting and charting capability – Management reports could be presented graphically, easily.
4. Statistical capabilities – Although the initial requirements for RMS did not call for extensive statistical analysis of resource management data, the ability to enhance the system easily to include more decision – support functions for management at the Institute was an extremely desirable feature.

The risk related factors and possibly extended learning time-frame potentially associated with SAS during the preliminary investigation had been dissipated upon actual utilization of the product. Other important features of SAS – based systems, including flexibility and expandability,
were borne out as well, as the RMS system became operational. Also, via implementation with SAS, the Institute could derive the intangible learning and staff-development benefits associated with the in-house development of a major information system.

However, SAS did not offer (at that time) facilities for screen design and on-line data entry and verification. Thus, data entry functions remained programmed in APL.

III. SYSTEM OVERVIEW.


The management process supported by RMS can be briefly overviewed as follows. (see also Table 1) Initially, plans are established in order to realize some desired performance target tied to deliverable outputs of a certain quality. The plans typically include an anticipated level of effort for different categories of employees, a schedule, and an estimated budget. Staff qualifications and availability are reviewed, staff members are assigned, and activities are carried out. Actual performance is measured in terms of level of effort, schedule, and expenditure and compared to plans in the context of the outputs achieved and their quality. Management analyzes deviations and, if required, develops and implements corrective procedures. These corrections may involve changing the level of effort, the staff assigned, the schedule, the budget or the deliverables.

RMS supports this process in several ways (see Table 1 again). Planning estimates may be improved by reviewing plans and results of similar projects or activities, which have been or are being carried out and are maintained in the system (historic or comparative resource utilization information). Reports on research-related equipment assist in ascertaining whether new equipment expenditures must be planned for and budgeted. Periodic inventories of research staff members, their qualifications, their current and planned assignments and availabilities support managers in the staff allocation function. The recording of actual utilization of manpower and money resources, and the system reporting of actual versus planned utilization for the current month, cumulative, and projected to project completion help the manager to analyze any deviations and identify possible corrective actions. Of course the status of actual accomplishment in terms of deliverables and their quality is ascertained by the manager and it is only in this context that reports on resource utilization become meaningful. If corrective actions are necessitated, the system facilitates the recording of revised plans, maintaining the original plan as well.

3.2. The RMS Data Base.

The resource management support data base is composed of six interrelated SAS files containing information about organizational units, projects, employees, employee assignments, expenditure accounts, and commitments. Figure 1 provides a schematic view of the files and their relationships, and each file is overviewed below.

Organizational Units.- Organizational units are conceptualized hierarchically to include the Institute as an overall unit, deputy directorates, divisions, and departments. Directly associated with each organizational unit are its name, abbreviation, and hierarchical reporting code; a number of positions (filled and vacant) for employees in different categories; and monthly income generated from the utilization of its resources.

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<table>
<thead>
<tr>
<th>Management functions.</th>
<th>Supportive functions.</th>
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<tr>
<td>1. Plan desired performance and resources required.</td>
<td>1. Provide historic or comparative resource utilization information.</td>
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<tr>
<td>2. Allocate resources.</td>
<td>2. Provide information on resources and availability.</td>
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<td>3. Measure performance as activities are carried out.</td>
<td>3. Maintain resource utilization plans.</td>
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<td>4. Analyze deviations.</td>
<td>4. Record actual resource utilization.</td>
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<td>5. Implement corrective procedures.</td>
<td>5. Provide analytical resource utilization reports.</td>
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<td>6. Accept and maintain revised resource utilization plans.</td>
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Logical model of RMS Data Base.

Projects. Projects are coordinated activities carried out in a specified time and with specified resources to meet some objective. Every organizational unit has one "general project" associated with it which umbrellas the general activities of the functional unit. Then any additional number of research projects may be associated with a unit. Projects which are interdisciplinary are associated with an organizational unit at a level that includes the units of all the functional areas (or disciplines) involved. Currently, the functional manager at that level thereby doubles as a program manager for projects managed through the matrix organization.

Each project is thus directly associated with an organizational unit and has planned start and completion dates, an actual completion date, a funding status, a name, a code, and a project leader associated with it.

Employees. Employees occupy positions associated with organizational units. Associated with each employee are employee name, a code (I.D.), a home organizational unit, an employee category, and salary information.

Assignments. Assignments link employees to projects and include an activity code designating the assigned type of activity planned or actually carried out. Activity types represent, for example, project work, research development work, administrative work, training, missions, leaves, etc. Assignments are maintained in a number of hours for each month in the current fiscal year plus the next fifteen months. An assignment may be a planned allocation of hours and/or an actual allocation of hours spent by an employee performing a given type of activity associated with some project.

Expenditure Accounts. Expenditures are linked to projects and are identified by expenditure account codes. A project may have no account or several accounts associated with it. Several types of planned and actual resource expenditure are associated with an expenditure account for each month of a fiscal year including: number of employee positions, by employee category planned to work utilizing this account each month; the actual number of positions reporting (by category) each month; the original plan, adjusted plan, and actual number of manmonths expended, for each category each month: the original budget amount, adjusted plan, and actual expenditure of funds for each of about 50 budget items, each month; and the total amount of outstanding or unspent committed funds for each budget item.

Commitments. Commitments are amounts of money committed or earmarked for later expenditure, associated with a particular budget item of an expenditure account. A commitment has a commitment number, a date, and an amount of money associated with it.

3.3. Data Base Maintenance.

RMS inputs originate from several different organizational units of the Institute and are collected and entered weekly or monthly or as events affecting the data base occur. The inputs facilitate the addition, alteration, or deletion of records maintained on the RMS data base and initiate extensive validation and recording procedures often involving several of the data base files.

3.4. Data Extraction and Reporting.

The RMS data base is designed so that details describing major entities of interest to the system are maintained on separate files to avoid duplication of information. However, for reporting purposes, supportive details are extracted from the separate files and brought together to form the major files used for report generation. The major outputs of the resource management support system are structured as follows:

1. Reports on resource utilization in relation to a project.
2. Reports on resource utilization in relation to an organizational unit.
3. Inventories of research-related resources.

These outputs are summarized in Table 2, and briefly overviewed below:

1. Reports on resource utilization in relation to projects.

Five reports provide information on resource utilization in relation to ongoing projects. All five reports compare actual versus planned utilization of manpower and/or money over three time periods: the current month, cumulative from start of project (within fiscal year), and total (projected) to end of project (within fiscal year). The deviation between actual and
planned utilization is reported along with status indicators reflecting the seriousness of the deviations. Also included with expenditure summary is an accompanying bar chart of cumulative total actual versus planned expenditure, by month, to provide a visual aid to managers tracking expenditure trends. The reports differ in the amount of detail provided and, accordingly, the intended user. Expenditure summaries however are provided to the head of the organizational unit the project manager reports to for this project to accommodate matrix management reporting requirements.

Table 2. RMS Outputs

1. Reports on Resource Utilization in Relation to a Project.
   a. Personnel Utilization, By Employee.
   b. Personnel Utilization, By Category.
   c. Account Expenditure, By Budget Item.
   d. Expenditure Summary.
   e. Status Summary of All Accounts.

2. Reports on Resource Utilization in Relation to an Organizational Unit.
   a. Research Staff Availability.
   b. Personnel Utilization, By Employee.
   c. Distribution of Hours worked, By Activity Type.
   d. Project Classification.
   e. Income from Services.

3. Resource Inventories.
   a. Research-related Staff.
   b. Research-related Equipment.

2. Reports on resource utilization in relation to an organizational unit.

The preceding five reports support managers concerned with resource utilization in the context of a particular project, where resources may be drawn from various organizational units. The next set of reports provides information and analysis on the use of resources attached to a particular functional organizational unit, whose resources may be utilized on various projects. The research staff availability report provides information on planned assignments of research staff for the coming 15 months. The personnel utilization report provides details of the actual activities carried out by individual staff members, for the current month, and cumulative since start of fiscal year. Reports on the distribution of hours worked by work activity type and by project type are provided in a series of pie charts. These charts represent the actual efforts of employees directly attached to a unit at any level (unit level report), and the combined actual efforts of employees attached to a unit plus any other functional units that report to that unit in the hierarchical management scheme (i.e., combined divisional reports, combined deputy level reports, and overall Institute reports). The report on income from services as a result of the utilization of resources of the unit, also provides information based on resources directly attached to the unit (unit level report), as well as resources attached to a unit by means of the hierarchical reporting structure (combined reports).

3. Resource Inventories.

The Inventories of personnel and equipment are generated by programs operating within the Personnel System and the Purchase and Stores System.

IV. SELECTED SYSTEM REQUIREMENTS FACILITATED WITH SAS.

Several characteristics of SAS were found to be particularly useful in the development and operation of RMS. Selected features and facilities are overviewed below.

4.1. Maintenance of Integrated Files.

RMS needed to maintain a consistent base of valid data derived from distinct functional areas of the institute. SAS facilitated this requirement in three ways: SAS data management constructs enabled validation checks to be made against several of the SAS files maintained; tables of code equivalencies were set up and maintained as SAS files to allow individual units to provide data according to their established procedures, but rely on the system to integrate and regroup the information for consistency and integrated reporting; data from other computer-based systems (i.e., Personnel) could be accepted easily by a SAS-based system due to flexible inputting facilities.

Although file maintenance procedures often necessitated passing through several files sequentially for validation and recording purposes, this did not impose unacceptable operational burdens. This was so because for the major transactions, a large number would become available at scheduled intervals, they would be processed together, and in fact they would effect changes on a high percentage of the data base records maintained. Also if validation necessitated more than one pass of a file, the required validation dependent variable(s) could be extracted first.

4.2. Satisfying Complex Reporting Requirements.

SAS data management facilities, report writing features, and charting procedures facilitated the complex reporting requirements of RMS. Variables could easily be extracted from several data base files and MERGE'd to form reporting files. Then some report programs were prepared so as to generate multiple reports and output files based on a single pass of the extracted reporting files. Especially noteworthy were the facilities provided by PROC SUMMARY combined with PROC CHART which enabled labor distribution.
pie charts to be generated easily for the many reporting hierarchies of the institute. The SYSPARM feature was also useful for passing a required reporting date to SAS programs which could then generate regular or ad-hoc reports for the period of time identified by selective extraction of data from the reporting files created for that purpose.

4.3. Flexibility and Expandability.

After initial implementation, several system modifications were necessitated based on changes in organizational procedures. These were easily accommodated using SAS. For example, work classification activity types were changed from one character to three characters (causing no problem with data independence characteristics of SAS), and then later activity code designations changed (causing no problem when a SAS format library is being used for code descriptions). A completely revised chart of accounts was implemented (again causing no problem when a table of pre-coded-report code equivalencies is being maintained), and new requirements for more detailed validation trails of financial transaction processing were easily implemented.

As operation progressed, the files grew to include about a half a million variables and a significant improvement in storage requirements and processing time was realized by running a simple SAS program that reduced the length of all numeric variables on the SAS files. Furthermore, during RMS operation the personnel system was converted from the IV Phase to run under QBE on the 4341, but RMS was easily modified to link with the new system.

V. CONCLUSIONS.

This paper has thus far described selected characteristics of an integrated information system used to support managers of research resources. Some design decisions and experiences related to the use of SAS for this system have also been overviewed.

In conclusion, the major advantages found in using SAS for this system were enhanced programmer productivity, flexibility and expandability, and ease in generating management reports. Drawbacks lay in the fact that SAS could not accommodate the type of data entry interface required (SAS/FP had not yet been announced). SAS definitely led to better utilization of human resources. However, no benchmarks were run to assess the performance of the system in respect to the utilization of computing resources.

Lastly, a few notes are provided on current activities related to the use of SAS at KISR.

1. RMS was the first major SAS-based information system developed at the Institute. Since its implementation, SAS has been and is being used to develop other systems that require data management and management reporting.

2. SAS is now being used heavily in research data, and for its analysis using techniques ranging from descriptive statistics and quality control charts to analysis of systems of linear equations.

3. SAS training courses are now given in-house by KISR staff covering data management and statistical applications.

4. KISR research staff members have learned SAS quickly, found it effective and user-friendly, and come to rely on SAS as an integral tool in their working environment.

ACKNOWLEDGEMENT.

The author wishes to acknowledge the many people at Kuwait Institute for Scientific Research who contributed in different ways to the development of the system described here. Ms. Arwa Saleh assisted in the definition and design phases, and Mrss. Ahmed Imam and Mahmut Krougl assisted in system implementation. Mr. Yousef Yacoub, and Ms. Jinan Al-Mahdy helped in the operation and maintenance of the system, and data collection, conversion, and control responsibilities were held by Ms. Haha Hussein.

Mr. Kais T. Ali, Manager of KISR's Computer Center, provided guidance and support, and all functional area managers, especially Mr. Jassim Al-Sarraf, Director of Finance, Mr. Fouad Taha, Manager of Office of Project Management, and Mr. Habib Sahaf, Personnel Manager, facilitated access to the data required to operate the system.

Lastly, but most especially, the author wishes to acknowledge Dr. Adnan Shibab-Eldin, Director General of Kuwait Institute for Scientific Research, whose deep concern for effective management support initiated this project, and whose involvement and invaluable guidance offered continual encouragement to all those involved.

REFERENCES.
