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DEVELOPING A MEASURING SYSTEMS BODY OF KNOWLEDGE

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Abstract – This paper discusses issues to be considered in setting up a Measuring System Body of Knowledge, an MSBOK. It covers the benefits of it being available; what it should contain; why online delivery is required; and progress being made on a project developing such a knowledge service for those who need reliable and rapid access to measurement knowledge.

Keywords: body of knowledge, measuring systems, on-line knowledge.

1. INTRODUCTION

This paper continues to expand issues about the nature and relevance of knowledge to measurement as outlined in [1].

There exist many good reasons for defining the nature and extent of knowledge pertaining to a discipline; such a defined set of knowledge is becoming known as a Body of Knowledge – a BOK.

Some projects that identify BOKs are:-

- PMBOK - Project Management Institute (PMI)
- SEBOK - International Conference on Systems Engineering (INCOSE)
- BOK - Australian Computer Society (ACS)
- SABOK - Systems Administration Group
- SWEBOK – Software Engineering of Computer Society
- NPDBOK - New Product Development

Many other sources of defined knowledge exist that are not called a BOK, as such. For example there are the book series, encyclopaedias, and Major Reference Works produced by publishers.

The measurement fraternity needs its own defined Measuring Systems Body of Knowledge (MSBOK). The list of potential users is large because measurement is involved with most of human endeavour:-

- Researchers of non-measurement topics who need to establish available measurement methods for use in their research investigations
- Researchers of measurement science and technology who need to be aware of the front line of knowledge and the past knowledge already externalised.
- Users of measuring systems in pursuit of their application area
- Managers and operators of measuring systems
- Personnel selling instruments
- Students learning about measuring systems
- Government staff, and others, when conducting surveys of need and supply
- Government projects seeking to improve national industries and services
- Auditors of measurement applications
- Legal practitioners representing clients involved with measurement
- Manufacturers of measuring systems
- Installation engineers and crafts persons
- Designers developing and using measuring systems
- Technical authors and editors
- Publishers of measurement books and journals
- Writers of technical application notes and other guides

The existence of a BOK for a field enables the necessary knowledge to be systematically defined, located, organized and upgraded over time. Missing areas can be identified and added as they are seen to be needed.

Most importantly, as is explained in Section 4, consensus definition of the content of a BOK is needed to enable the power of on-line methods of storage, retrieval and manipulation to be used in support of all who need to make use of this knowledge in a timely manner.

The nature of existing BOK projects is quite varied. The one discussed here - the MSBOK - attempts to define the knowledge content needed by the majority of users in the norm situation. That Table of Contents (TOC) is then populated with article style sets of knowledge that are well integrated and cross referenced.

Many of the available BOKs deliver guides on the knowledge needed for graduates and thus are aimed at academic course development for the members of

their professional society. They do not offer the detailed knowledge.

One BOK interpretation is that it is a defined small group of living experts, see - www.iog.com.au

The closest to the MSBOK described later is that of the Systems Administration Group (www.is.com.au/sa-bok). It is, however, still in the early development stage and does not reveal the depth and detail of knowledge that is intended to be made available.

The MSBOK discussed here is much more than a guide to the topics of the discipline; it contains knowledge prepared by subject experts to a well researched master TOC.

To be effective a BOK implementation needs to able to accommodate the many types and formats of the methods used to store knowledge, that is text, equations, tables, figures, sound, animations, presentations, full colour and monochrome.2D and 3D images. All of these must be capable of e-file interactive use - but more on that in Section 4 and 5.

A key issue is how what knowledge needs to be provided in a BOK. Some insight is found on this issue by considering the generic types of published knowledge.

Knowledge is located in a hierarchy of levels according to how recent it is, and how much it has been condensed. These levels are:-

Primary records

These knowledge items are found in the learned journals, and the like, that report research findings. They often also give well considered subject reviews that create new knowledge. Data bases of scientific data and information also are found here as the material is 'prime'. Material in this group is that recently generated from original thought and that has been 'tested'.

Being refereed by peer experts this primary knowledge has the highest level of fidelity at the time it is published. It is the starting point for communicating newly created knowledge.

It, however, is often later proven to be not as exact as expected. Additionally the processes of reviewing are often lacking insufficient control of veracity.

Primary knowledge often quite difficult to interpret and apply; it can lack clarity of ideas and be masked with considerable material later found to be erroneous.

It can be hard to apply as it is often not recorded in a condensed and orderly didactic manner.

Well in excess of tens of thousands of researchers are publishing new journal articles at several per year each. Thus the rate of expansion of knowledge is usually too rapid to keep up with when the full range of topics that contain measurement material are considered. That issue is taken up in Section 2.

Due to the importance of keeping abreast of the contributions of new knowledge to the progress of research studies, plus being a major factor in academic career progression, this level of knowledge is well documented and now usually available in e-file form via publisher's online subscription services. It is now possible to carry out detailed searches of the content lists and full materials of many journal papers via the web.

Secondary material

This set of knowledge comprises primary material that has become condensed and processes over time. The key content of the original primary publications is ordered and formed into more understandable language. Much of the less salient extraneous material has been taken out, along with much of the traceability citations that show where a chunk of knowledge stems from. For this reason secondary knowledge need to be accepted with care as to its veracity.

Here fit scientific and technical books; major reference works; some of the journals; commercial house publications such as application notes and in-house journals; and magazines.

The veracity and audit of this level of knowledge ranges from being very sound to really dangerous to use. The issue for users is how to grade its level of truth. Publishers of technical and scientific titles, and research organisations, have refereeing processes in place but the efficacy of the audit processes is variable. Much more control is left to the editor chosen by the publisher than with primary material.

As with primary publications a vast amount of secondary material is published over time. Again measurement topics will be spread widely over a truly enormous range of publications – see Section 2.

The greatest variation in veracity is that associated with the virtually infinite amount of knowledge now available on the Internet. Literally tens of millions of computer sources are able to put any kind of item whatsoever up for retrieval by a search engine. The result is that Internet sources often fail to:

- Provide substantiation of its material
- Produce a well defined set of potentially useful hits on a topic. Even well constructed searches will too often fail to adequately filter the 'chaff from the wheat'. It is rather like looking over a huge rubbish tip of old paper documents in the hope, and faith, that what is needed is there somewhere.
- Provide material on a topic that has its place in the breadth of knowledge defined or its depth of explanation regulated or ordered with respect of its detail. Generally what is found may well be a starting introduction but it is often not be able to be mined down to the depth that it is already available in the primary literature.

A guide of what to look for when questioning the veracity of material from any source is found by application of Kuhn's 5 key questions that *collectively indicate what is at stake*, [2] about the quality of a scientific theory. These are:

- Accuracy (demonstrable performance)
- Consistency (internally and externally)

- Breadth of scope (goes far beyond local proofs)
- Develop order, in a simple way (to existing isolated laws)
- Fruitfulness (lead to new appreciations and relationships)

Tertiary knowledge gateways

Being able to find and retrieve substantiated primary and secondary material rapidly and at low cost, but paid for, manner is a dream that is gradually being made real by the integrated efforts of publishers.

Because primary publications are reasonably well financially supported by researchers and their institutions things are improving the fastest there.

Primary journals now have central web-based agencies for locating and purchasing articles. Publishers are moving toward common entry points to overcome the need to hold numerous access licenses and use different searching facilities.

The secondary literature field is not advancing as well. The problem here is its great diversity and variable level of audit.

The TOC of books published by the main line technical publishers can now usually be searched and titles purchased with relative ease. However, not all users will be prepared to purchase a large and costly book in order to get a small amount of material on their particular topic of the time. Nor will they be certain what they want is there until they receive the book.

Online offerings of books allow content to be examined if the product access license has been purchased. Smaller chunks, as little as a page can sometimes be downloaded but there is still the need to register at relatively high cost. This is not attracting the majority of users making the online market only suited to multiple user situations such a libraries where an occasional page is needed. Several publishers licenses are still needed to get access to a wide range of material as can be accessed in a traditional library.

In some cases it takes longer to set up an access account than it does to purchase and receive delivery of the book.

To make this area still more difficult to use is the fact that the tables of contents (TOC) of titles are often not able to be searched lower than the title of the work and some keywords. This means a user needs to pay for registration before they can be sure it can provide the needed chunk of knowledge.

The obvious solution, now being considered in many quarters, is to set up tertiary, knowledge gateways (or portals) that enable access to a wide range of publications- but not to all.

A current question re this at present is whether these are set up at the individual title level, or at the publisher's whole catalogue level.

There also exists the pragmatic problem of how can the user pay for material as it is collected as many small items; how royalties are paid to authors for these items.

The overwhelming benefits of the online delivery of knowledge over the traditional hard copy format are discussed in Section 4. An example of a tertiary gateway measuring system publication is discussed in Section 5.

2. DEFINING AND ESTABLISHING A MSBOK

Although many BOKs under development it seems they are not being developed to any well reasoned guidelines for deciding their content and form.

Generally a group has used their experience to decide the draft content with consensus being developed by inviting membership to provide further comment. A more defendable and rational approach to the development of the Table of Contents (TOC) of a BOK is needed. That used by the writer and his colleague is described here.

To begin a definition of a BOK is needed. That used here is:-

An appropriate and comprehensive set of knowledge assembled to efficiently support the practice of users in a defined area of endeavour.

Invariably a search of a topic, despite the time devoted to it, does not generate the desired depth, coverage and interconnectivity of knowledge. Knowledge in libraries, and now the Internet, is not stored in that way.

BOK compilations can pre-filter, from the vast set of available information, a more manageable and appropriate amount of material.

To be effective they need careful development in which overall content, context, depth of explanation, progression of difficulty of material, ease of access and use are all well controlled.

The prime requirement for a BOK will greatly influence the appropriate content, making general agreement on generic content problematic.

There are many ways in which the TOC for a BOK can be decided. For example, the following are all valid foundations for use as the first level of classification in determining what to include in a MSBOK:-

- Applications of measuring devices (ex. laser ranger used in survey work)
- Principles used in design of measuring system (ex. laser distance ranger)
- Maker's products (ex. all measuring products from a maker)
- Name of sensor involved (ex. Hall effect sensor)
- Names of measurands
- Place in a national statistical classification

- and so on.

Disciplines already have well developed knowledge support systems but the development of their knowledge base has been largely as an undirected process driven by reasonably freely scoped research,

coupled with the decisions of publishers and secondary literature authors.

The elements for creating a sound BOK development are not well defined. They have not been debated. Some are developed in the paper.

One can look to traditional library classification systems for a ready made guide.

However, severe difficulties exist when classifying measuring system material for placement in library collections. The material has such diverse uses; involves numerous principles; considerable science and engineering; and attracts diverse interpretation.

Titles of measurement books are catalogued in numerous, often quite unexpected, locations. It is not unheard of that the several copies of the same title will be located in different places in a library collection.

Another way to see the difficulties arising in the location issue is to consider where a measuring system query might be found in the well established Dewey Decimal Code library classification system. Reference [3] states, with lists as evidence, it might be found in one or more of 650 locations.

Fortunately this long-standing classification difficulty is a problem associated only with of hard copy forms of knowledge storage. It is largely overcome by the use of electronic e-BOKs that can be set up, by appropriate searching, to extract and assemble blocks of knowledge as are needed by any user as they improve their understanding of topic.

The order in which fundamental pieces of knowledge are stored is not nearly as critical in the e-format as it is in traditional hard copy storage.

3. CONTENT OF AN MSBOK

Turning now to the specific task of creating a Measuring System BOK (MSBOK), deciding what the content should be is not at all well established.

Consideration shows that there are three groups of interest to satisfy when building a BOK:-

- BOK development and maintenance. These functions need a well defined methodology for developers to feed in relevant information. It must have sufficient detail of description to support:-
  - Rapid determination of the location of a likely topic under consideration for inclusion
  - Establishing if a topic is already covered and how
  - Setting up logical relationships with other items
- Browsing capability by users who use lists to stimulate thinking about a topic.
- Specific topic(s) retrieval. This is the most likely need of users

In the past the need for a TOC would be to define the sequential architecture of a hard copy book. These can take several forms of locational structure:-

- Prose rendition of topics and their explanations as a set of chapters or the like that convey both material and some context.
- Encyclopaedia format wherein entries are ordered in alphabetic order of their main keyword. These do not read that well in formative use.
- Case studies. These contain principles spread over the work, thus making their location somewhat problematic but things are in good context.

In each case the book format, for reasons of not be able to repeat material, suffers the heavy constraint that the material has to be placed into a single serial delivery order. An index, alphabetic ordering and use of cross referencing are means of directing the user to related topic locations. Such mechanisms are the best available means to make up for the limitation of not being able to carry out a rapid e-search of the whole.

The digital form of publication does not need to suffer this serial limitation. Knowledge items can be entered into the BOK in any order provided sufficiently small chunks are uniquely identified as a unit and have sufficient key words present. Each item will need a unique identification which also needs to contain no sequential meaning.

Thus an electronic BOK can be assembled as needed; be easily expanded over time by hyper linking files using linking set up by subject experts; and be easily corrected.

Linking requires the addition of mark up language code into text parts of files adding cost to the publication production. Publishers usually add the code.

Linking between sets of e-file information is not new. It is commonly used in applications such as office tools sets. Published, on line, material uses it to support complex searches.

Text can be searched using symbols and strings that are matched; this is the most used method of searching.

Images can now also be searched using ontological searching. Here a large (100,000 is not uncommon) set of simple rules regarding recognisable, simple, features of imaged objects allows images to be located that match a stated set of rules. For example, an image of the Sun can be found using the facts that it is generally ‘yellow’, ‘ round’ and is found in a ‘blue background’.

For the MSBOK project described in Section 5 it was decided that the best information input structure to use for the purposes defined should be based on the life cycle of the generalised measuring system.

This was used to assist development as it was likely to be the best mental prompt of what material should be included and where to look when entering new material. It was not done that way for users for they tend to search for more detailed level of topic.

There was no intention of this MSBOK being used to drive curriculum development but obviously

it covers that need. Course notes could be generated from it by use of lecture development tools that find and paste items from the MSBOK.

Each stage of the engineering system life cycle was then first set up as Super Clusters (SC) of information. The subsequently adopted SCs were:-

1. Understanding (the measurement need – the meta level of appreciation)
2. Defining (concept generation and requirements generation)
3. Designing (engineering detail)
4. Implementing (making and applying)
5. Assessing (evaluation of effectiveness)
6. Maintaining (keeping it operating and valid)
7. Replacing (replacement and removal from service)

It was also realized that each of the numerous areas of application of measuring systems have their own peculiarities for such things as terms, methods, standards and support organizations. This led to addition of an eighth Super Cluster:-

8. Applications.

The SC topics were then set up in sequence in a single Word text file.

Each SC category was then visited. Its major topics were identified from experience. These were called Clusters (C).

For example Super Cluster - *Understanding the measuring system* subdivided into Clusters:-

- Using the MSBOK
- Historical Aspects of Measurement
- Reasons for Measuring
- Types of Measures
- Professional Associations for Measurement
- Measurement Education and Training
- Measurement Theory and Philosophy
- The Measurement Process
- The Sensing Interface
- Decision Making
- Multi-sensor Systems
- Knowledge Representation
- Environmental Factors
- Distributed and Networked Measurement Systems

etc.

This was done for all SC groups, resulting in some 100 Clusters.

That a Cluster topic could also be relevant to other life cycle stage is not important for the task was fundamentally to create an online BOK in which the final order of a session of use is set up by the user. The key thing was not to omit an important topic.

Each cluster was then subdivided into Blocks (B), being the sub areas of Cluster topics.

For example *Cluster – Types of Measures* leads to

- Measures in general
- Measures of Effectiveness (MOE)
- Measures of Performance (MOP)
- System Performance Parameter (SPP)
- Technical Performance Parameter (TPP)
- Measures trees or dendritics
- Technical Performance Measure (TPM)
- Metrics in general
- Metrics database for software
- Metrics database for defence systems

Etc

Again the order in which they were placed was not vital but they were set up in the expected order that would be needed in a serial exposition. This stored their context for later use where a set of Blocks might be needed as a form of chapter. This resulted in some 800 Blocks.

The Block is the fundamental element for structuring and identification.

Cluster and Block topics were placed in context using the SC, C and B levels. The result is generation of the TOC of the MSBOK in a Word file. This method allowed the TOC to be seen as a whole as it grew. Searching for a topic was easy using the Control F 'find' function.

The resultant Word TOC file was then transferred into the table of an Access relational data base using considerable automatic file type conversion and manual editing of locations.

Each Block was then given 10 locations for its sub-section headings. As many as were needed of these 10 section headings was populated using experience and consultation with books, etc.

The size of a section heading text was set to be nominally of 400 word size being a typical screenful in online delivery.

Figures and tables for a Block are provided as individual files that would be called up with links from the text file.

This degree of control of structure, size and content assisted ensure a balanced breadth and depth was achieved for the material, and that a sound subdivision index was available for search purposes. It also provided a solid foundation for expansion as the MSBOK is expanded over time.

The overall result was some 4000 section headings titles. The full listing was set up as a report from the relational data base, being a 55 page TOC document.

An example set of section headings for the Block - *Metrics in general* is:-

1. What is a metric and where is one used; some simple examples
2. Definition of a metric
3. Comparison with the measures tree method of measures development
4. Areas of application of metrics
5. Suggested recording system for metrics
6. Validation of metrics as a characterised measurement
7. Outline of online storage and delivery of metrics
8. Common misuses
9. Standards on metrics
10. Case study example

Creating the various headings in the above TOC was first set up using the personal experience of the joint Co-Editors (Peter Sydenham and Richard Thorn).

To expand the consensus a survey project was undertaken of the TOC of books on measurement. TOCs were photocopied. Some 150 books were consulted in this way, along with the measurement books in print and upcoming from the publisher's production list.

As these various studies were undertaken the data base of the MSBOK was edited for completeness, location, context and overlap.

Development was an iterative process and took several months to reach the state where duplication was becoming commonplace as other sources were consulted.

Use of thesauruses, and other lists of terms on measurement, were also consulted but in general they did not assist that much – many were not in good shape, not well developed, and seemingly had no clear strategy for development.

With areas predefined the many invited contributors were asked to address the topics suggested in their invited blocks, thus avoiding the tendency for contributions to be of their recent research thinking.

Although the method of development is based on a well developed consensus methodology it was recognised that it is the contributors that are the experts on a Block topic so they were invited to flex the titles in cooperation with the editors.

Extensive use of the full TOC and consultation of the TOC's and indexes of measurement books has a spin-off. It has shown that current measurement reference works are often lacking in vitally needed areas of knowledge.

The MSBOK listing has identified a balance of breadth of topics, and depth within them. This is, therefore, a basis for hooking on measuring system knowledge as a sound gateway for continuous development.

Rather than republish time-tested foundational material in new ways it is now possible to keep using a basic set of knowledge that is topped up over time, along with tuning of the foundational items.

At first thought it might seem to be a useful thing to produce a totally 'complete' reference work on measuring systems. Compilation of the full listing showed that to be quite impractical. This is easily seen because the potentially available information on a topic is infinite when its detail is probed ever more deeply.

Having controlled the breadth and depth of material in terms of topics and material space available it was clear that coverage on topics in the foundation version could not take users down to depths that were much more than introductory to the subject expert. Each Cluster topic generally has at least one book published on its subject and even those books still cannot take users to all of the frontiers of knowledge that might be called for.

As a rough estimate it would require, to be called 'complete', at least the space occupied by over 200 books. At typically 400 pages per book that means such a BOK would need to contain 800,000 pages or 400million words!

Clearly no publisher will make that sort of commitment to measurement systems because the sale price would exceed market realism and compilation would take decades to get into place.

This shows that online reference 'tertiary' publishing products will not attempt to be totally comprehensive but will, instead, be gateways to other, already existing, published material.

Possessing their own sizeable set of ordered and commissioned knowledge that it kept current will allow users to first sort out their need to a reasonable depth, then being pointed/linked to other sources such as books, journals, magazines and websites.

4. POTENTIAL IMPACT OF ON-LINE KNOWLEDGE SUPPORT SERVICES

Hard copy printed knowledge, in hard copy book format, came into reasonably available use in the times of the first reusable type printing press of Guttenberg. That was in the 15th century.

Since then the methodology for preparation, storage and dissemination of knowledge to the general population did not receive any significant advances in methodology until electronic compilation and the Internet came into widespread use in the mid to late 20th century. The process of preparation was streamlined but not the usability of the product.

It will surely be recorded in the future that this period of time is an epoch in knowledge availability. The impact of the online and e-file form utility is a massive step function in improvement; especially when its delivery on the Internet is sorted out to make it efficient and much more usable.

The predominant difficulty in setting up an effective BOK to date has been that the hard-copy format of storage has numerous shortcomings. Its nature limits storage to a single sequential assembly. Easily location of needed material is another limitation, as is updating and expanding the material in a short time period.

In general a revision version of hardcopy reference work will carried out some 5-6 years later than the original publication date; and it will be 1-2 years behind on publication.

The electronic form of information storage facilitates on-line operation of knowledge systems. It is, there, possible to set up an efficient gateway for entering a foundational set of knowledge of an area that, in turn, links the user out to the host of other information that is available.

As well as being potentially updatable on a daily basis, on-line format allows significantly improved

knowledge support and manipulation tool services to be offered wherein all of the desired information formats can be included – symbols, language, colours, images and sounds.

Advantages of the online form of knowledge are:-

- Complex search – Boolean and Expert System search
- Ontological searching – images found without word tags
- Form browser lists – terms, titles, headings, keywords, etc.
- Operate specialized 'doing task' tools which pull up tutorial assistance from the knowledge base when needed
- 'Copy and paste' items to integrate them with the user's knowledge, such as in a lecture presentation or a development of a specification of a sensor
- Operation of web links from the text out to other Internet sites
- Use its knowledge base to refine a user's knowledge then directing the user to appropriate online sources for greater depth.

It is also possible to set up chat rooms about the knowledge. The online version of MeasureMentor can be a living entity that draws experts and users together to work out issues, produce solutions, question the knowledge contained and allow contributions to be submitted.

Consider the key events that have emerged in e-knowledge handling: -

- Electronic storage and on-line access provides availability of knowledge to almost everyone on the Earth
- Most limitations of usability found in the hard copy knowledge storage products are eliminated
- There are no significant storage penalties; computer technology easily caters for the demands of specialist data bases
- Updating can be rapidly achieved
- Knowledge management and manipulation tools can be used to good effect
- Once formed it can be reused with ease thereby eliminating the current need to republish reference works that largely contain repeated material.

Externally a gateway knowledge product can link out to e-journals, e-books, e-libraries, e-business sites, e-product services, email, e-calibration facilities, product information, set up tests, run tests, perform calibrations, take records of tests, analyse and report tests. The list is large and almost all are not possible with the traditional book.

Benefits provided by the on-line methodology are, therefore, many. Information can be readily added, updated, located, sorted and outputted. This makes the provision of selected knowledge available to the many kinds of users discussed in Section 1. They can have knowledge available to call up as they progress a task.

At present publishers are still testing the water of this market but as has been suggested [4] it is not a matter of whether online support is needed but more of when it will become the norm. There remains the inhibiting attitude that knowledge should be free- as it seems to be from the Internet.

It will take time for users to realise that properly structured gateway BOKs, like the online MSBOK reported here, will be financially beneficial to users.

5. THE MEASUREMENTOR PROJECT

Specific discipline BOKs are being implemented and there also exist many other on-line products that would fit the BOK definition.

Most are being provided by commercial publishers as the current new generation of publishing methodology.

Some professional associations, such as the IEE in the UK, are also taking on the task to support the practice of their members with fellowship networks offering selected material for download.

The difficulty with most is that they are to be kept alive by volunteer labour – by committees and, more so, their leaders. Commercial underpinning is much more likely to produce a consistent and enduring product – if the market supports them.

MeasureMentor is of interest being a new product under development by a major technical publisher for release late in 2004. It is devoted specifically to the knowledge of measuring systems.

The size of the full TOC, described in Section 3, was too large for immediate full development by a commercial publisher. The number and style of articles needed met with considerable difficulty in obtaining them for contributors were invited to write to content listing, not to provide their latest research interest.

Commercial underpinning of a BOK helps to mitigate the ongoing support difficulties. This means the financial underpinning must follow publishing markets.

During development it was necessary to decide what form, allowing for market forces, the first release for this MSBOK should take.

At the time of that decision the global markets for books had flattened meaning the full TOC could not be implemented in the first version.

In general, secondary knowledge online products had not been taken up with the interest forecast. Sales were no where near the levels that market surveys had indicated; this took publishers by surprise [4].

It was decided, in the midst of this, that the first release for the MeasureMentor concept needed to be a foundational collection of nominally 250 Blocks that is published in traditional hard copy format,

accompanied by a download version. Release of both is set for late 2004 - see www.measurementor.com

The hardcopy title was subsequently named the *Handbook of Measuring System Design* (HBMSD) to differentiate it from the original *Handbook of Measurement Science* (HBMS) [3],[5],[6].

This initial requirement meant some potential advantages of online use would not be available immediately.

At the time of writing most materials for the 3 volume work are in production being copy edited and coded with mark up language for online delivery in the major reference works collection of the Wiley InterScience product platform.

The power of the carefully developed full TOC, coupled with its storage in data base format became evident when it took only a matter of hours to select a stripped down initial version that would allow future expansion in an orderly manner without incurring severe rework.

6. SUMMARY AND CONCLUSIONS

A case for developing a Measuring Systems Body of Knowledge (MSBOK) has been presented.

The nature of measurement knowledge and its selection and storage are discussed showing that the nature of hardcopy knowledge has many serious limitations that are mostly eliminated with on-line digital delivery.

How the table of contents for the long-term version of a MSBOK was generated has been outlined showing that a very large set of knowledge is needed to satisfy the needs of the wide range of defined potential users.

Market acceptance of online secondary level-reference knowledge has been very poor. This may be due to:-

- Lack of an adequately fine mechanism for 'paying as you download' for small chunks of knowledge
- Publishers are not yet offering users the service they need – which is to have access to many small chunks and to specialised tools for manipulating them into to form presentations, lecture notes, designs and the like.
- Online products are still rarely able to operate interactively in such ways as using the gateway's basic knowledge content to make decisions that allow live linking to other external products such as books, journals, trade product data, and purchasing.

These issues are believed to all be 'in work' but it will take time to convince purchasers that these products are value for money and that, in turn, publishers will make the investment needed to prove they are.

As a last comment what technical users clearly want from a BOK is the ability to integrate pieces of its knowledge with their own.

Provision of downloaded text, even at single page size as un-processable files, still does not allow them to 'knowledge smith' material into reports, presentations, leaflets, papers, lecture notes, instructions, specifications, purchase requests - and the like.

This issue seems to be hard for publishers to provide for it involves difficult copyright and royalty issues. It also may need a significant change in the publishing culture.

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