The Enterprise Ontology

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Abstract

This is a comprehensive description of the Enterprise Ontology, a collection of terms and definitions relevant to business enterprises. We state its intended purposes, describe how we went about building it, define all the terms and describe our experiences in converting these into formal definitions. We then describe how we used the Enterprise Ontology and give an evaluation which compares the actual uses with original purposes. We conclude by summarising what we have learned.

The Enterprise Ontology was developed within the Enterprise Project, a collaborative effort to provide a framework for enterprise modelling. The Ontology was built to serve as a basis for this framework which includes methods and a computer tool set for enterprise modelling.

We give an overview of the Enterprise Project, elaborate on the intended use of the Ontology, and give a brief overview of the process we went through to build it. The scope of the Enterprise Ontology covers those core concepts required for the project, which will appeal to a wider audience.

We present natural language definitions for all the terms, starting with the foundational concepts (e.g. entity, relationship, actor). These are used to define the main body of terms, which are divided into the following subject areas: activities, organisation, strategy and marketing.

We review some of the things learned during the formalisation process of converting the natural language definitions into Ontolingua. We identify and propose solutions for what may be general problems occurring in the development of a wide range of ontologies in other domains. We then characterise in general terms the sorts of issues that will be faced when converting an informal ontology into a formal one.

Finally, we describe our experiences in using the Enterprise Ontology. We compare these with the intended uses, noting our successes and failures. We conclude with an overall evaluation and summary of what we have learned.

Keywords – Enterprise modelling, enterprise integration, ontology, ontological engineering.

1 Introduction

In this paper, we give a comprehensive description of the Enterprise Ontology (EO), a collection of terms and definitions relevant to business enterprises. This includes its intended purposes, the process and results of identifying and creating natural language definitions for all the terms and our experiences in converting these into formal definitions. We also evaluate the ontology by presenting specific mechanisms and examples of how the ontology was used, as compared to the original purposes.[1]

This paper is a re-presentation of an official Enterprise Project deliverable [20], made suitable to this audience. The most significant change is the addition of new material describing and evaluating on our experiences of using the Enterprise Ontology.

A prior version of the EO presented here, served as the specification for the subsequent encoding in the formal language: Ontolingua [4, 6]. NB: unfortunately, the term 'Ontolingua' is overloaded in the literature, referring both to the *language* for representing ontologies (based on KIF) and to the software *system* which is used to create and manipulate them. In this document, we use the term 'Ontolingua' to refer to the language and the term 'ontology server' to refer to the system.

This paper incorporates the relatively small number of changes to the Enterprise Ontology identified during formalisation. The definitions reported here are informal, represented in natural language. They may be used to augment the documentation present in the Ontolingua definitions. This document is consistent with version 1.0 of the Ontolingua representation.

The ontology was developed in the Enterprise project (IED4/1/8032), which is supported by the UK's Department of Trade and Industry under the Intelligent Systems Integration Programme. The project was led by AIAI; the partners also include IBM, Lloyd's Register, Logica UK Limited and Unilever.

1.1 Background and Motivation

The Ontology was developed as part of the Enterprise Project [9], a collaborative effort to provide a method and a computer tool set for enterprise modelling. The business context driving the Enterprise Project is to enable coping with a fast changing environment. The primary means for doing this were seen to be through improved business planning, greater flexibility, more effective communication and integration.

The key for putting this all together was to design an enterprise modelling framework for integrating methods and tools. This framework is manifest in the Enterprise Tool Set, which uses executable process models to help users to perform their tasks. The Tool Set is implemented using an agent-based architecture to integrate off-the-shelf tools in a plug-and-play style in a single application.

1.2 Enterprise Modelling

The overall goal of enterprise modelling is to take an enterprise-wide view of an organisation which can then be used as a basis for taking decisions[2]. This is not a traditional organisational view, but rather,

[1] Except for the details of the process of building the set of informal natural language definitions (see [21]), this paper gives the full story of the Enterprise Ontology.

[2] Material for this section was drawn from [20, **?**]

a view of the subject area or domain in which an organisation operates. In order to achieve, use, and maintain such an enterprise-wide view, strong facilities for integration, communication, flexibility and support are required. These can be detailed as follows.

Integration must be achieved for relating information to obtain different views of the enterprise, for relating tasks to be performed to the tools that support them, and to establish connections between the tools themselves.

Communication must be achieved between people, ensuring that the enterprise models are shared within the organisation, between tasks that are performed so that information can be used where it is relevant, and between the tools used to perform the tasks so that relevant data can be passed between them.

Flexibility is important to allow an organisation to adapt its business processes to meet changing goals and changes in its environment; e.g. to take advantage of deregulation. It is also important to allow flexibility in the enactment of processes to ensure that people's time is used as effectively as possible, giving people the choice of what to do and when to do it.

Support Support must be provided, assisting the user by making clear what is going on and why, stepping them through difficult situations as well as taking care of technical details. This ensures that processes are carried out effectively and efficiently reducing risk of confusion which could arise with too much flexibility.

An important way to achieve both effective integration and effective business planning, is to ensure that all parties involved (from business managers to software engineers) have a *shared understanding* of the relevant aspects of a business enterprise. In particular, when terms are used in a certain context, it must be clear what concept is being referred to.

We have developed the Enterprise Ontology for this purpose; it includes a wide variety of carefully defined terms which are widely used for describing enterprises in general. There is no expectation that people can be forced to use someone else's terms and definitions. The idea is instead, to provide *one* set of terms and definitions which adequately and accurately covers the relevant concepts in the enterprise modelling domain. This can be used to resolve any misunderstandings where terms are used differently. The Enterprise Ontology is proposed as one such set of terms and definitions.

The current set of terms needs to be extended to include more detail specific to a particular business or application. The EO was intended to serve as a basis for the Enterprise Tool Set. Broadly, it is intended to help ensure effective interchange of information and knowledge between different users, tasks and systems.

Further information on enterprise modelling may be found in the Enterprise State of the Art Survey [5].

1.3 Role of the Enterprise Ontology

The following is an overview of the intended uses of the Enterprise Ontology as conceived in the early stages of the project.

> "The major role of the Enterprise Ontology is to act as a communication medium; in particular, between:
>
> - different people, including users and developers, across different enterprises;
> - people and implemented computational systems;

- different implemented computational systems (including modules of the Enterprise Tool Set, DBMS, spreadsheet etc.)

Also, and very importantly, the Ontology is intended to assist:

- acquisition, representation, and manipulation of enterprise knowledge; such assistance is via the provision of a consistent core of basic concepts and language constructs;
- structuring and organising libraries of knowledge;
- the explanation of the rationale, inputs and outputs of the Enterprise Tool Set modules.

The following are potential future uses of the Enterprise Ontology that are outside the scope of this project:

- the transition of research knowledge and systems into operational prototypes;
- the analysis of the internal structures, algorithms, and inputs and outputs of implemented systems, in theoretical and conceptual terms. [20]"

We intended that the core terms would remain substantially unchanged. However, the Enterprise Ontology as a whole was expected to evolve during the course of the Project, being refined and extended as required.

It was anticipated that the Ontology would be of wider interest, and be of value to others as codified knowledge in the enterprise modelling domain. However, this potential for wider use did not influence the development of the Ontology directly – its scope was limited to serve the purposes of the Enterprise Project. As the project progressed, the view of how the Enterprise Ontology would be used evolved. Facilitating better communication between humans is an important step in achieving an integrated enterprise. This remained a primary goal.

The Ontology was also intended to serve as the basis for more specific enterprise models which represent a shared understanding of an organisation. From an IT perspective, this can serve as a stable basis for specifying software requirements. Stability affects flexibility, and is thus extremely important.

Traditionally, the content of enterprise models is determined by requirements. When requirements change, the models must be updated. This usually results in a major re-engineering exercise of the IT solutions created to meet the original requirements. This limits the ability of an enterprise to respond quickly to changes.

To achieve more stability in the model and thus to increase flexibility, the content of the model should be determined by what is *important to a business*, independently of how it may be implemented. These stable models, in turn, are intended to support a wide variety of ever-changing requirements. The model is tested to see how well it supports a wide range of anticipated requirements; where it fails, the model needs to be more robust.

A stable enterprise model is to be shared throughout the organisation, being used as a basis for specifying and developing software, enabling consistency across all IT in an organisation. This, in turn, increases the scope for *inter-operability* which serves as a basis for enterprise integration.

Interoperability is a third major role of the Enterprise Ontology. The mechanism envisaged to achieve interoperability was to use the Ontology as a interchange format (i.e. a *lingua franca*) for terms relating to business enterprises. For each IT system or tool requiring to be integrated, (e.g. in an enterprise modelling application) a translator must be developed to convert the terms used by the tool to/from the Enterprise Ontology terms for use by other tools.

The expectation was that the Enterprise Ontology would contain most or all of the general terms relating to an enterprise (e.g. sale, activity, strategy), but that applications would have to extend the

Ontology to cater for their particular situation (e.g. 'project portfolio analysis' or 'analyse bid'). If the EO was properly engineered, and the people extending the Ontology clearly understand the concepts, then most extensions would mainly consist of specialising existing concepts for the more specific purpose. Occasionally, where the domain extends beyond what was covered in the EO, substantially new concepts will be introduced.

To make re-use of such extensions possible by others who may not wish to adopt all of the additional terms, we anticipated using a mechanism similar to 'partially shared views' [11, 12], with the Enterprise Ontology serving as the core shared by all.

In summary, the main intended uses for the Enterprise Ontology were:

- enhance communication between humans, for the benefit of integration
- serve as stable basis for understanding and specifying the requirements for end-user applications using the Tool Set which in turn leads to more flexibility in an organisation;
- to achieve interoperability among disparate tools in an enterprise modelling environment using the EO as an interchange format.

A secondary aim was to be able to reuse the EO to assist in specifying the requirements and developing the Tool Set itself, as opposed to the end user applications which benefit the enterprise directly (e.g via increased integration). For example, given the need for procedures and a task manager in the Tool Set, we hoped that we could use the concepts in the EO related to activities. This would save initial effort, as well as increase potential for a kind of bootstrapping approach.

Even in cases where no direct use of the EO was made, it still can play an important role for some other purpose. For example, the conceptual analysis implicit in the EO terms and definitions can inspire or kick-start another analysis or development task. We will refer to these uses as a *direct* use of the EO vs *reuse of the conceptual analysis* [implicit in the EO] for some purpose.

The actual uses of the Enterprise Ontology are considered in more detail in § 9

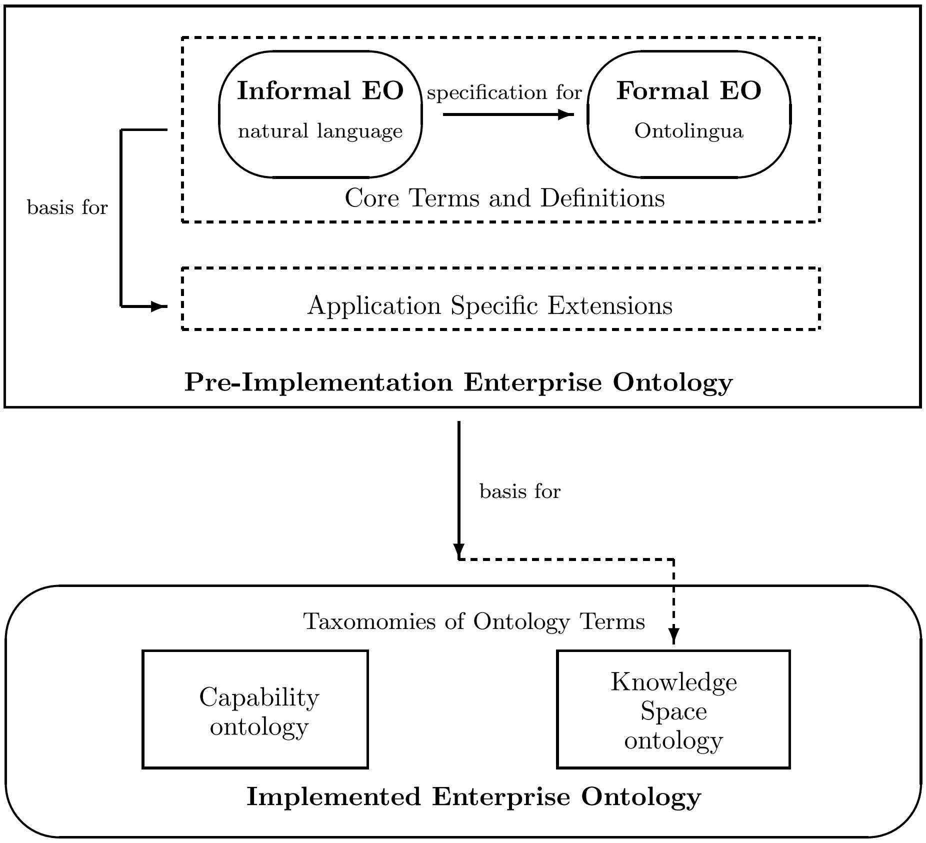
Ontolingua and Translation Ontolingua is designed to be an interchange format [4, 6]. It is a formal language grounded in first order logic, with built-in facilities to make it convenient to represent knowledge in an object-oriented style. Ontologies expressed in this language may be translated into a variety of other languages. The closer these languages are to the object-oriented nature or Ontolingua, the better the translation is.

Because Ontolingua was a well defined language, with considerable software support in the public domain, we chose it as the target formal language for the Informal EO. The Enterprise Tool Set is implemented in Clips, which also has a strong object-oriented base, so we were interested in the Clips translator[3].

1.4 Forms of the Enterprise Ontology

The Enterprise Ontology is manifest in various forms echoing its historical development (see figure 1). The first was informal, consisting of core terms and definitions in natural language. Individual applications extended the core EO to include their more specific concepts. All extensions were at the informal level, none being encoded into Ontolingua.

[3]Further information about Ontolingua and the KLS Ontology Editor may be found on the World-Wide Web at *http://www-ksl.stanford.edu/*.



This figure illustrates the relationships between the various manifestations of the Enterprise Ontology, echoing its historical development.

Figure 1: Forms of the Enterprise Ontology

Version 1.0 of the informal Enterprise Ontology was used as a specification for the formal encoding into the Ontolingua language[4][4, 6]. In § 8 we discuss this formalisation process. Feedback from this resulted in an updated version (1.1) of the natural language definitions [20] which is reproduced in full in sections 2-7.

Finally, there is the version of the Ontology implemented in the Tool Set, which we hoped, at least in part, would be produced automatically using the KSL Ontology Server [4] Clips translator. In § 9 we discuss what is actually implemented.

These manifestations of the EO are referred to as follows:

Informal EO: the natural language version.

Formal EO: the Ontolingua version.

Pre-Implementation EO: collectively refers to both of the above.

Implemented EO: the manifestation of the EO that is implemented in the Tool Set.

The term 'Enterprise Ontology' (or 'Ontology' for short) is used in various ways, the meaning being clear from context. In a general context, it collectively refers to all of the above manifestations. Very often, it just refers to the Pre-Implementation EO. We use the more specific terms only when we want to refer to a particular manifestation. When used in lower case, the word 'ontology' has no specific association with the Enterprise Ontology.

1.5 Development of the Informal Ontology

Here we briefly describe the process we went through in developing the informal Enterprise Ontology. Full details may be found in [19, 21]. We defer discussion of how formal definitions were produced until § 8.

1.5.1 Scope

Considerable time and effort has been devoted to deciding the scope and boundaries for the Ontology. We began by brainstorming to identify as many potentially important concepts as possible. This produced a totally unstructured list of words and phrases corresponding to a wide variety of concepts relevant to Enterprises. These were then grouped into various more or less distinct work areas such that there was more similarity in meaning and a need to refer to terms within an area than between different areas (*e.g.* Activity, Marketing, Organisation). Within each work area, the terms were assigned priorities indicating the importance of including them in the Ontology. At this point many terms were discarded and duplicates (*i.e.* nearly synonymous terms) were removed.

These work areas were dealt with one by one. For each concept, terms were chosen, and definitions given. The original work areas evolved somewhat, as new terms were added, and others removed or moved to other areas. Eventually, these work areas became the major structuring element for the Ontology and is reflected in the major sections of this document.

Within each work area, various important questions were addressed. What basic or core concepts are required? What mix of terms having a wide or general meaning and terms having a narrow or specific meaning are required?

[4]Available from the World-Wide Web:
http://www.aiai.ed.ac.uk/~entprise/enterprise/ontology.html

Many factors influenced the choice of terms in the Ontology. The ultimate criterion is the judgement of what concepts are likely to be sufficiently important to the Enterprise Project and be capable of a common agreement on their meaning. Many words in common use in enterprise management have been judged to have no sufficiently widely recognised or acceptable meaning to be included in the Ontology. This does not mean they cannot be used in the project. It does mean that the meaning of such words in the context of their use will have to be related to the terms in the Ontology all of whose meanings are shared. This document attempts to give guidance on how this can be done where a potential need for this has been recognised.

1.5.2 Choosing Terms

The terms in the Enterprise Ontology have been chosen as far as possible to match the natural use of English words by people managing enterprises. This is often difficult. For a term to be used in an ontology, it should ideally have one meaning precisely defined. Real people managing enterprises often use words very flexibly (*i.e.* with varying meanings). Much of the time the particular meaning of such a word used in a particular context is correctly interpreted without the hearer realising the word is potentially ambiguous. On other occasions mis-understanding may occur, but even then, will often be corrected by common sense very quickly.

Therefore some of the terms used in the Enterprise Ontology may not be the natural choice for a particular concept for a particular reader. For example, a widely used word may be given a more limited meaning, a surprisingly wide meaning, or even specifically excluded from the Ontology in favour of some other word. Sometimes important concepts are identified for which there is no obvious name; in such cases unusual words or phrases may be introduced and frequently referred to.

However, the choices for terms, far from being arbitrary, were reached only after much consideration. The main criteria for deciding were to conform to common usage and to avoid ambiguity. Ultimately there are no absolutely correct choices; they can only be the result of careful judgement.

We are not advocating that everyone be forced to use these or any one set of terms – social barriers make this infeasible. Rather, these terms and definitions are provided as a suggested standard for comparison, which may be used to resolve differences and misunderstandings where they may arise. Also, they may be used as a starting point, for any future effort directed at identifying and defining enterprise modelling concepts for any reason.

1.5.3 Definitions

The purpose of the definitions in an ontology are very different from that of dictionary definitions. The latter report how words are used; ontology definitions have a normative role. They define how a limited set of terms are to be used in relation to each other. Each definition in an ontology requires careful understanding in relationship to the other definitions in the ontology. Therefore, to understand the Enterprise Ontology requires a willingness to suspend preconceptions based on the dictionary meaning and/or other common usage of terms.

Within each work area, the Ontology has been developed by trying to identify a small number of concepts central to the subject of the section (this is called 'basic' in categorisation theory – see [10]). For example, 'person' is basic, whereas 'teenager' is more specific, and 'living organism' is more general. A basic term is defined first and then the related terms are defined as far as possible using the basic terms already defined. These other terms may be more general or more specific. The degree to which the definition of a term depends on other terms, and whether they themselves are dependent on more basic ones, provides an indication of how far a term is from the 'core' of the Ontology. The basic terms have been defined with the minimum possible reliance on other terms, however some dependence has been unavoidable.

Very importantly, the definitions themselves, which capture the many concepts, need to be expressed in as precise a language as possible. Such precision was gained through the identification and use of a small number of building blocks including such notions as: an Entity, a Relationship, a State Of Affairs and a Role. These terms are introduced and defined informally in § 3. They are more formally characterised in § 8.

Because such terms are the language primitives used for expressing the definitions in an ontology, they are collectively referred to as a 'meta-ontology'.

The Enterprise Meta-Ontology has been kept as small as possible. Frequently, the definition of an Ontology term will be given using the meta-ontological terms: *e.g.* an Activity is an Entity; Legal Ownership is a Relationship between a Legal Entity (owner) and an Entity (owned). However, sometimes the technical precision of this approach was sacrificed for readability and the relevant meta-ontological categories are implicit.

As noted earlier, the natural language definitions in version 1.0 of the Informal EO served as a specification for the subsequent encoding into Ontolingua. The formal definitions, by contrast to the natural language ones, are *all* based on terms from the Meta-Ontology. There are a number of important differences between the informal and the formal definitions. Also, the formalisation effort identified a relatively small number of changes to the Ontology which are reflected in this paper.

1.6 Document Structure

There are three main parts to the remainder of this document. The first contains the terms and definitions comprising the Informal EO. As noted above, the structure for this corresponds directly to the work area topics. Within each section, the terms have been grouped so that terms closely related to each other appear close together as far as possible. This is largely a pragmatic judgement. The relationships are a complex web and there is no perfect way to organise the terms to avoid references between sections. However, the groupings were first chosen by experience and common sense and have continued to appear valid and useful with minor modification as the Ontology has developed. These sections exist only for convenience of exposition; no meaning is to be inferred from the fact that a particular term appears in one section rather than another. The major sections in this document describing the content of the Enterprise Ontology are as follows:

§ 3: *Meta-Ontology and Time* – terms used to define the terms of the Ontology (*e.g.* Entity, Relationship, Role). We also consider a few terms related to time (*e.g.* Time-Interval).

§ 4: *Activity, Plan, Capability and Resource* – terms related to processes and planning (*e.g.* Activity, Planning, Authority, Resource Allocation);

§ 5: *Organisation* – Terms related to how Organisations are structured (*e.g.* Person, Legal Entity, Organisational Unit, Manage, Ownership);

§ 6: *Strategy* – Terms related to high level planning for an enterprise (*e.g.* Purpose, Mission, Decision, Critical Success Factor);

§ 7: *Marketing* – Terms related to marketing and selling goods and services (*e.g.* Sale; Customer; Price; Brand; Promotion)

In § 8 (the second part of the rest of this document) we summarise our experiences in converting the natural language description of the Informal EO into the formal language: Ontolingua. We also clarify the relationship between this natural language description and the formal version.

Finally, in the remaining sections, we describe our experiences in using the Ontology. We compare the actual uses with the intended purposes, noting our successes and failures. We conclude with an overall evaluation and summary of what we have learned.

1.7 Presentation

In the main sections presenting the Ontology, each term is introduced with a definition. Within each section, we proceed by defining the terms that we regard as most basic first, and then define other terms using these basic ones.

The definitions are written in carefully chosen English with other Ontology terms in UPPER case. A term is defined using a base word, however for convenience of exposition, we use grammatical variations also in upper case as if they were themselves officially defined (*e.g.* ACHIEVE, ACHIEVEMENT).

In general, any officially defined term will be presented in upper case throughout the document. However, in § 3, which describes the Meta-Ontology, terms defined in the main Ontology sections are Capitalised rather than being in full upper case (*e.g.* 'Activity' not 'ACTIVITY'). Conversely, terms defined in the Meta-Ontology are capitalised when used in the main Ontology definitions (*e.g.* 'Role' not 'ROLE').

Occasionally, we will use a word informally that is also used as an official term in the Ontology. The general rule is that official terms that appear in lower case, and all other words, should be interpreted in their dictionary sense in the light of their context.

The definition of each term is intended to be necessary and sufficient as far as this is possible in natural language. However, in many cases it is felt essential to provide clarification or additional information. This is done as notes following the definition.

1.7.1 Terms

The central purpose of the Enterprise Ontology is to achieve effective sharing of meaning. The Enterprise Ontology consists mainly of:

Defined Terms: Terms explicitly included in the Enterprise Ontology. In addition to the natural language definition provided here, there is also a formally coded definition (see § 8).

Related Terms To better understand the Enterprise Ontology, it is helpful to know how its terms and concepts relate to the terms and concepts widely used in other contexts (*e.g.* other ontologies). Therefore, at the end of each section we list a number of related terms that are fairly commonly used but are *not* defined in the Enterprise Ontology. Where possible, we specify the relationship between these terms and those in the Enterprise Ontology. These related terms fall into three categories:

1. *Synonyms*: Terms recognised as widely used in enterprises that are not defined in the Ontology, but which are considered the same or very close in meaning to defined terms.
2. *Borderline Terms*: Terms for which we make an attempt to show how they might be defined using Ontology terms. However, because they are deemed insufficiently important for sharing, are not formally included in the Ontology.
3. *Other Commonly Used Terms*: A list of commonly used terms that were not defined.

1.8 Conforming to the Enterprise Ontology

What to do to make a given term conform to the Enterprise Ontology depends on how and whether the term appears in the Ontology. Below we give some guidelines for various kinds of terms.

Defined Terms Conforming to the Enterprise Ontology requires conforming with the definitions of the main terms comprising the Enterprise Ontology. The Formal EO should be consulted to resolve any ambiguity found in the Informal EO.

Synonyms Ideally, for a given concept for which there is already a formally defined term, users should use that term. This ensures maximum ease of sharing. There may be a strong preference for using another term (*e.g.* one listed as a synonym in the Enterprise Ontology) – in which case the Enterprise Ontology needs to be extended to include the new term. Ontolingua has a convenient mechanism for defining synonyms. An alternative is to create the new term as a sub-class of the existing defined term. If there is nothing different about the sub-class, then it is semantically equivalent and effectively a synonym.

To increase sharing possibilities, users should avoid using one of the synonyms listed in the Enterprise Ontology and giving it a *different* meaning from that of the defined term it is synonymous with.

Borderline Terms The user may choose to use any of these terms, but must explicitly adopt a definition. Conforming with the Enterprise Ontology does not require this to be the provided definition, but this is recommended to increase potential sharability.

2 Ontology Overview

As already mentioned, the sections are as follows:

- Meta Ontology and Time
- Activity, Plan, Capability, and Resource
- Organisation
- Strategy
- Marketing

See figure 2 for a table listing of all the concepts defined in the Enterprise Ontology organised by major section.

For initial understanding, the Meta-Ontology will be dealt with last in this overview. The main concepts of each section and the main relationships between them are given in the following sections. Some readers may prefer to go directly to the main sections, and read this section as a summary.

2.0.1 Activities and Processes

The central term is ACTIVITY. This is intended to capture the notion of anything that involves actual doing, in particular including action. An ACTIVITY can have happened in the past and may be

ACTIVITY etc.	*ORGANISATION*	*STRATEGY*	*MARKETING*	TIME
Activity	Person	Purpose	Sale	Time Line
Activity Specification	Machine	Hold Purpose	Potential Sale	Time Interval
Execute	Corporation	Intended Purpose	For Sale	Time Point
Executed Activity Specification	Partnership	Purpose-Holder	Sale Offer	
T-Begin	Partner	Strategic Purpose	Vendor	
T-End	Legal Entity	Objective	Actual Customer	
Pre-Condition	Organisational Unit	Vision	Potential Customer	
Effect	Manage	Mission	Customer	
Doer	Delegate	Goal	Reseller	
Sub-Activity	Management Link	Help Achieve	Product	
Authority	Legal Ownership	Strategy	Asking Price	
Activity Owner	Non-Legal Ownership	Strategic Planning	Sale Price	
Event	Ownership	Strategic Action	Market	
Plan	Owner	Decision	Segmentation Variable	
Sub-Plan	Asset	Assumption	Market Segment	
Planning	Stakeholder	Critical Assumption	Market Research	
Process Specification	Employment Contract	Non-Critical Assumption	Brand	
Capability	Share	Influence Factor	Image	
Skill	Shareholder	Critical Influence Factor	Feature	
Resource		Non-Critical Influence Factor	Need	
Resource Allocation		Critical Success Factor	Market Need	
Resource Substitute		Risk	Promotion	
			Competitor	

This table contains all terms formally defined in the Enterprise Ontology. Within each column, the terms are listed in the same order as they appear in the main sections of this document. There is no relationship between terms that happen to be in the same row.

Figure 2: Overview of Enterprise Ontology

happening in the present. The term can also be used to refer to a hypothetical future ACTIVITY. However, there is a need to refer explicitly to specifications or plans for ACTIVITIES. This is called an ACTIVITY SPECIFICATION. Like a recipe, it specifies at some level of detail one or more possible ACTIVITIES. An EXECUTED ACTIVITY SPECIFICATION must have a corresponding ACTIVITY, the thing done.

The concept of ACTIVITY is closely linked with the idea of the DOER, which EXECUTES an ACTIVITY SPECIFICATION by performing the specified ACTIVITIES. A DOER may be a PERSON, ORGANISATIONAL UNIT or MACHINE. These terms are defined in the Organisation section and may collectively be referred to as [POTENTIAL] ACTORS.

The ability of a POTENTIAL ACTOR to be the DOER of an ACTIVITY is denoted by CAPABILITY (or SKILL if the DOER is a PERSON). ACTORS may have other Roles in respect of an ACTIVITY such as ACTIVITY OWNER.

Also closely related to ACTIVITY is RESOURCE, which is something that can be used or consumed in an ACTIVITY. An ACTIVITY can also have outputs or EFFECTS. An ACTIVITY is linked to a TIME INTERVAL. An ACTIVITY may take a short or a long time, and may be simple or complex. Complex ACTIVITIES may be de-composed into many SUB-ACTIVITIES.

An ACTIVITY SPECIFICATION with an INTENDED PURPOSE (defined in § 6 on Strategy), is called a PLAN. The concept of being able to repeatedly EXECUTE the same PLAN is captured in the term PROCESS SPECIFICATION.

Control of doing of ACTIVITIES is important to enterprises. For this, we define AUTHORITY to be the right (of an Actor) to perform one or more ACTIVITIES (*e.g.* as specified in a PLAN).

2.0.2 Organisation

Central to the Organisation section are concepts of LEGAL ENTITY and ORGANISATIONAL UNIT (abbreviated as OU). Both of these refer to things which have a "gestalt", whether or not they are composite. They differ in that a LEGAL ENTITY is recognised as having rights and responsibilities in the world at large and by legal jurisdictions in particular, whereas ORGANISATION UNIT need only have full recognition within an organisation.

LEGAL ENTITY includes PERSON and CORPORATION. Larger LEGAL ENTITIES may wholly own other smaller LEGAL ENTITIES. ORGANISATION UNITS may be large and complex, even transcending LEGAL ENTITIES. Large OUs will normally be seen as being made up from smaller ones. The smallest may correspond to a single PERSON, in fact a particular PERSON could be seen as corresponding with more than one small OU.

A MACHINE is a non-human, non-legal ENTITY that may play certain Roles otherwise played by a PERSON or OU (*e.g.* perform an ACTIVITY).

The OWNERSHIP of rights and responsibilities may only, from the legal point of view, lie with a LEGAL ENTITY. Within an organisation, rights and responsibilities for RESOURCES may be allocated to OUs. Therefore OWNERSHIP is defined to include this, with LEGAL and NON-LEGAL OWNERSHIP defined to enable the distinction where needed. OUs may be responsible for ACTIVITIES.

Within an organisation the management structure is represented by MANAGEMENT LINKS. The term MANAGE represents assigning PURPOSES to OUs. A pattern of MANAGEMENT LINKS between OUs determines an organisational structure. This can include multiple MANAGEMENT LINKS into any one OU with constraints on the different kinds of PURPOSES assigned through each link.

2.0.3 Strategy

The central concept of the Strategy section is PURPOSE. PURPOSE captures two related notions. One, is the intended reason for EXECUTING an ACTIVITY SPECIFICATION, *i.e.* what a PLAN is for. The other is something that an ORGANISATION UNIT can be responsible for (defined in the Organisation section). A STRATEGIC PURPOSE is one declared to be of 'strategic' importance. STRATEGIC PURPOSES tend to be on a relatively high level on long time scale. Other PURPOSES may be detailed and short term, or anything in between.

Like an OU, a PURPOSE can be composed or decomposed. That is, one statement of PURPOSE may relate to something which can also be seen to HELP ACHIEVE some grander PURPOSE. By this means, a spectrum of widely used terms like VISION, MISSION, GOAL, and OBJECTIVE can be represented without there being shared agreement on precisely how these terms are used.

STRATEGY is defined as a PLAN to ACHIEVE a STRATEGIC PURPOSE. Based on the concept of PLAN from the Activity section, the concepts key to STRATEGIC PLANNING can be represented with the terms DECISION, ASSUMPTION, RISK, and various kinds of FACTOR.

2.0.4 Marketing

The central concept of the Marketing section is SALE. A SALE is an agreement between two LEGAL ENTITIES for the exchange of a PRODUCT for a SALE PRICE. Normally the PRODUCT is a good or service and the SALE PRICE is monetary, however other possibilities are included. The LEGAL ENTITIES play the (usually distinct) Roles of VENDOR and CUSTOMER. A SALE can have been agreed in the past, and a future POTENTIAL SALE can be envisaged, whether or not the actual PRODUCT can be identified, or even exists. A PRODUCT targeted at a specific CUSTOMER is referred to as a SALE OFFER, otherwise it is just FOR SALE.

The MARKET is all SALES and POTENTIAL SALES within a scope of interest. The MARKET may include SALES by COMPETITORS. The MARKET may be decomposed into MARKET SEGMENTS in many ways in many levels of detail. This can be done by any properties of the PRODUCT, VENDOR, CUSTOMER, SALE PRICE or of anything else associated with a SALE. These properties are SEGMENTATION VARIABLES.

Analysis of a MARKET may involve understanding of FEATURES of PRODUCTS, NEEDS of CUSTOMERS, and IMAGES of BRANDS, PRODUCTS, or VENDORS. PROMOTIONS are ACTIVITIES whose PURPOSES relate to the IMAGE in a MARKET.

2.0.5 Meta-Ontology and Time

The basic concept of the Meta-Ontology is ENTITY. This is in a sense the catch-all for all other concepts. In creating the Ontology, some concepts will be seen as standing in their own right independent of others (e.g. PERSON). These will be directly classed as ENTITIES. Other concepts will more naturally be seen as a RELATIONSHIP between two or more other ENTITIES (e.g. SALE). Thus though SALE could legitimately be described as an ENTITY, it is more precisely characterised by being described as RELATIONSHIP.

Within a RELATIONSHIP, an ENTITY may have a ROLE (e.g. a Person may be Customer in a Sale). Alternatively, an ENTITY may be seen as an ATTRIBUTE of another ENTITY (e.g. Date of birth of a Person).

Certain ROLES in RELATIONSHIPS are special in that the playing of these ROLES entails some notion of doing or cognition (*e.g.* performing an Activity, or holding an Assumption). We refer an ENTITY playing such a ROLE as a ACTOR (roughly synonymous with 'agent' in other ontology work). A ROLE played by an ACTOR is an ACTOR ROLE. Only certain ENTITIES can play such ROLES, they are called POTENTIAL ACTORS. Currently this includes Persons, OUs and in some cases Machines.

To accommodate the needs of a multiplicity of users and viewpoints now and in the future, new ACTOR ROLES may commonly arise, as new RELATIONSHIPS are introduced into or used in conjunction with the Ontology. New major kinds of ACTOR ENTITIES may also arise, though perhaps less frequently.

Collectively, the situation characterised by one or more ENTITIES participating in one or more RELATIONSHIPS with one or more other ENTITIES is referred to as a STATE OF AFFAIRS. A STATE OF AFFAIRS may be said to hold or to not hold (*i.e.* to be true or false).

As has previously been mentioned, the terms in the Ontology have not been explicitly defined in terms of this Meta-Ontology unless this has seemed the most natural choice for a particular term. However, the Meta-Ontology has been implicit in much of the work leading to the choice of terms and definitions.

The relationship between the terms and the Meta-Ontology was expected to and did become much more explicit when the Ontology was later coded in Ontolingua.

Time The concept of time is not specific to Enterprises, but is used by them. We have made no attempt to re-think existing work on representing time; instead, we merely imported it (in particular, see [1]).

We specifically required TIME INTERVAL to refer to when ACTIVITIES are performed. A TIME INTERVAL is defined in terms of TIME POINTS, which in turn make up a TIME LINE.

3 Meta Ontology

In this section, we present the main terms and concepts used to define the Enterprise Ontology itself. In § 3.1, we introduce the main concepts and building blocks: ENTITIES, RELATIONSHIPS, and STATE of AFFAIRS. In § 3.2 we discuss special ACTOR ROLES in some RELATIONSHIPS which entail some notion of doing or cognition. They are played by ACTORS.

3.1 Entities, Relationships and States of Affairs

The Enterprise Ontology is composed of a set of ENTITIES and a set of RELATIONSHIPS between ENTITIES. ENTITIES can play ROLES in RELATIONSHIPS. An ATTRIBUTE is a special kind of RELATIONSHIP. A STATE OF AFFAIRS is a situation characterised by any combination of ENTITIES being in any number of RELATIONSHIPS with one another.

ENTITY: a fundamental thing in the domain being modelled.

Examples:

- a human being is an ENTITY
- a plan is an ENTITY

Notes:

1. An ENTITY may participate in RELATIONSHIPS with other ENTITIES.

2. To conform with common English usage, and to avoid complicating the text of the definitions in the EO, we intentionally avoid distinguishing between a *type* of ENTITY, (frequently called a class) and a *particular* ENTITY of a certain type (frequently called an instance). We use the word ENTITY for both, relying on context to resolve potential ambiguity.

RELATIONSHIP: the way that two or more ENTITIES can be associated with each other.

Examples:

- Have-Capability is a relationship between a Person and an Activity denoting that the Person is able to perform the Activity.
- a Sale is a relationship constituting an agreement between two Legal Entities to exchange a Product for a Sale Price.

Notes:

1. A RELATIONSHIP is itself an ENTITY that can participate in further RELATIONSHIPS.
2. In natural language the word 'relationship' has many meanings. The following are important but logically distinct concepts that 'relationship' commonly refers to:
   - the kind of relationship (closest to above definition);
   - a name given to the kind of relationship (e.g. 'Marriage', 'Have-Capability');
   - a particular relationship between particular ENTITIES.
     Examples:
     - Bill and Hillary Clinton are in a Marriage relationship.
     - Einstein was in a Have-Capability relationship with the Activity of developing a general theory of relativity.

   Further distinctions can be made reflecting the use of the mathematical concept of a tuple. For example, in mathematics, the set of all tuples related in a certain way is a useful concept (e.g. the set of all married couples).

   As for ENTITY, to conform with common English usage, and to avoid complicating the text of the definitions in the Informal EO, we will use the word 'Relationship' fairly loosely, including various of the above meanings. In § 8 we explain how these concepts are formalised.

ROLE: the way in which an ENTITY participates in a RELATIONSHIP.

Examples:

- Vendor is a ROLE played by an ENTITY in a Sale RELATIONSHIP (see § 7).

Notes:

1. A participating ENTITY is said to be *playing* the ROLE.
2. Strictly speaking, the correct way to refer to an Entity playing a particular ROLE, is to use a phrase like 'the Entity playing the Vendor ROLE'. This is awkward, and instead, we will often use the shorter phrase 'the Vendor'.

ATTRIBUTE: a RELATIONSHIP between two ENTITIES (referred to as the 'attributed' and 'value' ENTITIES) with the following property:

- within the scope of interest of the model, for any particular attributed ENTITY the RELATIONSHIP may exist with only one value ENTITY.

Examples:

- Date of Birth is an ATTRIBUTE associating only one Date with a given Person.

Notes:

- In this definition, RELATIONSHIP refers to the kind of association between two entities, not a particular case of two or more ENTITIES being so-associated.

- From a mathematical perspective, an ATTRIBUTE is a function.

STATE OF AFFAIRS: a situation; the following is necessarily true of a STATE OF AFFAIRS:

- it consists of a set of RELATIONSHIPS between particular ENTITIES;
  E.g. 'Joe Bloggs can lay bricks' (*i.e.* is in the Have-Capability RELATIONSHIP with the Activity: bricklaying.')
- it can be said to hold, or be true (and conversely to not hold or to be false)

ACHIEVE: the realisation of a State Of Affairs; *i.e.* being made true;

Notes:

1. When the State Of Affairs is a PURPOSE, one would frequently say it is being 'accomplished'.

3.2 Actors

Certain ROLES in RELATIONSHIPS are special in that the playing of these ROLES entails doing or cognition. These are called ACTOR ROLES; ENTITIES playing such roles are called ACTORS.

ACTOR ROLE: A kind of ROLE in a RELATIONSHIP whereby the playing of the ROLE entails some notion of doing or cognition.

Notes:

1. Some of the important RELATIONSHIPS in the Enterprise Ontology that have ACTOR ROLES are:

RELATIONSHIPS:	*ACTOR ROLES:*
Perform-Activity	performer
Have-Capability	haver
Hold-Authority	holder
Delegate	delegator
	delegatee
Hold-Purpose	holder
Hold-Assumption	holder
Ownership	owner

2. Users of the Ontology who define RELATIONSHIPS should indicate which ROLES are ACTOR ROLES.

ACTOR: an ENTITY that *actually plays* an ACTOR ROLE in a RELATIONSHIP.

Notes:

1. Whether or not a given ENTITY is an ACTOR or not depends on what RELATIONSHIPS it is participating in at a given point in time. The same ENTITY might be an ACTOR at one time but not at another time.

POTENTIAL ACTOR: an ENTITY that *can play* an ACTOR ROLE in a RELATIONSHIP, *i.e.* an ENTITY for which some notion of doing or cognition is possible.

Notes:

1. An ENTITY is either always a POTENTIAL ACTOR, or never one. It does not depend on what RELATIONSHIPS it is participating in (unlike ACTOR).
2. The set of POTENTIAL ACTORS currently includes, but is not necessarily limited to the following:
   - Person
   - Organisational Unit

- Machine

3. If users of the Ontology require other ENTITIES to be ACTORS, they should review the Ontology RELATIONSHIPS using the ACTOR ROLE to ensure the addition is valid for them. If it is, then the new kind of ENTITY must be added to the above list of POTENTIAL ACTORS.
4. A more elaborate classification of POTENTIAL ACTORS might consist of two main types: *Natural* and *Artificial*, the latter being synonymous with Machines. *Animals*, of which Person could be a special type would come under the former category as would *Gravity* which is rather different, and might be classified separately as *In-Animate*. *Artificial* POTENTIAL ACTORS might be further classified, *e.g.* into physical and conceptual Machines.
5. Some ACTOR ROLES can be played by only *some* of the above POTENTIAL ACTORS. For example, it may not be allowed for a MACHINE to own something. Where agreement exists, such restrictions may be specified in the Ontology itself; alternatively they may be specified later by individual users.

3.3 Time

The concept of time is not specific to Enterprises, but is used by them. Rather than to re-think existing work on representing time, we imported terms and definitions from KRSL [13] which in turn was based on Allen's work [1].

An ACTIVITY is performed over a TIME INTERVAL, which is comprised of TIME POINTS. The latter comprise a TIME LINE. We define just these three terms[5]. We anticipate that additional terms for representing time will be required *e.g.* a 'before' relationship for specifying temporal constraints between SUB-ACTIVITIES in a PLAN. They are already formally encoded in Ontolingua and publicly available. An ontology called 'Simple-Time' from the KSL Library of Ontologies [4] is imported in the Formal EO.

TIME LINE: an ordered, continuous, infinite sequence of TIME POINTS.

TIME POINT: a particular, instantaneous point in time;

Notes:

1. a TIME POINT can exist independently from knowing where it is on the TIME LINE (*e.g.* 'when the next big earthquake hits California'). You can still talk about it and perhaps constrain it to some extent.

TIME INTERVAL: an interval of time specified as two TIME POINTS and bounds on the distance between the two time points.

Notes:

1. The bounds imply that the interval is in a sense fuzzy; you do not know how long it is or necessarily where on the TIME LINE the TIME POINTS are.
2. The following is a special case of a TIME INTERVAL:
   - Always: the interval from infinitely far into the past to infinitely far into the future.

[5] In earlier versions of the Enterprise Ontology, over twenty time-related terms were defined. However, none of this was original work, so most of that has been removed.

3.4 Related Terms

3.4.1 Synonyms

- *Class* (in Object-Oriented systems *e.g.*: Ontolingua) &
  Concept (in Description Logics): a kind or type of ENTITY
- *Instance, Individual*: ENTITY
- *Relation, Predicate*: RELATIONSHIP
- *State*: STATE OF AFFAIRS
- *Slot* (in Object-Oriented systems): ATTRIBUTE;
- *Role* (in Description Logics): similar to ATTRIBUTE; Roles in Description Logics may have more than one value.
- *Agent*: ACTOR

3.4.2 Borderline Terms

1. (mathematical) *Function*: an ATTRIBUTE is a function, though not all functions need to be ATTRIBUTES.

4 Activity, Plan, Capability and Resource

In this section, we present the central concepts of an ACTIVITY, which is something actually done, and an ACTIVITY SPECIFICATION, which is like a recipe describing something to do. Most activity/planning/process ontologies only have a representation for the latter. To allow convenient modelling of process enactment and/or keeping of historical records of past activities, it is helpful to represent instances of the actual doing, *i.e.* the carrying out of the 'recipes'; this is what ACTIVITY is for.

We also present various important Relationships between ACTIVITIES and other ENTITIES. Important related concepts are: PLAN, which is an ACTIVITY SPECIFICATION with an INTENDED PURPOSE; CAPABILITY to perform ACTIVITIES, and RESOURCE which is something that can be used or consumed during an ACTIVITY.

4.1 Activities

ACTIVITY: something done over a particular TIME INTERVAL. The following may pertain to an ACTIVITY:

- has PRE-CONDITION(S);
- has EFFECT(S);
- is performed by one or more DOERS;
- is decomposed into more detailed SUB-ACTIVITIES
- entails use and/or consumption of RESOURCES
- has AUTHORITY requirements

- is associated with an [ACTIVITY] OWNER
- has a measured efficiency

Notes

1. an ACTIVITY can have happened in the past, may be happening in the present, and a hypothetical future ACTIVITY may be envisaged;
2. The word ‘something’ in the above definition is deliberately general; we mean to include mental activities, for example.
3. We wish to allow PURPOSE-free ACTIVITY, such as water flowing down a hill. An association between an ACTIVITY and a PURPOSE can be made by matching the INTENDED PURPOSE of a PLAN to the EFFECT(S) of ACTIVITIES specified in the PLAN.
4. ACTIVITIES may be informally classified as ‘strategic’, ‘tactical’ or ‘operational’ depending on the ‘level’ of an associated PURPOSE as characterised by the HELP ACHIEVE Relationship between PURPOSES.

ACTIVITY SPECIFICATION: a characterisation of something to do; a specification of activity.

Notes:

1. an ACTIVITY SPECIFICATION can be thought of as a constraint functioning as a selector identifying a restricted range of ACTIVITIES in the universe;
2. insofar as an ACTIVITY SPECIFICATION will be built up from various components (statements in some language), each constraining the specification in different ways, an ACTIVITY SPECIFICATION can be thought of a collection of constraints.
3. The language for expressing ACTIVITY SPECIFICATIONS will include statements about how ACTIVITIES are decomposed into SUB-ACTIVITIES; temporal ordering of (SUB-)ACTIVITIES; RESOURCE usage, and much more.
4. An ACTIVITY SPECIFICATION is deliberately intended to include any degree of specification of ACTIVITIES; for example:
   - a trivial level of specification: ‘go to Edinburgh’
   - comprehensive and detailed set of instructions involving many ACTIVITIES.
5. An ACTIVITY SPECIFICATION need not be EXECUTABLE; possible reasons are:
   - it contains constraints that cannot be met (*e.g.* regarding RESOURCE usage or timing)
   - it is underspecified and/or ambiguous, so the DOER has insufficient information to proceed with execution;

EXECUTE: a Relationship between one or more Potential Actors and an ACTIVITY SPECIFICATION whereby the one or more Potential Actors perform the specified ACTIVITIES.

Notes:

1. Because a PLAN is an ACTIVITY SPECIFICATION, it is also correct to speak of EXECUTION of a PLAN.
2. The EXECUTION of a PLAN should result in the ACHIEVEMENT of its INTENDED PURPOSE.

EXECUTED ACTIVITY SPECIFICATION: A Relationship between an ACTIVITY SPECIFICATION and an ACTIVITY whereby the ACTIVITY is the result of [one] EXECUTION of the ACTIVITY SPECIFICATION.

Notes:

1. An ACTIVITY SPECIFICATION has been executed when all the specified ACTIVITIES have been performed; if the ACTIVITY SPECIFICATION is a PLAN, then execution should result in the ACHIEVEMENT of the PLAN’S INTENDED PURPOSE.

2. This is a one-to-many Relationship because an ACTIVITY SPECIFICATION may in general be executed many times.

T-BEGIN and T-END: the two TIME POINTS that define the TIME INTERVAL over which an ACTIVITY is done;

PRE-CONDITION: a State Of Affairs required to be true in order for the ACTIVITY to be performed.

Notes:

1. The requirement may be specified to hold immediately before T-BEGIN, immediately before T-END, or throughout the whole TIME INTERVAL.

EFFECT: State Of Affairs that is brought about [i.e. made true] by the ACTIVITY.

Notes:

1. The EFFECT may be specified to hold immediately after T-BEGIN, immediately after T-END, or throughout the whole TIME INTERVAL.
   For example, ringing a door buzzer has EFFECT of producing noise during but not before or after the TIME INTERVAL of the ACTIVITY.

DOER: the Role of an Actor in a Relationship with an ACTIVITY whereby the Actor performs (all or part of) the ACTIVITY.

Notes:

1. There may be more than one DOER for a given ACTIVITY.
2. Not all ACTIVITIES need have an explicit DOER; *e.g.* flowing water; In such cases, it may be more natural to think of the DOER as the supplier of force behind an ACTIVITY (*e.g.* the environment, gravity).

SUB-ACTIVITY: The Role of an ACTIVITY in a Relationship with another ACTIVITY such that performance of the first ACTIVITY is considered to be part of the performance of the other ACTIVITY.

Examples:

- performing each of the following SUB-ACTIVITIES may be considered to be part of performing the ACTIVITY "go to Edinburgh"
  - go to Heathrow
  - fly to Edinburgh airport
  - go to Edinburgh city centre

Notes:

1. Typically an ACTIVITY is decomposed into SUB-ACTIVITIES to provide more detail.
2. There is much more structure in an activity decomposition than a simple the set of SUB-ACTIVITIES; *e.g.* temporal constraints may define a partial order.

AUTHORITY: the right of an Actor to EXECUTE an ACTIVITY SPECIFICATION. Informally, this is equivalent to the right to perform one or more ACTIVITIES.

Notes:

1. The holder of AUTHORITY need not have the CAPABILITY to perform the ACTIVITIES;
2. The ACTIVITY that the Actor has the right to perform may itself be the granting of such a right, normally to another Actor – this is a kind of DELEGATION.
3. The holder of AUTHORITY may be self-authorised;
4. This definition allows for the case of a MACHINE having AUTHORITY.
5. The idea of CAPABILITY vs AUTHORITY is analogous to that of 'can' vs 'may'.

ACTIVITY OWNER: Actor responsible for an ACTIVITY.

Notes:

1. May be identified indirectly via Role (e.g. project manager) or directly as a named PERSON.
2. This will normally be NON-LEGAL OWNERSHIP

Depending on their requirements, users of the Ontology may find the need to define a variety of specific kind of ACTIVITIES. We introduce EVENT as one kind of ACTIVITY, but give no details. This allows users of the Ontology to distinguish EVENT from an arbitrary ACTIVITY, while ensuring that it inherits all the properties of ACTIVITY as defined in the Ontology.

EVENT: a kind of ACTIVITY

Notes:

1. Various formalisms for modelling activities distinguish between EVENT and ACTIVITY; the former being is seen as outside the scope of interest of the model apart from its EFFECTS. In particular, the model will not recognise the DOER, the DURATION, or choice or control over its occurrence (*e.g.* a hurricane which is performed by the 'environment').
2. Another common distinction between EVENT and ACTIVITY is that the former is seen as instantaneous and the latter as having duration. In fact, it is arguable that any event has some duration even if it is not measured, and the duration of ACTIVITY can be made arbitrarily small. Therefore, this is not considered a valid distinction to include in the Ontology.

4.2 Plans

PLAN: an ACTIVITY SPECIFICATION with an INTENDED PURPOSE.

Notes:

1. See notes under ACTIVITY SPECIFICATION.

SUB-PLAN: a PLAN whose INTENDED PURPOSE HELPS ACHIEVE the INTENDED PURPOSE of another PLAN.

PLANNING: an ACTIVITY whose INTENDED PURPOSE is to produce a PLAN.

PROCESS SPECIFICATION: a PLAN that is intended to be or is capable of being EXECUTED more than once.

Notes:

1. We intentionally do not define the term 'process', as it means so many things to so many people. The terms in this Ontology should be sufficient to define whatever specific notion of 'process' is required.
2. Typically, a PROCESS SPECIFICATION will be parameterised to enable reusability in various forms at different times. As such, it may be viewed as a PLAN schema.

4.3 Capabilities

CAPABILITY: a Relationship between a Potential Actor and an ACTIVITY SPECIFICATION denoting the ability of the Potential Actor to perform the specified ACTIVITIES.

Notes:

1. The idea of CAPABILITY vs AUTHORITY is analogous to that of 'can' vs 'may'.

SKILL: a CAPABILITY such that:

- the Potential Actor is a PERSON;
- the ability must be practised/demonstrated to some measurable degree.

4.4 Resources

RESOURCE: the Role of an Entity in a Relationship with an ACTIVITY or ACTIVITY SPECIFICATION whereby the Entity is or can be used or consumed during the performance of the ACTIVITY or the ACTIVITIES as specified in the ACTIVITY SPECIFICATION.

Notes:

1. a RESOURCE may have a quantifiable measure denoting how much is available for use in ACTIVITIES
   e.g. amount of fuel; number of typewriters
   - If the RESOURCE is used but not consumed, the quantity available will decrease at the beginning and return to the original level at the end of the TIME INTERVAL of the ACTIVITY.
   - If the RESOURCE is consumed, the quantity available will decrease over the TIME INTERVAL of the ACTIVITY.
2. a RESOURCE may be shared by more than one ACTIVITY
3. An Entity produced by an ACTIVITY may be viewed as a RESOURCE in that *other* ACTIVITIES may use/consume it; however such outputs are not RESOURCES with respect to the producing ACTIVITY.

RESOURCE ALLOCATION: the allocation of RESOURCES to ACTIVITIES.

Notes:

1. RESOURCE ALLOCATION is itself an ACTIVITY, though it may not be necessary to model it explicitly as such. Indeed, the ACTIVITY of RESOURCE ALLOCATION itself may have RESOURCES allocated to it (e.g. personnel).
2. RESOURCE ALLOCATION is the responsibility of OUs
3. an OU responsible for RESOURCE ALLOCATION may DELEGATE it to another OU.

RESOURCE SUBSTITUTE: a RESOURCE that can be used or consumed in an ACTIVITY instead of another RESOURCE.

4.5 Related Terms

4.5.1 Synonyms

- *Behaviour*: ACTIVITY
- *Task*: ACTIVITY
- *Action*: ACTIVITY

4.5.2 Borderline Terms

1. *Personal Skill*: the degree of SKILL recognised for a PERSON

4.5.3 Other Commonly Used Terms

1. *Process:* see note 1 under definition of PROCESS SPECIFICATION.

5 Organisation

The central concept in this section is that of an ORGANISATIONAL UNIT, the main structural element of an organisation. Complex ORGANISATIONAL STRUCTURE is captured by the various MANAGE relationships between OUs.

First, however, we define the notions of a LEGAL ENTITY (which includes a PERSON, CORPORATION etc.) and a MACHINE, all of which themselves may correspond to a single OU.

Other important concepts defined in this section are DELEGATION, OWNERSHIP, STAKEHOLDER, SHARE, SHAREHOLDER and ASSET.

5.1 Legal Entities and Machines

PERSON: a human being

Notes:

1. For the purposes of this Ontology, PERSONS are of interest for their capacity to play various Actor Roles in an enterprise (*e.g.* perform ACTIVITIES).
2. The concepts of sole trader and a registered business are included here. For most purposes, the law makes no distinction between these things and the PERSON owning/operating them.

MACHINE: a non-human Entity which has the capacity to carry out functions and/or play various roles in an enterprise.

Notes:

1. a MACHINE is similar to a PERSON in that many functions and roles may be performed by either. However, it is anticipated that some functions and roles will be exclusive to one or the other. For example, a MACHINE may not be held responsible for anything.

CORPORATION: A group of PERSONS recognised in law as having existence, rights, and duties distinct from those of the individual PERSONS who from time to time comprise the group.

Notes:

1. Historically, in law, rights and duties apply to individual humans; rights and duties of groups are inherited from this.

PARTNERSHIP: A group of PERSONS carrying on business in common.

Notes: The following is true in English law, but not necessarily in other legal systems:

1. there is a distinction between PARTNERSHIP and CORPORATION;
2. each PARTNER may have unlimited liability for the debts of the PARTNERSHIP to other LEGAL ENTITIES;
3. the PARTNERSHIP does not have a legal identity separate from its PARTNERS; e.g. if PARTNERSHIP is sued, this means all PARTNERS are sued.

PARTNER: a PERSON who forms part of a PARTNERSHIP;

LEGAL ENTITY: the union of PERSON, CORPORATION, and PARTNERSHIP

Notes:

1. For the purposes of the Ontology, this is equivalent to the more commonly used definition of a LEGAL ENTITY: 'that which can enter into a legal contract'.

5.2 The Structure of Organisations

ORGANISATIONAL UNIT (OU): an Entity [with a defined identity] for MANAGING the performance of ACTIVITIES to ACHIEVE one or more PURPOSES. An OU may be characterised by:

- the nature of its PURPOSE(S);
- one or more PERSONS working for the OU;
- RESOURCES allocated to the OU;
- other OUs that MANAGE or are MANAGED-BY the OU;
- its ASSETS;
- its STAKEHOLDERS;
- being LEGALLY OWNED;
- its MARKET (if it is a VENDOR).

Notes:

1. The term OU is deliberately defined with no constraint on its size or place within an organisation. Furthermore, no special terms for OUs of any particular size are defined (e.g. division, department). This is because no consistent use of such terms can be found across different enterprises, or even within a single enterprise over time. Therefore the existence of a very small and simple unit, even corresponding with a single PERSON, or a very large and complex structure (e.g. a multi-national CORPORATION) can equally be represented as an OU. The structure of an OU is represented by the set of as many other OUs and MANAGEMENT LINKS (see below) as required.
2. The term MANAGEMENT LINK leads to the concept of higher-level and lower-level OUs depending on which MANAGE and which are MANAGED.
3. The terms 'enterprise' and 'organisation' are not defined in the Ontology, but a user of the Ontology may wish to define one or other of them as a high-level OU, perhaps corresponding with highest OU in the scope of interest.
4. An individual PERSON may correspond to, or belong to, more than one OU, one for each different role or function.
5. An essential PURPOSE of most OUs is to maximise performance against financial and other organisational OBJECTIVES.

MANAGE: the ACTIVITY of assigning PURPOSES and monitoring their ACHIEVEMENT

Notes:

1. This includes RESOURCE ALLOCATION and the power to give AUTHORITY;
2. This includes managing of people, (*e.g.* skill base, career development), and of OUs. This is reflected by the nature of the PURPOSES that are set and monitored; e.g. time horizon, deliverables.
3. This gives rise to an asymmetric Relationship between the managing and managed entities. See MANAGEMENT LINK.
4. Although the visible activity of management in an enterprise may take place between PERSONS (or possibly MACHINES), where the PURPOSE assigned and monitored clearly relates to the activities of the OU, it will frequently be natural to model it as being between the OUs.

DELEGATE: a kind of MANAGING ACTIVITY whereby there is a transfer of something to a (normally lower-level) Actor.

Notes:

1. We do not formally characterise DELEGATION, this is left to the users. Details to be considered include what may be delegated, (*e.g.* task, authority, responsibility).

MANAGEMENT LINK: a Relationship whereby one Actor directly MANAGES another Actor.

Notes:

1. The particular arrangement of MANAGEMENT LINKS determines what is commonly referred to as Organisational Structure, Control Structure, or Management Structure.
   - Examples of common Organisational Structures are hierarchical (e.g. line management), matrix (for project/programme management) and flat.
   - Co-management is a situation where an OU is MANAGED by more than one OU.
2. A single sequence of Actors directly connected via MANAGEMENT LINKS can be thought of as a management chain. More precisely, all management chains have:
   - Only one Actor (lowest level) that does not MANAGE another Actor;
   - Only one Actor (highest level) that is not MANAGED by another Actor;
   - No branching (*i.e.* no Actor MANAGES or is MANAGED by more than one other Actor).
3. An OU at the lower end of a Management Chain may correspond directly with one PERSON. The PURPOSES of such a PERSON may be very similar to the PURPOSES of the OU and therefore the PURPOSES may not need to be separately modelled. Higher up a Management Chain, the PURPOSES of an OU are likely to be dissimilar to the PURPOSES of a PERSON.
4. By virtue of being MANAGED by an OU, an OU may informally be thought of as being 'part of' the MANAGING OU.
5. Insofar as a MACHINE can be viewed as a MANAGED and/or MANAGING Entity, it may be considered to be an OU.

LEGAL OWNERSHIP: a Relationship between a LEGAL ENTITY and an Entity whereby the LEGAL ENTITY has certain rights with respect to the Entity.

Notes:

- the Entity in such a Relationship will be said to be 'LEGALLY OWNED'

NON-LEGAL OWNERSHIP: a Relationship between an Actor and an Entity whereby the Actor is recognised within a LEGAL ENTITY as having certain rights with respect to the Entity.

Examples:

- the Relationship between an OU and the RESOURCES allocated to it.

Notes:

1. In the eyes of the law, OWNERSHIP can only be vested in a LEGAL ENTITY. For practical purposes within an organisation, rights of an Actor with respect to an Entity within the organisation will be important to model.

OWNERSHIP: the union of LEGAL OWNERSHIP and NON-LEGAL OWNERSHIP.

Notes:

1. This is equivalent to: a Relationship between an Actor and some Entity whereby the Actor has certain rights with respect to the Entity.
2. It is *rights* that are OWNED, not the Entity itself; *e.g.* one who leases a car does not own the car, but they have legal rights with respect to it.

OWNER: the Role of the Actor in an OWNERSHIP Relationship

ASSET: an Entity LEGALLY OWNED that has MONETARY VALUE.

Examples:

- MACHINE, equipment, land, building, material,
- idea, design, patent, information.

Notes:

1. 'having monetary value' is not the same as 'can appear on a balance sheet'
2. capital asset, fixed asset and liquid asset are specialisations of ASSET but are not central to our concerns. The differences between these are determined by accounting standards.
3. An Entity may be both an ASSET and a RESOURCE but some ASSETS are not RESOURCES and some RESOURCES are not ASSETS.

STAKEHOLDER: a Role of a LEGAL ENTITY or OU in a Relationship with an OU whereby one or more PURPOSES of the OU are included in the scope of interest of the LEGAL ENTITY or OU.

Notes:

1. the STAKEHOLDER is usually one of: OWNER, PARTNER, SHAREHOLDER, EMPLOYEE.

EMPLOYMENT CONTRACT: An agreement [Relationship] between a LEGAL ENTITY in the Role of EMPLOYER and a PERSON in the Role of EMPLOYEE.

SHARE: A subdivision of the rights of OWNERSHIP of a CORPORATION recognised by law and the CORPORATION.

SHAREHOLDER: A LEGAL ENTITY OWNING one or more SHARES in a CORPORATION.

5.3 Related Terms

5.3.1 Synonyms

Party: LEGAL ENTITY

5.3.2 Borderline Terms

Company: roughly synonymous with CORPORATION; the minor legal differences between a Company and CORPORATION are ignored in this Ontology.

Registered Business that is not a CORPORATION: encompassed by PERSON

Sole Trader: encompassed by PERSON

Business: CORPORATION, or Sole Trader or Registered Business that is not a CORPORATION.

6 Strategy

The central concept in this section is PURPOSE which is either something that an Actor has, or is the main reason for executing a PLAN. PURPOSES may be decomposed into higher and lower level PURPOSES via the HELP ACHIEVE relationship. Special kinds of PURPOSE are: MISSION, VISION, GOAL, OBJECTIVE and STRATEGIC PURPOSE. A STRATEGY is a PLAN to achieve a STRATEGIC PURPOSE.

Other important concepts introduced include STRATEGIC PLANNING, STRATEGIC ACTION, DECISION, ASSUMPTION, (CRITICAL) INFLUENCE FACTOR, CRITICAL SUCCESS FACTOR and RISK.

6.1 Purpose and Strategy

PURPOSE: a Role of a State Of Affairs in one of the following Relationships:

- **HOLD PURPOSE**: a Relationship between an Actor and a State Of Affairs whereby the Actor wants, intends, or is responsible for the full or partial ACHIEVEMENT of the State Of Affairs;

  Notes:

  – The Actor will usually be a PERSON or OU, however MACHINE is not excluded.

  Example:

  – Some PERSON wants to be in Edinburgh on some date;

- **INTENDED PURPOSE**: a Relationship between an ACTIVITY SPECIFICATION and a State Of Affairs whereby:

  – EXECUTION of the ACTIVITY SPECIFICATION will result in fully or partially ACHIEVING the State Of Affairs;
  and

  – The State Of Affairs entails one or more of the EFFECTS of the ACTIVITY SPECIFICATION whose ACHIEVEMENT is declared to be the primary reason(s) for EXECUTING the ACTIVITY SPECIFICATION.

  Notes:

  1. An ACTIVITY SPECIFICATION with an INTENDED PURPOSE is *by definition* a PLAN.

  Example:

  – The PURPOSE of a PLAN is to be in some particular location on some date.

Notes:

1. a PURPOSE may be effectively decomposed into more detailed PURPOSES via the HELPS ACHIEVE Relationship.
2. A Responsibility may be viewed as a special kind of PURPOSE. Being responsible for implies the PURPOSE is DELEGATED by another Actor. This contrasts with the more general case where an Actor wants or intends a PURPOSE of their own volition.
3. A PURPOSE is characterised by one or more of the following:
   - *Measurability*: extent to which it is possible to objectively determine whether ACHIEVEMENT has occurred
   - *Time Horizon e.g.* short, medium, or long term
   - *Specificity*: how detailed the PURPOSE is; related to measurability in that very detailed PURPOSES will tend to be measurable.
   - *Relative Priority*: degree of desirability with respect to some Actor

PURPOSE-HOLDER: the Role of the Actor in the HOLD PURPOSE Relationship.

Kinds of Purposes

We introduce various different kinds or levels of PURPOSE: STRATEGIC PURPOSE, OBJECTIVE, GOAL, MISSION and VISION. We define the first two only, because the rest are used in many different ways. It is up to the Ontology user to specify what these may mean in a given situation.

STRATEGIC PURPOSE: A PURPOSE held by an ACTOR that is declared to be of 'Strategic' importance.

Notes:

1. Such a declaration is arbitrary; there is no way to otherwise infer whether PURPOSE is of strategic importance or not.
2. Frequently, a STRATEGIC PURPOSE will be fairly 'high-level' with respect to the HELPS ACHIEVE Relationship (*e.g.* it may correspond to a MISSION)

OBJECTIVE: a PURPOSE with a defined measure.

Notes:

1. The idea is that it is possible to detect the ACHIEVEMENT of an OBJECTIVE.

VISION, MISSION, and GOAL: kinds of PURPOSES

Notes:

1. They may or may not be OBJECTIVES.
2. Below we indicate some ways that these terms may be specialised:
   - Insofar as the HELPS ACHIEVE Relationship orders PURPOSES, the order will tend to be (from lowest-level): OBJECTIVE, GOAL, MISSION, VISION.
   - With respect to measurability, the order will tend to be (from most measurable): OBJECTIVE, GOAL, MISSION, VISION.
   - With respect to to time horizon, the the order will tend to be (from shortest time horizon): OBJECTIVE, GOAL, MISSION, VISION.

HELP ACHIEVE: a Relationship between two States Of Affairs whereby one State Of Affairs contributes to or facilitates the ACHIEVEMENT of the other State Of Affairs.

Notes:

1. The HELP ACHIEVE Relationship is particularly important when the States Of Affairs are PURPOSES. In this case, the HELP ACHIEVE Relationship may define a directed acyclic network of PURPOSES which gives rise to a notion of higher- and lower-level PURPOSES.
2. Users of the Ontology may wish to constrain the meaning of HELPS ACHIEVE more precisely, or even define more than one flavour. It is deliberate that the Ontology permits this while providing a basic structure that can be shared.

STRATEGY: a PLAN to ACHIEVE a STRATEGIC PURPOSE

STRATEGIC PLANNING: a [PLANNING] ACTIVITY whose INTENDED PURPOSE is to produce a STRATEGY

STRATEGIC ACTION: a SUB-PLAN of a STRATEGY

Notes:

1. Strictly speaking, this is a mis-nomer in that it is not an ACTIVITY, but a PLAN. It is left as such to conform with common usage.

6.2 Decisions, Factors, Assumptions

DECISION: commitment by an Actor to perform an ACTIVITY.

Notes:

1. this is roughly equivalent to the traditional definition: 'commitment to a course of action'. The notion of commitment appears synonymous with 'intention' as distinct from 'want/desire'

ASSUMPTION: a Role of a State Of Affairs in a Relationship with an Actor whereby the Actor takes the State Of Affairs to be true without knowing whether it is true or not.

Notes:

1. An ASSUMPTION may or may not be critical
2. ASSUMPTIONS are typically used during PLANNING and may be associated with PLANS.

CRITICAL ASSUMPTION: an ASSUMPTION that is associated with or used in STRATEGIC PLANNING.

NON-CRITICAL ASSUMPTION: an ASSUMPTION that is not associated with or used in STRATEGIC PLANNING.

INFLUENCE FACTOR: a State Of Affairs known to be true which is within the scope of interest of an Actor.

Example:

- current rate of inflation

CRITICAL INFLUENCE FACTOR: an INFLUENCE FACTOR that is associated with or used in STRATEGIC PLANNING.

NON-CRITICAL INFLUENCE FACTOR: an INFLUENCE FACTOR that is *not* associated with or used in STRATEGIC PLANNING.

CRITICAL SUCCESS FACTOR (CSF): A PURPOSE declared by an Actor to be critical to the success of one or more higher-level PURPOSES.

Notes:

1. the practical significance of this is that CSFs provide the central focus for STRATEGIC PLANNING.
2. it is important to note that the declaration is arbitrary in the sense that there is no set of Attributes that can objectively determine whether a PURPOSE is a CSF or not.

RISK: the Role of a State Of Affairs in a Relationship with an Actor whereby the Actor regards the State Of Affairs as a potential hindrance to the ACHIEVEMENT of one or more PURPOSES.

6.3 Related Terms

6.3.1 Synonyms

Threat: RISK

Programme: STRATEGY

Target: PURPOSE, GOAL

Measurable Target: OBJECTIVE

6.3.2 Borderline Terms

Contingency Plan: a PLAN which is used when a specified State Of Affairs occurs.

Notes:

1. usually associated with a RISK

7 Marketing

The central concept in this section is the SALE relationship, which is an agreement between a VENDOR and CUSTOMER to exchange a PRODUCT for a SALE PRICE. The MARKET is defined in terms of all SALES and POTENTIAL SALES, and may be subdivided into MARKET SEGMENTS using SEGMENTATION VARIABLES.

Other important concepts related to a MARKET include: BRAND, IMAGE, PROMOTION and COMPETITOR.

7.1 Sales

SALE: an agreement [Relationship] between two LEGAL ENTITIES to exchange one good, service or quantity of money for another good, service or quantity of money.

Notes:

1. The exchange in a SALE entails transfer of OWNERSHIP
2. A SALE may have as associated TIME-POINT indicating when the agreement was made.
3. A SALE may be characterised by a number of things, including: sales type, volume, value

POTENTIAL SALE: a possible future SALE.

FOR SALE: a situation whereby one LEGAL ENTITY offers to enter into a SALE. Associated with every such situation is a PRODUCT (being offered FOR SALE) and an ASKING PRICE.

Notes:

1. The definition for FOR SALE entails a necessary distinction between the seller (VENDOR) and the buyer (POTENTIAL CUSTOMER), in that only the former is offering something.
2. It is correct to say that the PRODUCT (the item being offered for exchange) is FOR SALE;
3. Informally, we may refer to the FOR SALE situation as a Relationship between the various parties and things exchanged.

SALE OFFER: A FOR SALE situation where a particular LEGAL ENTITY is being offered the PRODUCT.

7.1.1 Roles in Sales Relationships

The notions of customer, vendor, product and price are usually associated with sales. They are essentially roles that distinguish between the entities exchanged and the LEGAL ENTITIES involved. We reflect this in the Ontology by formally defining ACTUAL CUSTOMER, VENDOR, PRODUCT, ASKING PRICE, and SALE PRICE as Roles in the SALE and FOR SALE Relationships.

The Ontology caters for exceptional cases, where both things are goods (barter) or both money (currency exchange). However, in these cases the SALES Relationship is symmetric and there is no obvious way to distinguish between the Roles. Because of this, special care may be required in defining such SALES Relationships.

VENDOR: the Role of the LEGAL ENTITY who

- offers a PRODUCT, FOR SALE for an ASKING PRICE –or–
- agrees to exchange a PRODUCT for a SALE PRICE in a SALE.

Notes:

1. From the VENDOR's perspective, the exchange is referred to as 'selling'.

ACTUAL CUSTOMER: the Role of the LEGAL ENTITY agreeing to exchange a SALE PRICE for a PRODUCT in a SALE.

Notes:

1. From the ACTUAL CUSTOMER's perspective, the exchange is referred to as 'buying'.

POTENTIAL CUSTOMER: any LEGAL ENTITY who may become an ACTUAL CUSTOMER.

Notes:

1. This definition includes both LEGAL ENTITIES to whom PRODUCTS *are* offered FOR SALE, and LEGAL ENTITIES who might purchase something which is not but could be FOR SALE.
2. Since *any* LEGAL ENTITY can potentially participate in a SALE, the set of all LEGAL ENTITIES seems identical to the set of all POTENTIAL CUSTOMERS. Thus, this term may be redundant and unnecessary.
3. Various conditions are possible any of which, singly or in combination, may or may not be true in a particular case:
   - the actual offer of a PRODUCT to the LEGAL ENTITY [i.e. a FOR SALE Relationship];
   - the ability of POTENTIAL CUSTOMERS to afford the ASKING PRICE;
   - the LEGAL ENTITY having a NEED;
   - the existence of a PRODUCT having a FEATURE capable of satisfying a NEED;
   - the existence of a marketing PROMOTION aimed at POTENTIAL CUSTOMERS.

CUSTOMER: The union of POTENTIAL CUSTOMER and ACTUAL CUSTOMER.

One special kind of CUSTOMER is described below:

RESELLER: CUSTOMER who enters into a SALE agreement for the PURPOSE of making further SALES of the PRODUCT (or a derivative of it).

Notes:

1. A RESELLER is a CUSTOMER in one SALE and a VENDOR in another.

PRODUCT: the Role of the good, service, or quantity of money that is:

- offered FOR SALE by a VENDOR –or–
- agreed to be exchanged by the VENDOR with the ACTUAL CUSTOMER in a SALE.

Notes:

1. There is possible confusion with the use of the term 'product' when referring to something produced/manufactured but which is not sold (*i.e.* an intermediate product internal to a manufacturing process). It may become necessary to introduce two terms for this, such as 'Market Product' and 'Manufactured Product'.

ASKING PRICE: the Role of the good, service, or quantity of money being asked for by a VENDOR in exchange for a PRODUCT that is FOR SALE.

SALE PRICE: the Role of the good, service or quantity of money agreed to be exchanged by the ACTUAL CUSTOMER with the VENDOR for the PRODUCT in a SALE.

Notes:

1. We specifically chose not to define the price as the 'value' of the PRODUCT, because value is relative, the price is the actual thing exchanged. (usually money).

7.2 Market

MARKET: All SALES and POTENTIAL SALES within a scope of interest.

Notes:

1. A MARKET can be characterised by any number of SEGMENTATION VARIABLES
2. A MARKET may be measured in various ways. For example: the number of SALES, the sum of the SALE PRICE of the SALES, or ratios between one set of SALES and another.

SEGMENTATION VARIABLE: Any Attribute determinable from a SALE or POTENTIAL SALE in a MARKET. Examples include:

- PRODUCT: identity, size, shape, colour, sex appeal
- VENDOR: geographical location, size
- CUSTOMER: socio-economic class, age, sex
- SALE: geographical location, TIME POINT of occurrence (e.g. date and time)

MARKET SEGMENT: All SALES and POTENTIAL SALES in a MARKET having defined values of one or more SEGMENTATION VARIABLES.

Examples:

- Geography = Asia;
- Socio-economic class of CUSTOMER = yuppie.

Notes:

1. One person's MARKET may be another person's MARKET SEGMENT

MARKET RESEARCH: An ACTIVITY whose

- PURPOSE is to better understand a MARKET
- EFFECTS includes the existence of information about a MARKET

BRAND: A name identifiable by CUSTOMERS associated with one or more PRODUCTS of a VENDOR.

IMAGE: a set of properties that a CUSTOMER believes to be true of a BRAND, PRODUCT or VENDOR.

Example:

- Rolls Royce automobiles are believed by CUSTOMERS to be reliable

FEATURE: An Attribute of a PRODUCT which may satisfy a NEED of a CUSTOMER.

NEED: A physical, psychological or sociological requirement of a CUSTOMER.

MARKET NEED: an identifiable NEED of CUSTOMERS which is not fully satisfied by PRODUCTS currently FOR SALE.

PROMOTION: An ACTIVITY whose primary PURPOSE is to improve the IMAGE [of a PRODUCT, BRAND and/or VENDOR].

Notes:

1. A PROMOTION may have additional PURPOSES, all normally related to the MARKET.

COMPETITOR: a Role of a VENDOR in a Relationship with another VENDOR whereby one offers one or more PRODUCTS FOR SALE that could limit the SALES of one or more PRODUCTS of the other VENDOR.

Notes:

1. this competition is a symmetric Relationship; *i.e.* each VENDOR is a COMPETITOR of the other in the same manner.

7.3 Related Terms

7.3.1 Synonyms

Bid, Proposal: SALE OFFER

Consideration: SALE PRICE

Reputation: IMAGE

Supplier: VENDOR

Trading Entity: VENDOR

7.3.2 Borderline Terms

Buyer: the LEGAL ENTITY approving the SALE. In many cases the Buyer will be the ACTUAL CUSTOMER; alternatively, if the ACTUAL CUSTOMER is a high-level OU, the Buyer may be a PERSON or OU within that OU.

Consumer: the LEGAL ENTITY who will use the PRODUCT in a SALE; In many cases, the Consumer will be the ACTUAL CUSTOMER; alternatively, if the ACTUAL CUSTOMER is a high-level OU, the Consumer may be a PERSON or OU within that OU.

Product Substitute: a PRODUCT that may be offered by a VENDOR in place of a PRODUCT previously offered. Planning tools may need knowledge of the FEATURES of PRODUCTS to plan or optimise substitution.

Customer Base: A group of existing CUSTOMERS. These may be segmented by geography, demographics etc. Should be considered as part of MARKET RESEARCH and/or PROMOTIONS.

7.3.3 Other Commonly Used Terms

- *Product Portfolio*
- *Target Customer*
- *Target Market Segment*

8 Formalising the Enterprise Ontology

In this section, we report our experiences of converting the natural language definitions comprising the Informal EO into the formal language: Ontolingua.

One objective of this section is to clarify the role of the the Formal EO and its relationship to the Informal EO presented in sections 2-7. A prior version of the Informal EO served as a specification for the Formal EO. Overall, we believe that we were successful in accurately representing the intended meaning of the terms described in the Informal EO. There were relatively few changes to the Enterprise Ontology identified during formalisation. Differences include simple name changes, removing some terms, adding new terms and shifts in perspective for a particular concept. These changes have already been incorporated in the definitions given in the previous sections, thus sacrificing a certain amount of historical accuracy for clarity of exposition. See appendix A for tables summarising the correspondence between terms in the Informal EO, and their encoding in Ontolingua.

Another key objective is to shed light on the process of formalising the Enterprise Ontology. To our knowledge, the experiences described here are at a much finer level of granularity, than has been reported elsewhere. On occasion, we refer to technical details regarding Ontolingua. However, they may be safely ignored by readers unfamiliar with the language, as other material does not depend on these details. Appendix B contains examples of Ontolingua definitions for some of the key concepts.[6]

A third important objective of this section is to augment the documentation already present in the Ontolingua syntax of the Formal EO.

Our emphasis is on providing clear definitions for concepts in the enterprise modelling domain, in particular. In doing so, we have been led to address certain more general problems, but we make no attempt to solve deep problems such as on how best to give a detailed formalisation of activities. Instead, we provide a basis to which more details may be added as necessary.

Outline

In the remainder of this section, we begin by clarifying the role of the Formal EO. Then we describe how the terms in the Meta-Ontology in the Informal EO were handled. Of particular importance are Roles and States of Affairs. After this, we identify some of the main issues that arose during the formalisation process which resulted in changes from the Informal EO.

8.1 The Role of the Formal EO

The purpose and intended uses of an ontology affect decisions about how it is developed and ultimately, its content. The primary reason for formalising the Enterprise Ontology is to provide a more precise specification of the meaning of the terms than is possible in natural language. A consequential benefit of the analysis performed during the formalisation process is the likelihood of greater consistency and completeness.

It was also hoped that automatic translation might take place to support use of the Enterprise Ontology as an interchange format. In order for the Ontolingua translators to work most effectively, one must be very restricted in one's use of axioms. Unless an axiom has an obvious translation into an object-oriented (i.e. frame-based) representation structure, it will not be translated at all.

Because our primary emphasis was to ensure communication between humans, we used axioms fairly freely and had low expectations about translation support. If we were more interested in automated translation, we would likely have produced a very different formalisation.

We make no claims about formal rigour or completeness. Some of the terms have weakly specified semantics, with no related axioms. Semantics in these cases is limited to specifying that something is a class, relation or an instance, and what relations it can participate in.

[6]Readers with limited interest in technical details may wish to skip this entire section.

Where we do specify axioms to better characterise the semantics, we do not expect those axioms to be used directly by any theorem prover or automatic language translation software. Users of the Formal EO may add further axioms for greater rigour or completeness depending on their requirements.

8.2 Meta-Ontology

KIF, on which Ontolingua (OL) is based, gives the full expressive power of first-order logic. As such, it comes with a standard meta-ontology, namely: objects, relations, and functions. For the most part, Ontolingua provided adequate primitives to cover what was required to represent the Enterprise Meta-Ontology. There was little to be gained by formally defining things like 'ENTITY' and 'RELATIONSHIP' as described in the Informal EO. However, for clarity, we point out precisely what these correspond to in the Formal EO.

8.2.1 Entities, Classes and Instances

In the Informal EO, to conform to common natural language usage, we intentionally blurred the distinction between a type of entity, and a particular entity of a certain type. The majority of terms defined in the Informal EO correspond to types of entities, which, in Ontolingua are unary relations called *Classes* – *e.g. Person*, *Activity*, *Purpose*. Particular entities of a certain type are called *Instances*, in ONTOLINGUA.

Formally, 'ENTITY' in the Informal EO, (taken as a type of thing rather than a particular thing of a certain type) is equivalent to the union of the Ontolingua Frame-Ontology [6] classes: *Set* and *Thing*.

NB: we use italics to refer to formally defined terms in Ontolingua.

8.2.2 Relationships, Roles and Role Classes

Relationship 'RELATIONSHIP', in the Informal EO was also deliberately ambiguous, reflecting common usage of the term in natural language. It referred both to the set of tuples constituting a relation and a single tuple. If we restrict usage to refer to the set of tuples (*i.e.* the mathematical relation), then 'RELATIONSHIP' is equivalent to a subclass of *Relation@Frame-Ontology* which excludes *Unary-Relations*. We found no need to define this class explicitly in Ontolingua.

Attribute 'ATTRIBUTE' in the Informal EO is roughly equivalent to a Function in Ontolingua. However, in the main, what was said to be an ATTRIBUTE in the Informal EO is modelled in Ontolingua as a slot on some class whose slot-cardinality is set to 1.[7]

Role While it seemed useful in the Informal EO to introduce various terms defined specifically as ROLES, the concept of a ROLE is not directly represented in the Formal EO. Instead, a ROLE corresponds to the semantics of an argument in a relation.

A good example is RESOURCE, defined as the ROLE of an ENTITY in a RELATIONSHIP with an ACTIVITY whereby the ENTITY is or can be used or consumed during the ACTIVITY.

[7] There is a subtle distinction here. A slot with slot-cardinality set to 1 may not explicitly be a Function in Ontolingua; rather it *corresponds* to what has the defining property of a function. In particular, it corresponds to a sub-relation (i.e. a subset of tuples) of the [independently defined] *Binary-Relation* used in the slot. That *Binary-Relation* need not be a *Function*.

It is not obvious how or whether one might usefully represent this ROLE, per se, in Ontolingua. However corresponding to every ROLE, is the set of all ENTITIES that play that ROLE. For RESOURCE and other important ROLES, we formally represent this set and refer to it as a *Role-Class*.

We represent the RELATIONSHIP referred to in the definition of RESOURCE as a binary relation called *Can-Use-Resource*, where the first argument refers to the activity, and the second to the entity. The unary relation *Resource*, represents the class of all entities (i.e. instances) that participate in this relationship with some activity. It is defined as follows (see appendix B for the Ontolingua definitions):

$$\forall E.(Resource(E) \quad \leftrightarrow \quad \exists A.(Activity(A) \wedge Can\_Use\_Resource(A, E)))$$

So, the concept of a ROLE is adequately represented in Ontolingua, but from a different perspective than that in the Informal EO. Rather than formalise the way an entity participates in a relationship, instead we formalise the set of all entities that participates in a relationship in that certain way.

As a matter of convenience, we defined *Role-Class* in Ontolingua. It is a special kind of Class, one for which membership is based on what ROLES an entity plays. *Resource* is a simple *Role-Class* defined in terms of a single ROLE. *Purpose* is defined using ROLES from two different relations (see below).

Technically, *Role-Class* is a meta-class, *i.e.* the class of all classes which are defined in terms of ROLES. A particular role class, such as *Resource*, is an instance of the [meta-]class *Role-Class*.

To the extent that updates may occur which change the particular set of tuples comprising a relation, being an instance of such a class is dynamically determined. For example, an entity may, in principle, be a resource at one time, but not at another.

There are many other important ROLES in the Informal EO that give rise to a *Role-Class* in Ontolingua; a few are noted below:

Assumption: The *State-Of-Affairs* in an *Assumed* relationship with some *Actor*;

Stake-Holder: An *Actor* that *Holds-Stake-In* some *Organisational-Unit*;

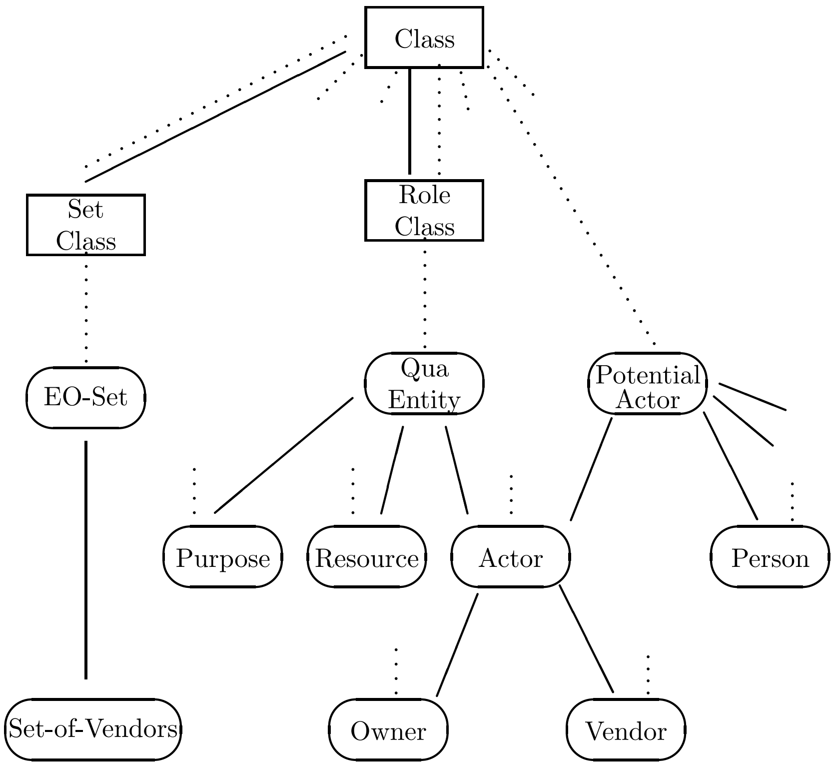
Purpose: a *State-Of-Affairs* that is either

- in a *Hold-Purpose* relationship with some *Actor*, or
- the *Intended-Purpose* of some *Plan*.

This is an interesting example Where *Purpose* is logically the union of two simple *Role Classes*.

8.3 Set Classes

A situation which commonly arises is the need to represent certain sets which are not themselves naturally viewed as classes. Consider a MARKET SEGMENT; it is a subdivision or component of a market. Every MARKET SEGMENT can itself be viewed as a MARKET, but is distinguished by being defined explicitly as being limited to certain PRODUCTS, VENDORS, and or CUSTOMERS. It is reasonable, then, to represent a *Market-Segment* as a sub-class of *Market*. Its attributes are *Product-Range*, *Vendor-Range* and *Customer-Range*. What is the type/class of values of these attributes? A product range, is a set of products, a customer range is a set of customers, etc. So, we create three new classes called: *Set-of-Products*, *Set-of-Vendors* and *Set-of-Customers* and appropriately restrict the type of entity that can fill the range slots.



This figure illustrates the key meta-classes and some of their instances and subclasses. Qua-Entity is the most general instance of Role-Class. Actor is a major subclass of Qua-Entity.

As formalised in Ontolingua, a meta-class is a sub-class of Class *distinguished by having instances that are are themselves classes. Examples of meta-classes include Class, Role-Class and Set-Class. The meta-classes are also classes, so so they are both instances* and *sub-classes of Class, as depicted above.*

Ovals and rectangles denote regular classes and meta-classes respectively. Solid lines denote the class/subclass relationship, and dotted lines the class/instance relationship. The dotted lines which are not connected from above indicate that the class is an instance of the meta-class Class.

Figure 3: Classes and Meta-Classes

However, how do we represent these latter things? One way is to invent new classes (*e.g. Set-of-Products*) independently from the underlying class (*e.g. Product*). Instead, we chose to capture the fact that these are special kinds of classes; they are special in that every instance of such a class is itself a set, and furthermore, every member of such an instance set is restricted to be of a single class. For example, *Set-of-Products*, is defined as follows:

$$\begin{aligned} \forall Ps.(Set\_of\_Products(Ps) \quad \leftrightarrow \quad & set(Ps) \wedge \\ & \forall x.member(x, Ps) \rightarrow Instance\_of(x, Product)) \end{aligned}$$

We define all classes defined in this manner to be instances of a meta-class *Set-Class* which is the class of all such classes. *Set-of-Products* is one of its instances.

See appendix C for formal definitions in Ontolingua. See [18] for a detailed motivation for set classes and alternative formalisation in a higher order logic.

8.3.1 State of Affairs

Informally, a STATE OF AFFAIRS is some kind of situation. It is something that can be thought of as holding, or being true (or conversely, as not holding, or as being false). Thus, in first-order logic, any state of affairs can be represented by a syntactically valid sentence, or formula. Note that while it may be convenient to think of a state of affairs as a set of sentences (*e.g.* $\{S_1, S_2, S_3\}$), this is equivalent to a single sentence using explicit conjunction (*i.e.* $S_1 \wedge S_2 \wedge S_3$). Strictly speaking, then, to formally represent a state of affairs, is to formally specify the syntax of a first-order logic sentence. Fortunately, this and other meta-level things are already formalised in KIF, so there was no need to re-define this from scratch.

From a practical standpoint, the reason for having *State-Of-Affairs* in the Ontology is to clarify the meaning of certain terms (*e.g. Help-Achieve*, *Intended-Purpose*, *Pre-Condition* and *Effect*). In the Formal EO, this is done by restricting the argument types in certain relations. However, to be *any* sentence at all is a minimal ineffective restriction. For example, Pre-Conditions and Effects relate to activities in the domain being modelled, thus we should like to further restrict the state of affairs to be only those sentences which refer to world state conditions. For example, *Home-City(John, Edinburgh)* should be allowed, but *Relconst('Intended-Purpose')* which refers to the representation language itself, should be prohibited[8].

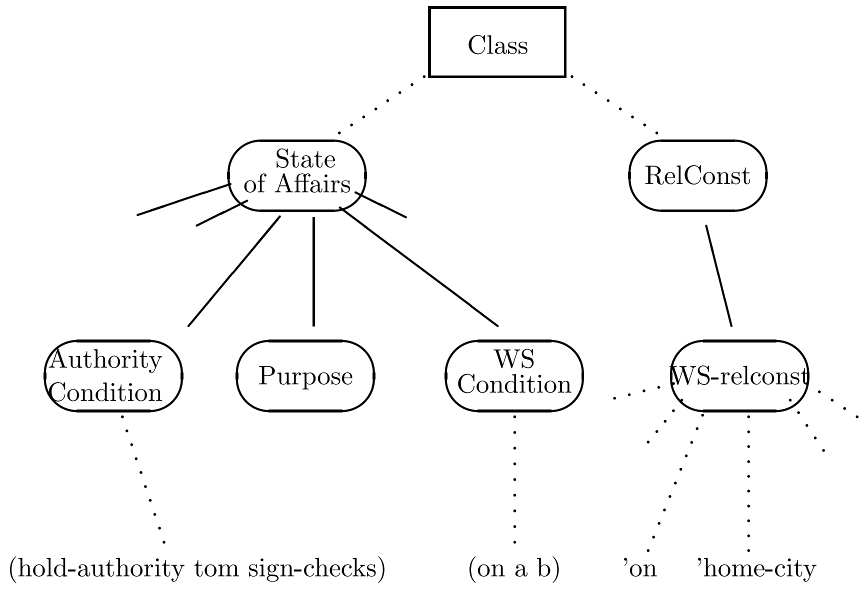
So, the class *State-Of-Affairs* is too general because it allows sentences to be constructed referring to *any* relation at all. We require a way to define sub-classes of *State-Of-Affairs* by restricting the set of relations that can be referred to when constructing sentences representing states of affairs.

To do this, we define a meta-level binary relation: *Restricted-Sentence* whose first argument is a sentence, and whose second argument is a set of relational constants. The relation holds if and only if:

1. the first argument is a syntactically valid first-order logic sentence;
2. all relational constants referred to in the first argument are in the set comprising the second argument.

Here, the most general case is the degenerate one, where the second restriction has no effect. S is a *State-Of-Affairs* if and only if *Restricted-Sentence(S, AllRelconsts)* is true; where *AllRelconsts* is the set

[8] In KIF, *Relconst* is a unary relation representing relational constants; it is used in a bootstrapping fashion to define KIF syntax.



State-of-Affairs may be specialised for the purpose of restricting the argument types of certain relations.

Solid lines denote the class/subclass relationship, and dotted lines the class/instance relationship. Meta-classes are rectangles and regular classes are ovals.

Figure 4: State of Affairs

of all relational constants. Formally,

$$\forall S.(State\_Of\_Affairs(S) \quad \leftrightarrow \quad Restricted\_Sentence(S, setofall(?r, relconst(?r))))$$

The more useful cases arise when one wishes to define sub-classes of *State-Of-Affairs*, such as *WS-Condition*, or *Authority-Condition*. Because there are likely to be a wide variety of world state relations, it would be awkward to have to explicitly list them. It is more convenient to create a separate class of world state relation constants, (*WS_Relconst*) and use the *setofall* function. Formally,

$$\forall S.(WS\_Condition(S) \quad \leftrightarrow \quad Restricted\_Sentence(S, setofall(?r, WS\_Relconst(?r))))$$

Where, for example, *WS_Relconst('Home-City')* would be true and thus in the restricted set of relational constants.

In other cases, the restriction may be to a very small number, or a single relational constant; then it is simpler to list them directly. For example,

$$\forall S.(Authority\_Condition(S) \quad \leftrightarrow \quad Restricted\_Sentence(S, setof('Hold\_Authority')))$$

Final remarks. Strictly, to do a comprehensive job of formally defining *State-Of-Affairs*, we would have to essentially repeat what is defined in the KIF-Meta ontology, re-structuring it slightly to suit our purposes. We have chosen not to do this at this time.

This completes the discussion of how the Meta-Ontology was formalised. It provides the constructs in which all other definitions are formally expressed. See appendix A for a table indicating how the informal Meta-Ontology terms were formalised.

8.4 Producing Formal Definitions

The point of producing formal definitions is to more precisely specify the meaning of all the important concepts in the informal EO. In this section, we consider the process of converting the informal definitions into formal ones, suggesting guidelines for others who may engage in this activity.

In the main, each term in the informal EO corresponds to a term in the Formal EO, and the definitions are fairly directly captured in the formal language. However, exceptions arose, whereby it was appropriate to change the way terms and concepts were originally defined in the Informal EO. Often, but not always, these changes suggested improvements in the definitions in the original version of the Informal EO, which are reflected in the main sections of this paper.

The main content of this section is to identify and characterise the kinds of changes that arose, and give examples. The main message is to recommend that any similar exercise be done with care taken to watch out for these situations and to act accordingly. These are quite general, in no way depending on the specific domain of business enterprises.

There were a total of just over one hundred terms in the informal EO, including the meta-ontology. Most of the important changes fell into the following categories, which we will address in turn.

- Some terms were not defined at all (nine in all, seven from meta-ontology);
- Some terms were defined from a different perspective (six);
- About 50 new terms were introduced.

For example, in the Meta-Ontology, ACHIEVE, ENTITY and RELATIONSHIP fall in the first category; ROLE is defined from a different perspective (*i.e. Role-Class*); and POTENTIAL ACTOR is a new term (not found in version 1.0 of the Informal EO). Below we elaborate on these issues and give further examples.

8.4.1 Terms not Defined

In some cases, a term referred to an important concept which there was no obvious need to define explicitly, or there was no obvious way to do so in a useful manner. Because the concepts are important, they cannot be left out; instead they are implicitly captured in other formal definitions.

For example, ACTIVITY-DECOMPOSITION, while a very important concept, is manifest in the details of how SUB-ACTIVITIES are inter-related, and other constraints that comprise an ACTIVITY SPECIFICATION. Defining something formally corresponding to an ACTIVITY DECOMPOSITION did not seem useful.

A MANAGEMENT LINK is defined to be a relationship between two particular ORGANISATIONAL UNITS. This corresponds to a particular tuple of the *Manages* relation, and so the concept is captured, but there was no need for MANAGEMENT LINK itself to be defined as a separate term.

Similarly, in an earlier version of the Informal EO, ORGANISATIONAL STRUCTURE was defined to be "the MANAGEMENT LINKS relating a set of OUs" which corresponds to the set of tuples comprising the *Manages* relation, and thus is also unnecessary to define. ORGANISATIONAL STRUCTURE is no longer an 'official term' in the Informal EO, instead appearing in a note under MANAGEMENT LINK.

All of the above concepts can be modelled using the formal definitions of related terms, but are not explicitly defined themselves. E.g. a management linke can be created by specifying that two OUs stand in the *Manages* relation.

8.4.2 Terms Viewed from a New Perspective

In some cases, the perspective from which an entirely clear and natural definition was given in the Informal EO, was awkward to base the formal definition on. We have already seen one example of this, ROLE.

Consider also, AUTHORITY, which is defined as "the right of an Actor to EXECUTE an ACTIVITY SPECIFICATION". However, it was simpler to model this as a binary relation (*Hold-Authority*) denoting the <u>fact</u> that an ACTOR has the right to EXECUTE an ACTIVITY SPECIFICATION. There is no essential change in meaning, just of perspective. It would be possible to model the 'right' explicitly to retain the original perspective, but this was not deemed useful.

8.4.3 New Terms

There are rather more terms in the Formal EO than in the Informal EO. Three three main reasons for this are:

1. to fill gaps, *i.e.* things were missing in the Informal EO;
2. to make explicit much that which was only implied in the Informal EO which required teasing out;
3. to formalise logical connections that were clearly evident, but not precisely characterised in the Informal EO.

Filling Gaps Examples of the first situation are SALE OFFER and ACTIVITY SPECIFICATION. The latter is a particularly important concept which was deemed to require explicit definition, so as to distinguish a set of instructions for doing something from the doing of the thing itself (*i.e.* ACTIVITY). The underlying concept was clearly evident in the original definition of PLAN: "a specification of one or more ACTIVITIES for some PURPOSE". With the addition of ACTIVITY SPECIFICATION, this was changed to "an ACTIVITY SPECIFICATION with an INTENDED PURPOSE". This also has the benefit of reducing the number of undefined words in the definitions.

Making Things Explicit An example of the second situation arises where something is defined in the Informal EO as 'a Role in a Relationship between an X and a Y whereby ...'. For example, ASSUMPTION is defined to be "a Role of a State Of Affairs in a Relationship with an Actor whereby the Actor takes the State Of Affairs to be true without knowing whether it is true or not". In the Informal EO, it is only implied that the Relationship exists but it is neither named nor defined. These Relationships are formalised as [usually binary] relations. In this case, the *Assumed* relation was defined and *Assumption* is a *Role-Class* formally defined in terms of this relation.

Formalising Logical Connections As an example of the last situation, consider the following definitions from version 1.0 of the Informal EO:

PLANNING: an ACTIVITY whose major EFFECT is to produce a PLAN;

STRATEGY: a PLAN to ACHIEVE a high-level PURPOSE;

STRATEGIC PLANNING: an ACTIVITY whose PURPOSE is to produce a STRATEGY.

Problems with these definitions are:

- the idea of a 'major EFFECT' is undefined;
- 'high-level PURPOSE' has no meaning, though it appears to be a special kind of PURPOSE;
- STRATEGIC PLANNING is not defined in terms of PLANNING;
- the phrase 'to produce' is used in the definitions of STRATEGIC PLANNING and PLANNING, but is undefined.

To address this, we made the following alterations:

- We introduced a new term: *Strategic-Purpose* which is formally defined as a type of *Purpose*;
- *Strategic Planning* is formally defined as a type of *Planning*;
- 'to produce' is defined as a Relationship called *Actual-Output* between an *Activity* and an *Entity* where by the *Entity* is an output produced by the *Activity*;
- the idea of a 'major EFFECT' is formalised using *Intended-Purpose* which is linked with *Actual-Output* in the formal definition of *Planning*.

Most of these changes are reflected in updated Informal EO in this document, the major exception being *Actual-Output*, which is defined only in the Formal EO. The following definitions are taken from the Ontolingua documentation strings in the Formal EO.

Planning: An *Activity* whose *Intended-Purpose* is to produce a *Plan*.

Strategic-Purpose: A *Purpose* held by an *Actor* that is declared to be of ‘strategic’ importance.

Strategy: a *Plan* whose *Intended-Purpose* is a *Strategic-Purpose*

Strategic-Planning: a *Planning Activity* whose *Intended-Purpose* is to produce [an *Actual-Output* which is] a *Strategy*

Although we avoiding the use of the term ‘high-level’, the resulting definition of *Strategic-Purpose* has a circular aspect. This captures the fact that, whether something is ‘strategic’ or not, is a fairly arbitrary declaration. It is up to users to use this appropriately.

Summarising this example, by introducing two new terms: *Strategic-Purpose* and *Actual-Output* we have been able to make our definitions more precise, making various implicit connections explicit.

This sort of analysis could have been done purely at the informal level. However, the discipline of formalisation helps force one to notice such things. This leads to improvements in consistency and clarity and an improved Informal EO.

8.5 Summary and Conclusion

In this section, we have reported our experiences in converting the informal version of the Enterprise Ontology expressed in natural language, into the formal language: Ontolingua. We have attempted to do so in a general way.

First, we described proposed solutions to what may be general problems occurring in the development of a wide range of ontologies. This includes how to represent a state of affairs, role concepts and sets which are not themselves classes.

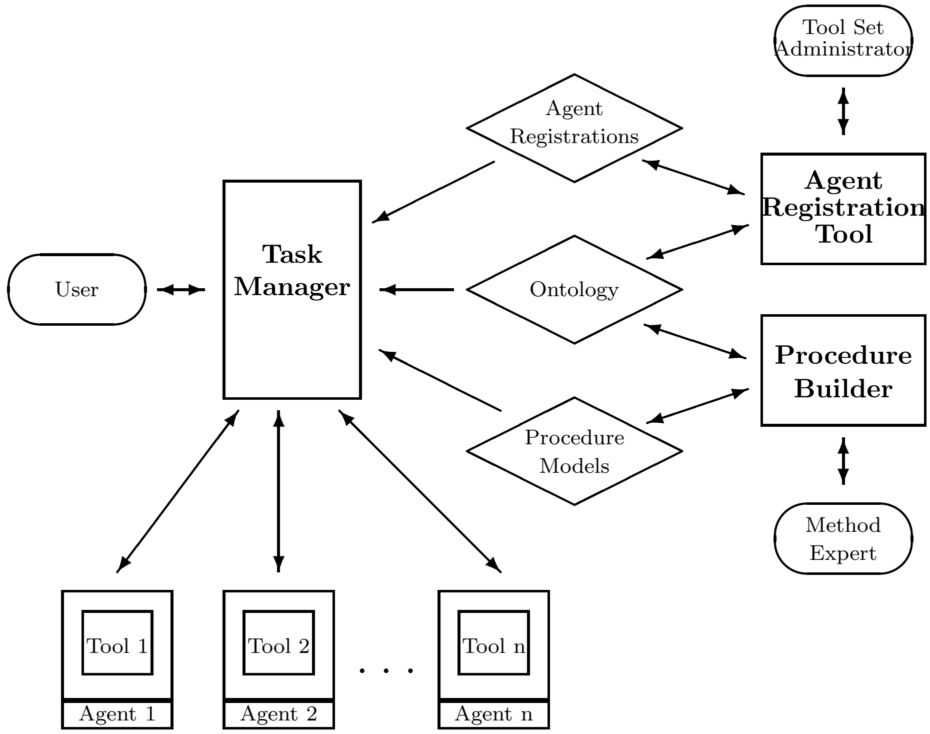
Then we characterised in general terms the sorts of issues that will be faced when converting an informal ontology into a formal one. This included:

- deciding when a term does not need to be explicitly defined;
- representing terms from a difference perspective; *e.g.* roles
- when and how to introduce new terms; in particular:
  - when an important concept is missing, so as to fill a gap;
  - to make explicit that which was clearly evident but only implied in the informal ontology;
  - formalising logical connections between terms that are related where such relationships were not initially obvious from the informal ontology.

The main message of this section is to be aware of the above situations and to act accordingly, when engaging in a similar formalisation exercise. We have given detailed examples to illustrate our points.

Semantics As noted previously, not all terms have related axioms. Semantics in these cases is limited to specifying that something is a class, relation or an instance, and what relations it can participate in. This is made precise by the formal semantics of KIF on which Ontolingua is based.

Choice of Language The choice of Ontolingua as a representation language has proved highly suitable from the point of view of representational adequacy. Some of our attempts to use parts of the Formal EO in the Tool Set are discussed in the next section.



This figure illustrates the flexible agent-based architecture of the Enterprise Tool Set used to achieve tool integration. Note the different types of users for different components of the Tool Set.

Figure 5: Tool Set Architecture

9 Using the Enterprise Ontology

In this section, we describe the actual roles and uses of the Enterprise Ontology in the Tool Set and in the applications. We first give a very broad overview of the way the Tool Set is structured, describing its main components and indicating how they interact. That sets the stage for clarifying how and where the Ontology fits in.

9.1 Overview of Tool Set

The Enterprise Tool Set is designed to facilitate the integration of multiple independently developed software tools in a single package (see figure 5). To an end user running an application, there is no visible distinction between a function being achieved by a module in the Tool Set itself or by an outside tool. To achieve this seamless integration, an agent architecture was adopted.

The Tool Set consists of various components each serving one or more main purposes. The main components with some of their key functions are:

Agent Toolkit: for transforming tools into agents and registering these agents with the Tool Set;

Procedure Builder: for generating process models and making them available to the Tool Set;

Task Manager: for enacting process models and running end user applications.

In addition, there is a facility for editing and browsing a hierarchy of Ontology terms. This is available from both the Procedure Builder and the Task Manager. Editing would be required to include additional terms for concepts specific to the desired application.

The various functions of the different components correspond to different phases of using the Tool Set; from initial set up, creating and registering agents and process models, through to process enactment. Apart from initial specifications these different phases are relatively independent of each other and they may typically involve different users.

All the earlier phases can be seen as support phases for the eventual enactment of process models in end user applications. However, they will have their own benefit, independently of their use in the Tool Set. For example, modelling work (ontology and processes) is a useful exercise in itself to gain insights into structures and processes, and it often shows scope for improvements.

Tools are turned into agents by agent programmers, in most cases by adding a communication layer to the tool. This can be done with the help of the Agent Toolkit. All software agents must be able to communicate using KIF and KQML and make their capabilities available to the Tool Set. Tools that have been turned into agents can be registered with the Enterprise Tool Set by the Tool Set administrator. The agents are registered stating their types (software or person) and their capabilities. The Ontology ensures that terms are used in a consistent way. Once an agent has been registered, its capabilities can be called upon by the Task Manager for the execution of tasks.

Processes are captured by the method expert using the Procedure Builder. Again this is done using the Ontology. The process models (i.e. procedures) can be loaded into the Task Manager where they can be selected as tasks and executed, thereby enacting the process. In this way, the procedures are used as a basis for supporting users and for coordinating the use of agents.

We now proceed with exploring how the Ontology fits into this framework. We first consider the use of the EO in the Procedure Builder and then the Task Manager and the agent registration mechanisms. Finally, we describe how the Ontology was used in the end user applications that were developed to validate and illustrate the use of the Enterprise Tool Set.

9.2 Procedure Builder

The first use of the Enterprise Ontology was as a basis for the representation of procedures for the Procedure Builder. This is a bootstrapping use of the EO, the benefit being in the development and maintenance of the Tool Set software itself. This is not to be confused with a use of the EO which directly contributes to integration or better communication in an enterprise.

Enterprise Process Modelling Language (EPML) was developed for representing procedures in the Procedure Builder.

We conducted a test to see how close we could come to the following ideal situation:

- We could directly use the exact concepts already in the Enterprise Ontology as a basis for EPML;
- We could directly use the Ontolingua code for these concepts translated into Clips and directly inserted into the code which implements the Tool Set.

This would have resulted in:

- savings due to reusing the conceptual analysis, avoiding the need to start from scratch and build yet another special purpose process modelling language;
- savings in initial coding time;
- more responsive to change due to the increased modularity of the Tool Set software. Changes could be automatically updated avoiding need to painstakingly alter the code manually. This, in turn would:
  - save time
  - ensure accuracy.

It should be possible to use concepts and terms from the Enterprise Ontology as a starting point. If correct, and if the Ontolingua Clips translator was effective, then it should have worked fine. In practice, what we learned from this experience is:

1. The Informal EO was too ambiguous to be a direct basis for representing procedures.
2. The Formal EO was far less ambiguous. The viewpoint and concepts of the activity-related terms in the EO were out of step from traditional process modelling languages. For example, most do not distinguish and explicitly represent *both* the ACTIVITY and the ACTIVITY-SPECIFICATION, but rather just the latter.
3. EPML evolved to be essentially independent from the Formal EO. The main reason for this is that there were different goals for the development of the EO (a very general effort) and the development of EPML (specific to the Tool Set). For example, despite the importance of the distinction, ontologically. there was no need for both ACTIVITY and ACTIVITY-SPECIFICATION in the implementation.

   If the expected use differed, then the formalisation would differ accordingly.
4. There were problems with the Ontolingua Clips translation:
   - The Clips code was not syntactically correct, considerable manual editing was required to get it to load (e.g. the symbol for greater-than was wrong);
   - It came with an enormous amount of unnecessary baggage for which there was no use (e.g. the frame ontology). Only about 5% of the code would ever be used. We believe that this was mainly a practical problem (it considerably slowed loading) not a conceptual one.

   For these reasons, the translators were not used. The Clips code for representing procedures used in the Tool Set was manually created independently from EPML and the EO.

In summary, of the potential benefits listed above, the existence of the activity component the Enterprise Ontology was the most significant benefit as a starting point for implementing the Procedure Builder. See § 9.5 for other uses of activity-related definitions in the EO.

The difficulties of reusing existing class libraries in object-oriented analysis, design and programming are well known, and are analogous to the difficulties of reusing terms in an ontology.

What is important is what we learned from the exercise. We consider that the other benefits could have been achieved. Key issues are:

- the EO was being refined at the time EPML was being developed;

- there was insufficient time to fix the EO so that it could have been aligned with EPML, which in turn would have facilitated achievement of other benefits.

In this section, we have addressed possible indirect uses of the EO in the context of developing the Tool Set itself, rather than the applications (in particular, the Procedure Builder). In the following sections, we describe the mechanisms that are present in the Tool Set that assist the development of applications. We also describe our experiences in using these facilities in the applications.

9.3 Task Manager and Agents

As noted above, inter-operation of independent software tools is achieved via an agent mechanism. A key intended use of the Enterprise Ontology was as an interchange format to enable this inter-operation in conjunction with the agent mechanism.

As in the case of the Procedure Builder, there was also scope for making use of the EO in a bootstrapping sense, re-using the concepts as a basis for describing and specifying the software functionality and components with respect to goals, activities and tasks. Ideally, the terminology for describing the software would be the same for all components as well as being consistent with the EO. This would make it easier for all involved including system developers, application developers and end users.

9.3.1 Mechanisms Actually Used

Here we briefly describe the main mechanisms and some details of making use of the Enterprise Ontology in the Task Manager, including the interface with the Procedure Builder.

First we note that the ontology that is actually implemented in the Tool Set (in Clips) does not correspond precisely with either the informal or formal versions of the Pre-Implementation EO. One important reason for this is that the terms in the latter are at a rather higher level of abstraction than was required for the implementation. Ideally, the gap could have been bridged keeping the original more or less intact, but this was only partially achieved. Also, some terms were introduced for describing aspects of the Task Manager which are not consistent with those used in the original EO. In the following discussion, we clarify important differences, to avoid confusion.

The Implemented EO consists of terms only; no definitions (natural language or formal axioms) are included. This is mainly because there is no required use for them at this time. It would be straightforward to include the definitions which could be used to browse and help ensure that the definitions were used correctly.

Conceptually, there are two main parts to the Implemented EO, corresponding to two main sets of terms. One part is called the *capability* ontology, the other, the *knowledge space* ontology. Note that our use of the word 'ontology', here is very loose. Normally, a taxonomy of terms only without any definitions is not called an ontology. However, we do this because we anticipated that the definitions would later be incorporated, and the terms are meant to correspond to those in the Pre-Implementation EO.

Capability Ontology The Capability ontology is a taxonomy of terms referring to kinds of activities or tasks that can be performed by agents. See appendix D for the complete taxomony of capability terms currently implemented. All are verbs; e.g. 'calculate', 'visualise'. The capability ontology is used for registering what agents can do and recording what capabilities are required for a procedure to be executed. If an agent can do the appropriate thing, it is said to have the 'capability'. This is how the procedures exported from the Procedure Builder are linked to the Task Manager. Agents are selected to execute a procedure only if they have the required capabilities.

In order for inter-operation to be possible among agentified tools, it is necessary to use the terms from the capability ontology during both agent registration and the capture of process models that have required capabilities. If the terms do not match, then no agents will be found to carry out the required procedures.

The terms of the capability ontology are organised into a hierarchy for convenience during agent registration and process modelling. For example, specifying "calculate" as a capability for a calculator is easier than specifying all the individual calculations it can do.

This use of the term 'capability' adopts a slightly different perspective than that used in the Pre-Implementation EO, and thus is not interchangeable. In the latter, a capability was captured as a relationship between an ACTOR and an ACTIVITY SPECIFICATION denoting that the ACTOR is capable of performing the ACTIVITIES as specified. In the Tool Set, a 'capability' is referred to by a verb term and though it corresponds to a kind of ACTIVITY, it is not specifically tied to an agent. Registering an agent in the Tool Set as able to perform a capability (in the capability ontology) captures the same thing as the *Have-Capability* relationship in the Pre-Implementation EO. The difference is that the thing to be done is referred to as a 'capability' in the implementation, and it is referred to as an ACTIVITY SPECIFICATION in the Pre-Implementation EO.

Knowledge Space Ontology The other main part of the Implemented EO includes all other concepts relevant to an enterprise; this is referred to as the *Knowledge Space* ontology (see Appendix E for details). These include things that are required for the tasks to be carried out including, for example, inputs, outputs and resources used. The knowledge space ontology contains many terms taken directly from the Pre-Implementation EO, and as such it has been directly incorporated – however as noted above, only the terms are used, not the definitions.

Terms in the knowledge space are part of capability specifications for agents and tasks as well as for specifying inputs and outputs. These take the following forms:

- Agent A has Capability C with respect to Knowledge Space things: KS_1, KS_2
  E.g. If C is *modify*, and KS_1 is*document*, this specifies that agent A can modify a document.
- Task T requires an Agent to have Capability C with respect to Knowledge Space things: KS_1, KS_2
- Task T requires Knowledge Space things: KS_{12}, KS_{23}, and KS_{42}
- Task T produces Knowledge Space things: KS_8 and KS_{21}

As with the capability terms, it is essential that the correct Knowledge Space terms are used in order that tools are properly integrated and the tasks are performed properly.

Assisting Communication In addition to the above-described uses of the terms in the implemented EO that are strictly enforced for the Tool Set to function, there is also a more passive use which is to facilitate human communication.

During the process of modelling an organisation, and its processes, it is wise to use good discipline in using terms consistently so others understand what is said. Among different groups, there may be inconsistent usage, which can cause problems of misunderstanding. This may be avoided by appealing to the appropriate term in the Enterprise Ontology.

9.3.2 Translation

Another use of the ontology that has been considered in some detail is translation, both between different ontologies (e.g. corresponding to different tools) and between different agent communication languages. The Enterprise Tool Set was designed to incorporate such translators, which could provide more flexibility for agent communication and would reduce the demands made of the agent programmers.

For instance, the current capability ontology uses the term 'calculate' but another tool may be independently agentified which might use the term 'compute'. A translator could convert these terms back and forth, saving agent programming effort. The same applies for terms in the knowledge space.

Further details and examples are found in the section on the evaluation of the Agent ToolKit.

9.3.3 Summary

In summary, the actual uses for the Enterprise Ontology (with respect to the Task Manager and Agents) were different from those originally conceived. The key uses are:

- as a vehicle for achieving tool inter-operation through a common terminology used for specifying tasks, capabilities and agents;
- as a way to enhance communication between humans by using terms in a consistent way.

The main areas where further work is required are:

- only terms are used, not full definitions; this could be improved by incorporating text definitions for convenience of human users. Automatic interpretation and use of formal definitions is more difficult.
- there is no translation;
- There was not a well developed method for using the Ontology. Thus, how and whether the Enterprise ontology got used depended largely on the experiences and talents of the people assigned to the task.

9.4 Applications

In this section, we consider how the Enterprise Ontology was used in the end user applications. There were four in total. One is the public demonstrator, and is concerned with assisting the process of analysing relevant information and deciding whether to bid for a contract. The others contain commercially sensitive information and are discussed in less detail.

9.4.1 Pilkington Optronics: Bid Analysis

This demonstrator is concerned with the process of deciding whether or not to bid on a contract. A major part of this is information acquisition and analysis leading up to a final decision. It was carried out in conjunction with Pilkington Optronics (P.O.) who recognised that technologies such as the Enterprise Tool Set are a means of adding real value to their organisation.

A key role of the application is to provide a structured way to perform the bid analysis process in a consistent accurate manner. The user is in control of the analysis, directing the course of events, interpreting the data and deciding what to do next. Important goals of this demonstrator include:

1. Effective co-ordination of Bid analysis process between parties involved;
2. Mechanisms in place for accurately and efficiently updating, improving and extending aspects of the Bid analysis process. This includes:
   - changes to the process itself;
   - changes to the IT tools that support the existing process.

Nature and Role of the Ontology

To achieve these goals, it is necessary that all parties have a thorough understanding of concepts, tasks and issues related to the Bid analysis process. Ideally, all information, knowledge and assumptions will be explicitly documented. To avoid multiple ambiguous usage of jargon terms and consequent talking across purposes, there must be a *shared understanding* using consistent agreed terminology.

An extension of the Enterprise Ontology was built specific to the Bid analysis application. For example, we defined BID to be "a kind of SALE OFFER", where the latter is a term from the EO. This reuse of an Enterprise Ontology term saves time, avoiding need to come up with a definition from scratch. Also, because SALE OFFER has already be defined with great care, the meaning of BID is made much more clear and less likely to be misunderstood. To define BID in another way, would mask a clear relationship between the meaning of two terms.

This reduced ambiguity increases potential for reuse in the future. However, in the short term this can result in the definitions given in the extension not being expressed in the most natural or obvious manner for someone interested *only* in the Bid Analysis decision process. To alleviate this problem, one must consult the original terms and definitions in the EO in order to best understand the extension.

How does the Ontology help?

Below are some of the intended uses of the Enterprise Ontology for this application.

Inter-group communication By using terms in the agreed ontology, when different groups talk to each other, communication is likely to be more accurate and take place with less effort. Within a group, the local jargon may still be used.

Inter-group cooperation Agreeing to use the same terms enables different groups to independently produce inputs to the Bid analysis process and still other groups to assess all the available information, whatever its source.

Cooperation is also facilitated if the tasks in the Bid analysis process itself are carefully defined and mutually understood.

Consistency By providing a framework for performing the bid analysis process, greater consistency is achieved.

Inter-Operability The ontology maybe used as an interchange format to enable tools to inter-operate.

IT Support The ontology can be embedded into an IT tool which guides the user through the bid analysis process. Tasks are identified, information is requested, and at any point, the user may see the definitions of the terms and concepts involved. This helps ensure that the correct information is entered into the analysis process.

Our Experiences

This system is a demonstrator. Participants from P.O. consider that a major advantage of the Tool Set was the fact that the system supported and encouraged consistent usage of terms. Also, structuring the actual steps of the analysis process proved useful.

The actual use of the Pre-Implementation EO in this application was minimal. Even the trivial step of introducing BID as a type of SALE OFFER to link with the Pre-Implementation EO was not taken. Why? Mainly because there was no immediate advantage in doing so. 'Sale offer' is not a term used or needed by Pilkington Optronics people doing bid analysis. They know what a bid is, it really does not help to say it is also a specific kind of sale offer, especially given the fact that there are no definitions included in the Tool Set, only terms.

One potential future advantage of linking with the original EO is noted above: on line documentation. Another is the possibility of inter-operation using translators. This would necessitate more careful and consistent use of terms.

The task models built to structure the bid analysis process proved very helpful. A number of the capabilities of steps in the overall process are in the capabilities ontology (e.g. visualise, report). The only knowledge space term used is 'bid', giving rise to tasks such as 'Analyse bid' and 'Report bid'.

9.4.2 Application: Market Analysis

The concepts of MARKET and MARKET SEGMENT, from the Enterprise Ontology formed the basis for the domain model (i.e. the domain-specific ontology) for this application. The model was used during requirements and design as a reference model against which the impact of changing requirements and technology could be evaluated.

One important benefit from using the Enterprise Ontology for this application was the savings achieved by not having to start from scratch to define the marketing concepts. Thus, the conceptual analysis underpinning the EO was re-used. The domain model developed for this application was used to facilitate achievement of a flexible design for the application and to enable the design choices to be well-motivated and auditable.

An important factor in the successful use of the EO in this application is the fact that the person doing the work is familiar with the use of enterprise modelling ontologies as a basis for implementing IT systems.

9.4.3 Application: Continuous Process Improvement

Lloyds Register's application demonstrates the execution of a continuous process improvement (CPI) procedure implemented using the Enterprise Tool Set.

The Enterprise Ontology was intended to support the communication of business performance feedback generated within the CPI framework. The communication problem being that feedback generated by different staff was difficult to interpret in order to be compared or grouped together for use in improvement decisions.

The use of the Enterprise Ontology to improve this communication was tested. People were told to conform to the terms in the EO when producing their feedback. There were mixed results. Many found the discipline useful; it forced them to think more carefully about what they were doing and what terms meant. Others questioned the utility of conforming or found it too difficult to do so.

A limitation to understanding the EO was the non-availability of diagrams or graphical browsing mechanisms to show the main concepts and how they are inter-related. A plain list of terms with an index does not clearly depict the general structure and details of the Enterprise Ontology.

Another issue was the gap between the very high level concepts in the EO and the much more specific concepts in CPI. Addressing the issue would have required producing a separate CPI sub-ontology, a time-consuming task.

Nevertheless, those who persevered and conformed to the EO, produced results of higher quality. The tradeoffs were: it took longer or less feedback was produced.

9.5 External Uses

The goal to have the Enterprise Ontology be of value to others 'as codified knowledge in the enterprise modelling domain' has been successful, in a number of ways.

There has been considerable interest in the EO, shown by the browsing at our web site; also, we received dozens of private email messages requesting information about the Ontology, or the lisp code to work with.

In addition, some members of the Enterprise Ontology development team also participated in the following projects:

- Process Interchange Format (PIF) [12]
- Work Flow Management Coalition (WfMC) [14]
- Object Management Working Group – Core Planning Representation [15]

These projects were primarily concerned with the activity-related concepts in the EO, but there were more general issues as well such as roles and states of affairs which were relevant. The conceptual analysis underpinning the EO was reused in both of these efforts. In some cases, decisions were made to do things just as they were done in the EO, in other cases, debates occurred and other decisions were made, for well-documented reasons. This makes comparisons easier. Where there are differences, an effort was made to ensure that the alternatives are compatible.

Although we are a long way from the existence of a single 'true' ontology in the domain of enterprise modelling, we are encouraged by the fruitful exchange of ideas and the movement towards cooperation and compatibility.

9.6 Summary and Evaluation

We have described many examples and perspectives of how the Enterprise Ontology was intended to be used. These may be summarised as follows:

- enhance human communication in organisations both inside and outside the project;
- serve as a basis for acquiring and representing enterprise models which in turn may be used:

  - to ensure agreement among members in an organisation
  - as a stable basis for specifying IT requirements

- to achieve integration of software tools, both
  - as part of agent communication language
  - as an interchange format
- to assist in developing the Tool Set itself, in a bootstrapping fashion

We consider these in turn.

9.6.1 Bootstrapping

We used the activity definitions in the Enterprise Ontology while developing EPML for the Procedure Builder. We successfully reused the conceptual analysis implicit in the EO, in that many concepts are represented in EPML, but they are adapted, sometimes with new terms, rather than being used directly. The main reasons for this was the fact that the EO took longer to build than we anticipated.

We also looked into using the Ontolingua translator to produce Clips code for EPML which could be directly inserted into the implementation of the Procedure Builder. This attempt was abandoned for two reasons. First, bugs in the Clips translator required manual editing. Second, the majority of the Clips code was excess baggage not required by the application.

9.6.2 Human Communication

Significant use of the Enterprise Ontology was made in facilitating human communication. As noted above, the EO terms and definitions were used to kick-start the development of EPML for the Procedure Builder.

More generally, having a consistent set of well defined terms that people could agree on meant that the Tool Set and the applications could be developed with less ambiguity. This was particularly true for the Lloyds Register and Pilkington Optronics applications. In the latter case the extension relating to Bid information was seen to be of more value than the Core EO.

The conceptual analysis underlying the Enterprise Ontology in general, and the set of terms and definitions in particular were also found to be useful input to the outside communities of enterprise and process modelling. This included projects such as PIF, OMWG-CPR, WfMC. We hope that the EO will continue to serve as a basis and inspiration for others developing ontologies and/or reusable class libraries in this domain.

9.6.3 Acquisition and Representation of Enterprise Models

The IBM application team used the Enterprise Ontology successfully as a starting point for acquiring their model and using it as a stable basis for flexible and robust design of their application.

Other applications were less successful. We have learned from this experience. The difficulties of reusing existing class libraries in object-oriented analysis, design and programming area well known, and are analogous to the issues of reusing terms in an ontology. It is not an easy task. For ease of implementation:

1. the user must thoroughly understand the particular ontology,

2. the ontology must be at the appropriate level of generality,
3. the user must be familiar with the basic idea of what an ontology is and how it may be used.

An issue relating to the first point was the non-availability of diagrams or graphical browsing mechanisms. The plain list of terms with an index provided by the Informal EO limited one's ability to see the overall structure, the main concepts and how they are inter-related. Using an html browser the Ontolingua code helped, but this did not directly address the issue of seeing the overall picture.

Another barrier to understanding an ontology occurs when the particular viewpoint taken and terms used differ significantly from what the user is familiar with.

On the second point, some of the users found that the Enterprise Ontology was at too abstract a level. Bridging the large gap between the EO and the concepts in the applications would have been a significant ontology building effort.

Attention is drawn to the final point. In the Enterprise Project consortium, IBM had significant experience. IBM's WSDDM (Worldwide Solution Design and Delivery Methods) includes a method called BSDM (Business System Development Method [8]). This method requires the use of an ontology as the starting point for Business Analysis and Requirements Definition. Thus IBM has a framework in place and a method to follow for using ontologies.

It is thus unsurprising that they had the greatest success in using the Ontology in their application. As it happened, the IBM application on market analysis was first worked on by someone not familiar with BSDM. There were problems with conflicting terminology, as well as an application design that was less adaptable to change.

On this same point, even with a framework and method in place, it is necessary for the user to really understand it. BSDM training is time-consuming. It is useful to again draw an analogy with object-oriented methods. There is often resistance until one finally 'sees the light', at which point the enlightened ones become enthusiastic.

9.6.4 Integration

We used two taxonomies of terms as part of the agreed language for agent communication. This was necessary to allow integration. The Pre-Implementation EO is essentially independent from the capability terms, and was the basis for many of the Knowledge Space ones used in the Tool Set implementation.

The use of the Enterprise Ontology as an interchange format to assist integration is not completed.

10 Conclusion

In this paper, we have given a comprehensive description of the Enterprise Ontology, a collection of terms and definitions relevant to business enterprises. We described the context and motivation for its development, detailing its intended purposes. We briefly summarised the process of identifying and defining about a hundred terms in natural language and presented them in glossary format. We then described our experiences in converting these definitions into the formal language: Ontolingua. Finally, we gave a detailed account of how we used the Enterprise Ontology, including an evaluation which compares the actual uses with original purposes.

We conclude by summarising what we have learned, recommending some future work, and acknowledging various other enterprise-related projects that influenced the development of the Enterprise Ontology.

Observations We make the following observations and recommendations:

- Ontologies take time to build well, project planning must take this into account;
- The Enterprise Ontology was successfully used as a basis for much work both within and outside the Project. The main use was at the conceptual level for humans, rather than at the programming/technology level (i.e. incorporated in the Tool Set implementation);

  We accept that there are large social barriers in getting people to agree to use any standard terminology if it is foreign to them. The approach we advocate is to allow local groups to use terminology as they see fit among themselves. The terms and definitions in the EO may be used to resolve ambiguity when it arises during communication between groups who use different terminology. The benefits of conforming to a standard have to be very clear before people will adopt new usage.
- Successful use of ontologies requires that the people who are required to use them clearly understand methods for applying them;
- Good presentation is essential for understanding a new ontology;
- Automatic translation technology may not be sufficiently well-developed to one's needs. If needed, experiments should be performed at an early stage to establish feasibility.
- The nature of this ontology was in part determined by our requirements. For example, because our emphasis was more on reducing ambiguity for humans, and less on automatic translation, we freely used axioms in our Ontolingua definitions. If this had been reversed, we would have had to severely restrict usage of axioms.

Distinguishing Features We believe that the Enterprise ontology is distinct from other efforts at developing ontologies for enterprise information in that:

- it covers a broader set of terms which are important to enterprises. Most others address limited areas;
- it exists in the form of a comprehensive, carefully prepared natural language glossary *and* in a formal language. Others must be gleaned from various scattered papers, or exist mainly in formal languages and are thus inaccessible to non-technical readers.

Future Work Here we note some areas of future work which may lead to a greater understanding the usage of the Enterprise Ontology and other ontologies.

- **Translation:** The Tool Set architecture was designed to handle translation using the EO as an interchange format. This needs to be completed.
- **Controlled Experiments:** It is the nature of an emerging field that many initial results are not fully explored. Controlled experiments which measure the benefits of various approaches and techniques would address this issue.

10.1 Relationship with existing efforts

An important goal has been to ensure that the Enterprise Ontology is compatible with existing ontologies. Thus, the development of the Ontology has taken account of other external ontology developments whenever possible. In the early stages, considerable use was made of Collin's Business dictionary to ensure consistency of usage of terms. The Activity ontology is broadly consistent with two major external ontologies: TOVE and KRSL. The Time and Meta-Ontology both have input from external activity. For other parts, (*e.g.* Market, Organisation), it has not yet been possible to do significant benchmarking against external activities.

The Enterprise Ontology has been developed largely from scratch; however it was inspired and influenced by many other projects and efforts, too numerous to mention. The main influences are listed below, together with references:

TOVE: TOronto Virtual Enterprise project, University of Toronto, especially the activity and resource components of the TOVE enterprise ontology. [7].

O-Plan: Planning and Scheduling group, AIAI, the plan representations used influenced the activity component of the Enterprise Ontology. [16, 17, 3];

ARPA/Rome Laboratory Planning and Scheduling Initiative: Knowledge Representation Specification Language (KRSL) [13] was consulted for the time component of the Enterprise Ontology. Also, the Plan Ontology influenced the development of the Activity section.

ORDIT: ORDIT [2] influence the Enterprise Ontology handling of concepts relating to rights, responsibilities and delegation.

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Formal EO Persons who provided useful comments and feedback on various versions of the Formal EO include: Florence Fillion, Nicola Guarino, Ian Harrison, Pat Hayes, Chris Menzel and Austin Tate. Also, and very importantly, the existence of the Ontolingua language (based on KIF) in general and the Ontology Editor in particular greatly facilitated the formalisation process. We extend thanks to James Rice in particular and the team at Knowledge Systems Lab (KSL) Services in general who were extremely helpful during this effort showing a high level of commitment to our being satisfied users. Details of KSL are available on the World-Wide Web at *http://www-ksl.stanford.edu/*.

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A Term Encodings

In this appendix, we indicate whether and how each term in the Specification of the Enterprise Ontology is formally represented in Ontolingua. This information is given in a series of tables, one for each major section of the Ontology. Within each table, terms are listed in alphabetical order. This is valid for version 0.1 of the code of the Enterprise Ontology, currently available for browsing on the World-Wide Web from:
http://www.aiai.ed.ac.uk/∼entprise/enterprise/ontology.html.

ACHIEVE	*not defined*; see Help-Achieve
ACTOR	Actor
ACTOR ROLE	*not defined*; see Actor, Role-Class, Qua-Entity
ATTRIBUTE	*not defined*; meaning as: Function@Kif-Relations
ENTITY	*not defined*; equivalent in meaning to union of Set@Frame-Ontology and Thing@Frame-Ontology most similar defined term: EO-Entity
POTENTIAL ACTOR	Potential-Actor
RELATIONSHIP	*not defined*; equivalent in meaning to Relation@Frame-Ontology (excluding unary relations)
STATE OF AFFAIRS	State-Of-Affairs
ROLE	*not defined* implicit in the semantics of an argument in a Relation see Role-Class; Qua-Entity
TIME POINT	Time-Point
TIME INTERVAL	Time-Range
TIME LINE	*not defined*

This table indicates for each term in the Specification, which term or terms most closely correspond to it in the formal code.

Figure 6: Meta-Ontology and Time

N.B. the time terms were not defined by the Enterprise Project team, but were imported from the KSL Library of Ontologies.

ACTIVITY	Activity
ACTIVITY OWNER	Activity-Owner
ACTIVITY SPECIFICATION	Activity-Spec
AUTHORITY	Hold-Authority
CAPABILITY	Have-Capability
DOER	Actual-Doer; see also Specified-Doer
EFFECT	Effect; see also Planning-Constraint
EVENT	Event
EXECUTE	Specified-To-Execute; see also Actually-Execute
EXECUTED ACTIVITY SPECIFICATION	Execution-Of-Activity-Spec
PLAN	Plan
PLANNING	Planning
PRE-CONDITION	Pre-Condition; see also Planning-Constraint
PROCESS SPECIFICATION	Process-Spec
RESOURCE	Resource; see also Can-Use-Resource
RESOURCE ALLOCATION	Resource-Allocation
RESOURCE SUBSTITUTE	Resource-Substitute
SKILL	Have-Skill
SUB-ACTIVITY	Sub-Activity; see also Sub-Activity-Spec
SUB-PLAN	Sub-Plan; see also Sub-Plan-Of
T-BEGIN	T-Begin
T-END	T-End

This table indicates for each term in the Specification, which term or terms most closely correspond to it in the formal code.

Figure 7: Activities and Processes

ASSET	Asset
CORPORATION	Corporation
DELEGATE	Delegate
EMPLOYMENT CONTRACT	Employment-Contract
LEGAL ENTITY	Legal-Entity
LEGAL OWNERSHIP	Legal-Ownership
MACHINE	Machine
MANAGE	Manage
MANAGEMENT LINK	*not defined*; see Manages
NON-LEGAL OWNERSHIP	Non-Legal-Ownership
ORGANISATIONAL UNIT	Organisational-Unit
OWNER	Owner
OWNERSHIP	Ownership
PARTNER	Partner; see also Partner-Of
PARTNERSHIP	Partnership
PERSON	Person
SHARE	Share
SHAREHOLDER	Shareholder; see also Shareholder-Of, Shareholding
STAKEHOLDER	Stakeholder; see also Holds-Stake-In

This table indicates for each term in the Specification, which term or terms most closely correspond to it in the formal code.

Figure 8: Organisation

ASSUMPTION	Assumption; see also Assumed
CRITICAL ASSUMPTION	Critical-Assumption
CRITICAL INFLUENCE FACTOR	Critical-Influence-Factor
CRITICAL SUCCESS FACTOR	Critical-Success-Factor
DECISION	Decision
GOAL	Goal
HELP ACHIEVE	Help-Achieve
HOLD PURPOSE	Hold-Purpose
INFLUENCE FACTOR	Influence-Factor
INTENDED PURPOSE	Intended-Purpose
MISSION	Mission
NON-CRITICAL ASSUMPTION	Non-Critical-Assumption
NON-CRITICAL INFLUENCE FACTOR	Non-Critical-Influence-Factor
OBJECTIVE	Objective
PURPOSE	Purpose
PURPOSE-HOLDER	Purpose-Holder
RISK	*not defined*; see Perceived-Risk
STRATEGIC ACTION	Strategic-Action
STRATEGIC PLANNING	Strategic-Planning
STRATEGIC PURPOSE	Strategic-Purpose
STRATEGY	Strategy
VISION	Vision

This table indicates for each term in the Specification, which term or terms most closely correspond to it in the formal code.

Figure 9: Strategy

ACTUAL CUSTOMER	Actual-Customer
ASKING PRICE	Asking-Price
BRAND	Brand
COMPETITOR	Competitor
CUSTOMER	Customer
FEATURE	Feature
FOR SALE	For-Sale
IMAGE	Image
MARKET	Market
MARKET NEED	Market-Need
MARKET RESEARCH	Market-Research
MARKET SEGMENT	Market-Segment
NEED	Need
POTENTIAL CUSTOMER	Potential-Customer
POTENTIAL SALE	Potential-Sale
PRODUCT	Product
PROMOTION	Promotion
RESELLER	Reseller
SALE	Sale
SALE OFFER	Sale-Offer
SALE PRICE	Sale-Price
SEGMENTATION VARIABLE	Segmentation-Variable
VENDOR	Vendor

This table indicates for each term in the Specification, which term or terms most closely correspond to it in the formal code.

Figure 10: Marketing

B Role Class

This is Ontolingua code; note that it includes html for display formatting purposes.

```
;;; Role-Class

(define-frame Role-Class
  :own-slots
  ((Documentation "Role-Class is a meta-class.  Its
instances are classes for which membership is based
on what roles an Entity plays in one or more relations.
The simplest kind of Role-Class is defined to be the
set of all Entities playing a single role in one
Relation (e.g. Resource).

<p> To the extent that updates may occur which change
the particular set of tuples comprising a relation,
being an instance of such a class is dynamically determined.")
  (Subclass-Of Class))
  :axioms
  (=>  (Exists (?r ?n)
 (and (relation ?r)
      (natural ?n)
      (forall (?z)
                (<=> (instance-of ?z ?rc)
     (exists (?args)
     (and (list ?args)
  (holds ?r ?args)
  (= (nth ?args ?n) ?z)))))))
       (Role-Class ?rc)
       )
  :issues
  ("The axiom defines the simplest kind of Role-Class.
Other cases are possible. For example,  Purpose is defined
as the union of two simple Role-Class s.  A Role-Class
might also be defined as the union of a Role-Class and a
non Role-Class"
   "?: Why not have Role-Class a super-class of various
Role-Classes such as Purpose and Resource?

<p> I can think of no good reasons for it to be one way or
the other, thus choice was mainly arbitrary.  The other way
would entail use of a different name for the superclass so
as to suggest the right meaning (e.g. Role-Player, or
Role-Playing-Entity)."
   ) )

;;; Qua-Entity

(define-frame Qua-Entity
  :own-slots
  ((Documentation
    "An EO-Entity that is defined in terms of the role it
     plays in one or  more Relationships.
<UL>
<li> Qua-Entity is the most general Role-Class
<LI> Every instance of Role-Class is a subclass of Qua-Entity.
</UL>")
```

```
   (Instance-Of Role-Class) (SubClass-Of EO-Entity))
   :axioms
   (<=> (Qua-Entity ?x)
        (Exists (?rc)
                (and (Instance-Of ?rc Role-Class)
                     (Instance-Of ?x ?rc))))
   :issues
   ("This is an abstract class provided mainly for convenience,
     so it is easy to see what all the Role-Classes are."
    "It is up to Ontology developers, users and maintainers to
     make sure each Role-Class is declared to be a subclass of
     Qua-Entity or of Actor, which is itself a subclass of Qua-Entity."
   ) )
```

Example: Resource

```
;;; Can-Use-Resource

(define-relation Can-Use-Resource
  (?activity-or-spec ?resource)
  "a Relationship between an Activity or Activity-Spec
   and an Entity whereby the Entity is or can be used
   or consumed during the performance of the Activity
   or the Activities as specified in the Activity-Spec"
  :def
  (and (Eo-Entity ?resource)
       (Activity-Or-Spec ?activity-or-spec))
  :issues
  ("a Resource may have a quantifiable measure denoting
    how much is available for use (e.g. amount of fuel)"
   "If the Resource is used but not consumed by an Activity,
    the quantity available will decrease at T-Begin and
    return to the original level at T-End."
   "If the Resource is consumed, the quantity available will
    be less at T-End than at T-Begin."
   "a Resource may be shared by more than one ACTIVITY"
   "An Entity produced by an Activity may be viewed as a
    Resource in that *other* Activities may use/consume it;
    however such outputs are not Resources with respect to the
    producing Activity."
   ))

;;; Resource

(define-frame Resource
    :own-slots
    ((Documentation
      "The Entity that is used or consumed in the
       Can-Use-Resource relationship")
     (Instance-Of Class) (Subclass-Of Qua-Entity))
    :axioms
    ((<=> (Resource ?resource)
  (exists (?activity-or-spec)
  (Can-Use-Resource ?activity-or-spec ?resource))))
    :issues
    ("See notes under Can-Use-Resource"
     "This is a special Role-Class."))
```

C Set Classes

```
;;; Set-Class

(define-frame Set-Class
  :own-slots
  ((Documentation "Set-Class is a meta-Class.  Its instances are special
kinds of classes,  all of whose instances
are themselves sets (not Classes) such that every member of such a set
is specified to be a member of a certain Class.")
   (Subclass-Of Class))
  :axioms
  (<=>
   (Set-Class ?set-of-things)
   (Exists (?thing)
   (and (Class ?thing)
(forall (?things)
(<=> (instance-of ?things ?set-of-things)
     (and (set ?things)
  (forall (?x)
  (=> (member ?x ?things)
      (instance-of ?x ?thing)))))))))

  :issues
  ("The Class which forms the basis for what sets are instances of the
    Set-Class is called the ‘base class’."
   "The denotation of a Set-Class is the power set of the denotation of its
    base class."
   "In a higher order logic, the set classes may be formed by
a type constructor function, which take as input the base class and returns
the corresponding set class. <p>
Here, we use a naming convention to indicate this; the names of
all set classes are prefixed with the text ‘Set-of’, as in Set-of-Customers"
  (:Example   "<pre>
(<=>   (Set-of-Customers ?customers)
       (and (set ?customers)
    (forall (?x)
    (=> (member ?x ?customers)
(instance-of ?x Customer)))))
</pre>")) )

;;; EO-Set

 (define-frame EO-Set
   :own-slots
   ((Documentation
    "The most general Set-Class in the Enterprise Ontology.
Every instance of Set-Class is a subclass of EO-Set.")
   (Instance-Of Set-Class) (SubClass-Of EO-Entity Set))
   :axioms
   (<=> (EO-Set ?x)
        (Exists (?sc)
                (and (Instance-Of ?sc Set-Class)
                     (Instance-Of ?x ?sc))))
   :issues
```

```
   ("This is an abstract class provided mainly for convenience, so it is
easy to see what all the Set-Classes are."
    "It is up to Ontology developers, users and maintainers to make
sure each instance of Set-Class is declared to be a subclass of EO-Set."))



;;; Set-of-Products

(define-class Set-of-Products
  (?products)
  "A Set-Class all of whose instances are sets whose members are all of
Class Product."
  :iff-def
  (and (EO-Set ?products)  ;;;  i.e. Set-of-Products is a subclass of EO-Set
       (and (Set ?products)
    (forall (?x)
    (=> (Member ?x ?products)
(Instance-Of ?x Product)))))
  :issues
  ("This is a special Set-Class") )
```

Note that *EO-Set* is the most general instance of the meta-class *Set-Class*. All sub-classes of EO-Set are thus, also instances of this meta-class.

D Capabilities Ontology

This is the taxonomy of capability terms from an early version of the implementation. As noted in the main text, these terms and the word 'capability' are essentially independent from the terms in the Pre-Implementation EO.

One way a connection could be made, is to viewing each of these capability terms as kinds of ACTIVITY SPECIFICATIONS (*e.g.* sub-classes).

```
Capability Ontology
  Storage Capability
    store
      store structural
        store relational
        store hierarchical
      store flat
    access
      retrieve
      control / access
      search
    update
      delete
      truth maintenance
      restore
      edit
      control version
  Processing Capability
    compute
    select
    compare
    match
```

```
    reason
    modify
    create / build
      draw
      write
      annotate
      connect / relate information
      layout text / tree / graph
    calculate factorial
    random generate
    identify
    analyse
  Transformation Capability
    merge
    decompose
    transform
      translate
      filter
  Communication Capability
    relate / connect
    accept
    notify / inform
    import & export
    read & write
    translate
  Visualisation Capability
    present
    display / visualise
      colour
      smoothen
      plot / graph / chart
      diagramming
```

E Knowledge Space Ontology

This is the taxonomy of knowledge space terms from an early version of the implementation. Many of the terms are taken directly from the Informal EO, some new terms are included which were needed in the applications. Some terms from the Enterprise Ontology are not included, as they were not used in the applications.

```
Knowledge Space Ontology
  Legal Entity
    Corporation
    Shareholder
    Vendor
    Partnership
    Person
      Partner
  Document
    Report
      Technical report
    Share certificate
    Specification
  String
  Symbol
  Number
    Complex number
```

```
    Negative number
    Positive number
    Real number
      Rational number
        Integer
          Even integer
          Natural
          Non negative integer
          Odd integer
          Zero
    Product Number
  List
    Double
    Null
    Single
    Triple
  Time
    Day name
    Month name
    Time point
      Calendar date
      Calendar year
    Time range
  Market
    Market segment
  Product
  Profile
    Resource Profile
  Skill
  Bid
  problem
```

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