16th ICCRTS

"Collective C2 in Multinational Civil-Military Operations"

Information design for synchronization and co-ordination of modern, complex, multi-national operations

Topic(s):

Primary: (4): Information and Knowledge Exploitation
Secondary: (5): Collaboration, Shared Awareness, and Decision Making
(9): Networks and Networking

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Abstract

Information is generally understood as 'data plus context'. Alternative explanations for 'context' include meaning (via language), conditions and attributes (meta-data), cognitive states, and representations of situation and purpose.

Organizations conducting modern, complex, multi-national operations, with both military and non-military involvement, need to manage contexts in ways which are efficient, supportive of federation, and agile. This paper builds on earlier ideas, notably those of Fitchett, McConnell and Sowray (at 11th ICCRTS) who emphasise that information needs to be *designed*, not merely found or catalogued, to achieve synchronizations and co-ordinations in support of network-enabled behaviours. The aim is *safe use*, a prescription for "right information, right people, right time" which guards against both misinterpretation (failures in context management) and mis-recognition (not appreciating, or not disseminating, pertinent information).

This paper explores ways in which Fitchett et al's *information schemata* can be implemented and supported through non-Equipment Lines of Development, and in particular the world of organization and work. It considers how Design-time, Assemble-time and Run-Time (DART) contributions impact differentially on efficiency and agility. It shows how extant principles of military organization can be interpreted as a highly-adapted contribution to information management and exploitation (IM/IX), and hence should not be subverted by approaches which threaten 'death by meta-data'.

Introduction

Information is generally understood as 'data plus context'. The context (in which information is generated, or in which it is used) is about the situation (to which the information refers) and the standpoint (including the repertoire of potential actions) which the generator or consumer adopts.

The aim for a context management scheme (equivalently, the aim for effective information management and exploitation (IM/IX)) should be the *safe use* of information, a prescription for "right information, right people, right time" which guards against misinterpretation (failures in context management) and mis-recognition (not appreciating, or not disseminating, pertinent information). Loss of context is a threat to the integrity of the enterprise.

The issues which this paper discusses are:

- the nature and content of 'context';
- whether this can all be encoded into machine-representable form (and at what cost, in particular in terms of the flexibility and agility which might have to be traded away):
  - through a formal language or information model;
  - through a set of conditions and attributes encodable as meta-data; or
  - through a set of complementary artefacts (representing goals, methods, processes, structures, roles);
- alternatively, whether context (and its manipulation) will always have to be completed by reference to artefacts or processes which are external to the computer system and for which no adequate encoding is possible (such as cognitive states, organizational behaviours and culture).

The approach adopted in this paper

This paper seeks to bring together three different strands of thinking about information in order to build a rich account of *information in transit*, that is to say information being 'shared' or 'exchanged' by enterprise participants whose roles and/or viewpoints are not identical. The three strands (shown iconically in Figure 1) are:

- the diverse appreciations of information offered in the broader literature;
- approaches to IM/IX, including federated approaches which differentiate between uses of information within, and between, communities;
- an approach to 'safe use' through the design of information schemata in which context is formally defined.

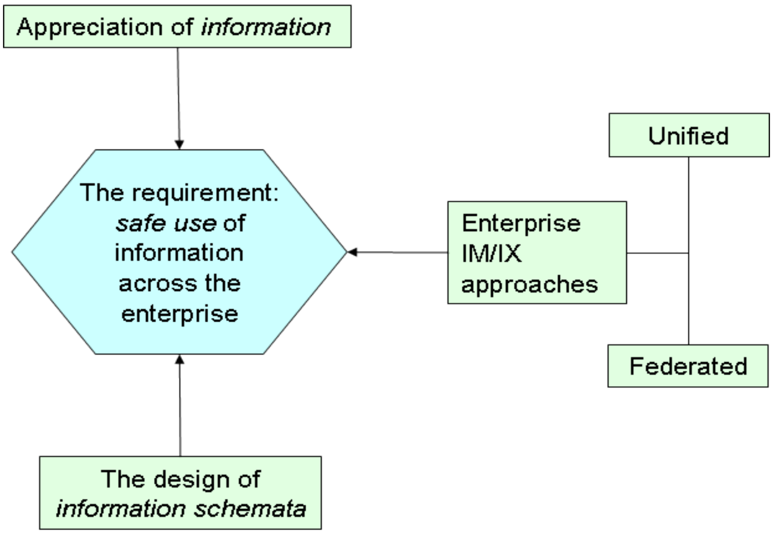
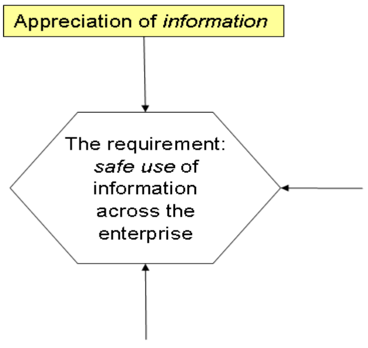


Figure 1: Scheme of paper, shown as three strands being synthesised into a concept of 'safe use' of information[1]

The resulting account of information in transit suggests that:

- solutions which seek to rely on everything being encoded into machine-representable form (e.g. as meta-data) cannot cope with organizational complexity; and
- a competent model of informatics must necessarily encompass a model of the organization.

What do we mean by information?



An extensive review [1] of different appreciations of information in the literature [2-10] reveals a diversity of definitions, and also some common features.

Notably, definitions of information usually take the form of an association between symbolic data (such as could be held or conveyed within a computer network) and something external to the physical network. This 'external' target of the association can reside in a number of different domains (physical, social, cognitive, virtual). No single extant set of definitions (of information and related terms, like data and knowledge) attempts to embrace all of these domains; each definition focusses on particular areas and aspects, according to its specific intended utility.

Despite this variety, we can say that there is a generic form (for a *well-formed definition* of information), from which extant definitions can be derived as specialisations. The generic definition declares that:

> *information* is an association between a *symbolic representation* and a *purposive element* towards which it can be flowed.

More specialised definitions, according to the particular analytic purpose, can then be generated by providing answers to the following questions:

- What do these symbolic representations refer to, and what form do the truth conditions on these representations take?

[1] Subsequent 'way-marking' icons will cite, selectively, the elements shown in this figure.

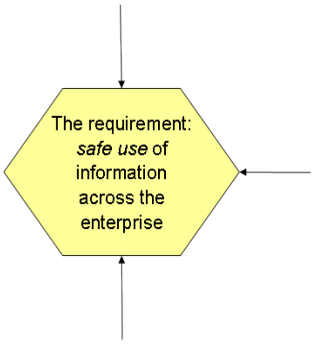
- Of what type is the purposive element, and when (in Design-time / Assemble-time / Run-Time (DART) terms) is the notion of 'purpose' assigned?
- What is the nature of the flow from the symbolic representation to the purposive element?

Purposivity, though an intrinsically human / organizational construct, can be invested in non-human elements (e.g. in equipment and machinery) at Design-time or Assembly-time, and then exercised by those elements at Run-Time. Hence it is acceptable to talk (as surely Shannon [10] would) about the information content of a stream of signals from a sensor to a state estimation system. Nevertheless we must resist saying that computers process information: what they process are data, and a (physical) state estimation system has no awareness of its own purpose. Purpose is something which the designers assign to the system and reflect in a model of the system.

The definitions of information and related terms from [1] are reviewed in Appendix A.

Two specific definitions of information will be developed later in this paper; both will correspond to this generic form.

Safe use



Fitchett, McConnell and Sowray [11] report that there is recurrent evidence from post-incident enquiries that failures in shared understanding are an important contributory factor to disastrous outcomes. They reiterate that development of shared understanding requires some degree of shared context, and that this is also a necessary feature for the achievement of synchronised effect.

They also point towards an idea of non-localised meaning in their assertion that:

- "The information domain offers a means to create a wider system of interest, a global context, for local decision making."

Their response to the challenge is a programme of information design, aimed at:

- "supporting a coherent and complete 'common understanding', and the best possible information available against which to test intent (supporting the interpretation of the command 'view')";
- a mechanism for producing synchronised effect;
- the design of information to support behaviour;
- a basis for *recognition* (the ability "to cluster real-world events that are causally unrelated");
- the grounding of meaning in "underlying patterns evident in information structures".

The paper of Fitchett et al [11] consists of a motivation (outlined above) and a programme (which we will consider later). At this stage, we build on their motivating statement to propose the enterprise objective of *safe use*. Safe use is a prescription for "right information, right people, right time" which guards against mis-interpretation (failures in context management) and mis-recognition (not appreciating, or not disseminating, pertinent information). Note the two-sided-ness of this prescription: we need to avoid both the wrong use of information and the failure to make the right use.

The following are examples of where significant context has to be provided in order to avoid one or both of these perils:

- <u>Missing information</u>. A database of blue force locations contains a number of entities in area X and no entities in area Y. But we cannot infer that there is no risk of fratricide from friendly fire in area Y without an appreciation of both the procedural conditions of blue force data collection (e.g. that the currency of the information is no better than 30 minutes latency with respect to reality) and the contingent conditions (e.g. that some friendly assets are currently not transmitting blue force locations, perhaps because of network problems).

- Sampling effects. It is hypothesised that recent developments will be reflected in a shift in adversarial tactics, for which a number of indicators can be set up (e.g. size and frequency of events of a certain type). A trawl of an event database shows up a distribution which is similar to that which might now be expected. However, we cannot interpret this as confirmatory without knowing how that events database has been created (e.g. whether there are collection biases in operation, either independently of or driven specifically by the original hypothesis).
- Information incest. Stripping out data duplicates does not necessarily mean that information incest has been prevented, if insufficient context comes back to strip out the real underlying duplication. Information may be reflected in quite diverse data representations and yet derive from a common military activity and/or group of events. An inability to identify the underlying correlations can lead to a misleading impression of frequencies and priorities.
- Procedural gaps. Information holdings can refer to one facet of reality but its structure might lead us to think it refers to another. For example, a medical records database may show a particular individual as a casualty currently receiving care from a Medical Unit, but that does not necessarily mean he or she is physically located at the Medical Post or Field Hospital which appears as the nominal location of that Medical Unit.

The current dominance of the 'pull' paradigm in IM/IX means that we commonly place the responsibility for safe use with the recipient of information and the responsibility for confidentiality with the producer. In fact, producers might also be said to have responsibility for ensuring that information which is potentially accessible is 'safe to be used', over and above the security classification of information products. However, addressing broader IM/IX objectives (e.g. ensuring that everyone gets the information which they might find useful) is an extraordinarily difficult responsibility to meet, unless either:

- there is an enterprise-wide agreement on an information model sufficiently rich to support all known uses of information; or
- producers of information have an exhaustive appreciation of the possible uses and abuses, by other stakeholders, of the information which they generate; or
- information is provided through contexts which support mutual appreciation of information capabilities and needs.

In general, safe use responsibilities apply in respect of both the generation and consumption of information. An information design programme cannot remove these responsibilities but should ensure that they are addressed in a disciplined fashion.

What could contribute to context?

Context is anything that relativises some information (so the only information for which explicit context need not be provided is that with universal, or enterprise-wide, meaning). Generally, the context required in particular cases may have components in respect of some, or all, of the following dimensions:

- Ontological (e.g. domain-specific ontologies)
- Organizational (e.g. functional communities)

- Ideologies[2]
- Unobtrusive controls[3]
  - assumptions and definitions that members of the organization take as given
  - agreed-upon system of power and authority
- Activities:
  - 'routine' activities[4]
  - standard operating procedures
- Stories[5]

- Standpoint (e.g. strategic, operational, tactical):
  - Shared definitions of the environment
  - Theories of action[6]:
    - associating interpretations of the environment with response actions
- Systems of interest:
  - Granularity of interest
  - Timescale of interest
  - Filters on environmental cues
  - Purpose (e.g. intervention type)
  - Security classification.

There is a connection here between context and the notion of a frame in the account of sensemaking offered by Weick [13]: essentially, frames are determined (i.e. populated) by context.

Barriers to safe use

There is a potential for 'loss of context' wherever producers and consumers of information are at different points along any of the dimensions discussed above, e.g.:

- members of different organizations (e.g. different functional communities);
- having different standpoints (e.g. strategic v. tactical).

Differences in context settings give rise to the notion of *informatic distance*, which is a measure of the separation between producer and consumer, taking all of the dimensions of context (above) into consideration.

Informatic distance is not a barrier to the exchange of purely factual[7] information, but it is a potential problem if there is a measure of *conditionality* associated with the information. This applies in the case of:

- hypotheses, proposals, provisional and contingent information – all of which is non-factual in nature; examples include:
  - Killing Areas, Target Areas of Interest, Named Areas of Interest and Decision Points, which are not factual or observable features but are a response to (and hence contingent on) a Commander's intentions;

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[2] Ideologies operate at the societal level.
[3] Unobtrusive controls are organizational frames, described by Perrow [12] as assumptions and definitions that members of the organization take as given. Unobtrusive controls "influence the premises people use when they diagnose situations and make decisions" (Weick [13]).
[4] The word 'routine' is used here to imply 'regular' rather than 'menial'.
[5] Stories are frames for describing sequences of interrelated events from experience
[6] Theories of Action (Argyris & Schön [14]) are organizational frames based on a stimulus-response paradigm: they associate interpretations of the environment with response actions.
[7] We take a *fact* to be unambiguous and not dependent (i.e. not contingent) on other information.

– intermediate calculations (e.g. processed meteorological data, neither purely observational but not (yet) suitable for non-specialists to support their own decision-making).

In general, conditional information is that which requires collateral information to guarantee correct interpretation. Safe use implies:

- provision of sufficient context for the detection of informatic distance; and
- the means to do something about the consequential impact on the interpretability of conditional information.

There is some connection here with the I-space model of Boisot [6], who notes that the ease or rate of diffusion of information across an organization is higher for codified and concrete information than for uncodified and abstract. In the terms used in this paper, the I-space model could be interpreted as saying that rich context is difficult to diffuse. One difference between the two frameworks is that Boisot does not distinguish between rates of diffusion along different axes within the organization. The 'complicated' model of CIBM [15] says that even uncodified and abstract information can flow efficiently within established communities of practice.[8]

A brief note on informatic distance

This term has been used in a number of different contexts, usually to refer to some kind of computation on a graph, string-encoding or network, e.g.:

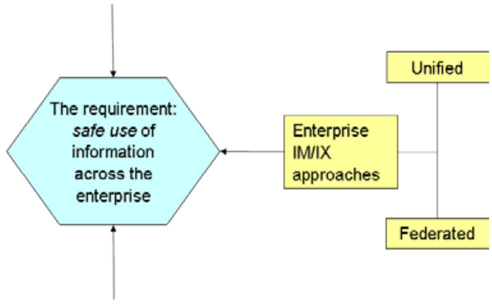
> "a concept of remoteness between pairs of sequences or strings of characters on the basis of their relative information content (relative entropy); starting from the evaluation of an informatic distance between pairs of sequences of characters, the methods leads to the following applications: 1) recognition of the context of a sequence; 2) construction of a hierarchical classification of a corpus of sequences (for instance constructing a tree-like structure; 3) construction of search engine based on the similarity relations among sequences." [16]

This points to the ontological component of our broader definition of informatic distance. The literature on ontologies naturally makes the assumption that everything in the domain of interest can and should be encoded into an ontology.

If that assumption were true, then our broader definition of informatic distance could be said to be double-counting. However, as we have said, this assumption is only one of two positions that can be taken. The 'informatic distance' term has been designed to operate under the opposing position in which it is neither practical nor desirable to encode the whole world into formal ontologies, and hence the additional dimensions shown here reflect aspects which may not (either fully or partially; and either necessarily or contingently) be compiled into purely ontological form.

An analogy might be a method for computing distances on a street map of a city. This is fine for urban navigation, but we also require a broader definition of distance which copes when there are no streets, e.g. when the respective points are in different cities, or even different continents.

A variety of enterprise IM/IX approaches



There exists a variety of options for enterprise IM/IX, exhibiting some quite different characteristics in terms of the following inter-linked themes:

[8] CIBM stands for Command, Inform and Battlespace Management. CIBM also denotes the research programme FTS2/RAOCCI/01, funded by the UK MOD, whose tasking has addressed topics including situational awareness, pictures, services acquisition for the CIBM enterprise and federated search & query capabilities.

- capacity to bridge informatic distance;
- the trade-offs between commonality and standards, and tailoring to the needs of different communities;
- the relative merits of 'early' (e.g. Design-time) and 'late' (Run-Time) definitions, with implications for flexibility, agility and usability; and
- Run-Time performance and loading (on both networks and human operators).

These can be broadly categorised into unified and federated informatic concepts[9]. Examples of unified informatic concepts are:

- Common information repository. Information items (of any form, including documents) are stored with associated meta-data tags.
- Common operational picture. This is an enterprise store of data items expressed in enterprise-wide language, e.g. common data model, with simple entity-level operations (e.g. create, read, update, delete) defined on it.
- Common operational database. This is an enterprise store of data items expressed in enterprise-wide language, e.g. common data model, with common business-specific (and complex) transactions defined upon them.
- Common message repository. Information content is preserved within defined formal messages, whose context of production and assimilation is pre-defined and understood across the enterprise.
- Public information services. Information content is delivered by defined information services, whose context of production and assimilation is pre-defined and understood across the enterprise.

These approaches are all what the CIBM Research [15] calls 'simplistic', the meaning of information being grounded in language (which is formal, universal and defined at design-time) as shown in Figure 2.

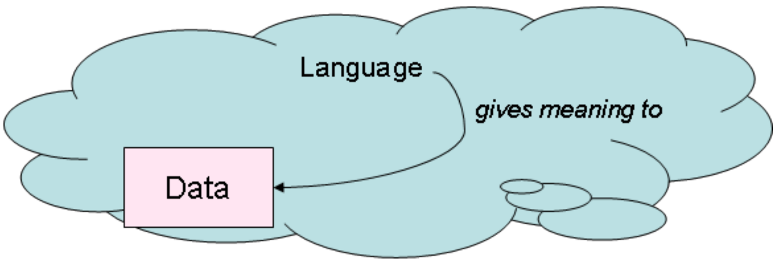


Figure 2: 'Simplistic' definition of information

The 'simplistic' model is appropriate for purely factual information, of which blue force location reports and reference information, e.g. geo-referenced data, might be prime examples. It can also cope with non-factual information provided that everyone in the enterprise understands what they are and how they should be used (i.e. 'public information'). The challenge (and the need for more context) comes when there is a need to appreciate, across the enterprise, how non-factual information has been handled, or will be interpreted, in particular organizational localities.

One approach to context management is an enterprise-wide ontology (c.f. the 'lingua franca' of Network Enabled Capability (NEC) [11], potentially to be reflected in meta-data schemata. This could be challenging. The greater the informatic distance encompassed within an organization, the greater the need for context. Moreover, organizations conducting modern, complex, multi-national operations, with both military and non-military

[9] Having said which, each of the 'unified' solutions could be employed in a way which is half-way to a federated or 'complicated' solution. For example, if messages in a common message repository, though recognisable and fully-defined at the enterprise level, are only effectively used within certain communities, or within specific channels between communities, then the common message repository supports a form of 'complicated' usage.

involvement, need to manage contexts in ways which are efficient, supportive of federation, and (critically) agile. Ontologies and standards for meta-data can be difficult to establish across multiple organizations and are far from agile (e.g. difficult to extend).

Alternative approaches include the use of some kind of federated scheme, in which information becomes to subject to local definitions in a partitioning of the enterprise. The partitions may be based on one or more of the contextual dimensions identified earlier, e.g.:

- functional communities;
- communities of purpose;
- participants in a particular event-response sequence (e.g. a kill chain).

This approach gives rise to a definition of information in which meaning is relative to a purposive element of the enterprise (Figure 3).

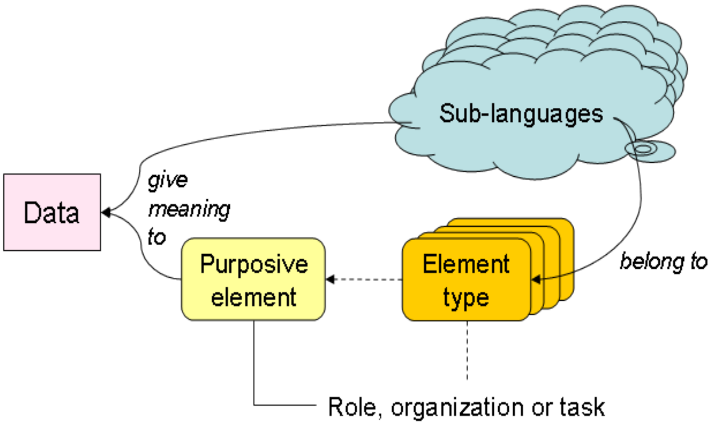


Figure 3: 'Complicated' definition of information

The sub-languages are particular to an element type and defined at design-time; purposive elements (i.e. role, organization or task) are instantiated at assemble time.

IM/IX across the enterprise works by:

- employing one set of mechanisms *within* the partitions (where informatic distance is not a significant problem), and
- using another set of mechanisms *between* the partitions.

Gaining access to data across the partitions becomes a matter of being judged fit to be admitted to organizational localities and to subscribe to the information available within them. Models for the operation of federated IM/IX options include the following:

- Virtual knowledge base. Information is held in multiple repositories; search and retrieve operations can operate (subject to some controls and differences in local context-encoding) across knowledge bases [17].
- Multiple repositories, with controlled flows of information between them. Information is held in multiple repositories which are specific to communities of users. Community information holdings are advertised in an information catalogue. Information is exchanged through controlled mechanisms (e.g. public information services) using pre-defined language intersections (including context descriptors, e.g. meta-data). There is support for controlled (but dynamic) affiliation to specific communities.
- Multiple chat sessions with managed attachments. Controlled (but dynamic) affiliation to specific chat communities. Information content can be archived, retrieved and searched from both session logs and a supporting document store. This is a hybrid approach which seeks to blend the virtues of chat informality with the merits of document management.

These concepts support IM/IX exploitation where it is not possible to create universal definitions of the meaning and correct usage of non-factual, or conditional, information. Instead, different communities operate according to their own procedures and culture, and information sharing is either by controlled affiliation to these communities or controlled[10] exchange of information subsets.

A practical approach: grounding IM/IX in the 'federated' organization

The UK's CIBM Research Programme Task 1 has developed a federated approach to Picture Management and Exploitation (PM/PX)[11] which is anchored in a model of organization. In this section we are focussing on the nature of this anchoring, and its implications for the definition of information.

There are two categories of federated models for the organization:

- there is a 'complicated' organizational model, which represents a 'baseline' model for today's military organizations [15];
- there is also a more provisional 'complex' organizational model, which is required to complete the account of the 'virtual organization' pursuing the Comprehensive Approach, or other forms of military / non-military engagement such as Civil / Military co-operation [18].

The 'baseline' or 'complicated' organization is founded on functional specialisms which are integrated through (pan-functional) communities and collaborations. This can be partially, but not wholly, supported by unified (or 'simplistic') PM/PX, which is still conceptually valid for 'factual' or 'unconditional' information; but something beyond this is required for coping with conditional information. This gives rise to the 'complicated' PM/PX concept, which is itself a federated approach to IM/IX, whose differences in relation to the 'simplistic' model can be characterised as follows:

- the 'simplistic' PM/PX concept is based on a metaphor of a 'sea of information' to which all have access;
- the 'complicated' PM/PX concept is built on a metaphor of a series of 'lakes' of information, connected by 'canals' with controllable locks and sluices.

The 'baseline' or 'complicated' organization also makes use of a 'quasi-complex' PM/PX, pertaining to a form of localised complexity and requiring human involvement to reach a negotiated meaning of information which may be specific to operational circumstances and the actors involved.

The federated (i.e. 'complicated' and 'quasi-complex') PM/PX concepts tell us primarily to attend to the organizational structure, and then to provide mechanisms for the controlled exchange and sharing of information. There are four aspects to this:

- conditional information becomes essentially subject to local definitions;
  - so encoding techniques (e.g. meta-data) can be used *within* the 'islands' formed by communities of practice;
- gaining access to data becomes a matter of being judged fit to be admitted to organizational localities, which in this model are communities of practice;
- sharing conditional information (between localities) requires that we address the contextual gap:
  - either we capture and codify large amounts of context, so that potential users can achieve proper interpretations of conditional information;
  - or we strive to define safe contexts at 'design time' by addressing the work and organization differences between would-be 'information sharers';

[10] I.e. the exercise of discrimination in terms of both content and distribution.
[11] The extension to a model of 'controlled IM/IX', broader in scope than PM/PX, is not a profound one.

- human judgement (duly supported by tools and mechanisms) is required for ensuring that data passed *between* 'islands' is 'safe for use';
  - this human judgement is exercised on the basis of knowledge acquired through 'quasi-complex' means.

Note the similarities with a requirement for human oversight of the passage of downgraded material between security domains (i.e. from 'High' to 'Low'), in order to satisfy Information Assurance (IA) requirements. In our 'controlled IM/IX/IA' model, security checks are just one particular type of control.

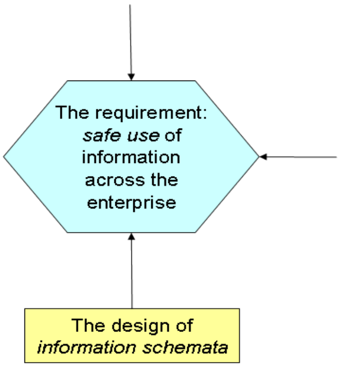
The 'complicated' CIBM definition of information, following Figure 3, is thus

- Data + purposive element, where the purposive element points us to
  - an actor or actor-group fulfilling a role, or
  - an organization characterised by its motivation or current direction.

So information has (in general) no intrinsic meaning, only a meaning borrowed (locally) from (the contingent form of) the organization. An immediate corollary is that information cannot (in this model) be copied. Exchange and sharing result in new information, which may be derived or inferred from the information offered but is not (by definition) the same information.

This is fine for the use of information local to a particular community of practice, and it also shows how another community might reason about information on the basis of 'where it has come from'. But we do not (at this point) have an account of *information in its own right, in transit*, through which we can explain in informatic (rather than organizational) terms how information is exploited and shared / exchanged around the enterprise.

Information design: the information entity and schema



The centre-piece of Fitchett et al's paper [11] is their proposal for the use of an information entity, which they describe as the 'gene pool' for information constructs, i.e. the basis for building 'complex information layer constructs':

- schema, which is described as "key to how the information layer can support … behaviour ... "; a schema represents "an enduring transform between the information space and physical space";
- context (which broadly corresponds with the account given in the present paper);
- alarm, a mechanism for the initiation of changes in attention within or between entities, usually being the precursor of action.

The information entity has the following elements:

- Intent, which is an internally generated information object derived as a result of external influences;
- Goal received (a specific and privileged external influence);
- Context supplied (which is global);
- Local context;
- Goal transmitted (through which other entities can be influenced);
- Name (own identity) and Certificate (recognition mechanism for authentication purposes).

The information design programme from which Fitchett et al's paper [11] is derived is ambitious, profound and not always easy (for the current author) to fully interpret. More importantly, there are a number of assumptions and implications which appear to place the paper into the 'unified' or 'simplistic' camp:

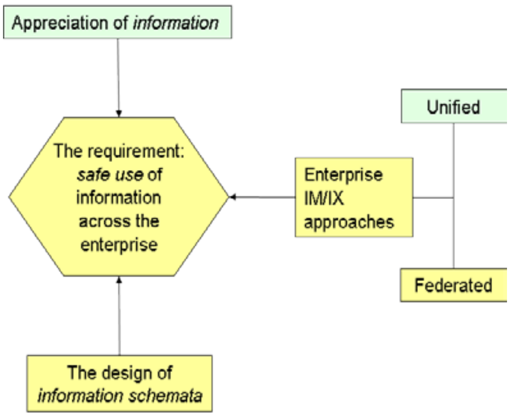
- the pursuit of a NEC 'lingua franca' to construct a context for relevant information;
- the determinism implied by:
  - a schema represents "an enduring transform between the information space and physical space";
  - the tight coupling between the information content and the action intended by an alarm.

On the other hand, the emphasis on a "trust relationship founded on a customer supplier contract/certificate" suggests that the *use* of information could be localised or limited, even if the language in which it is expressed is enterprise-wide (c.f. the earlier discussion of 'half-way complicated'). The determination, in this programme, to relate information to purpose and behaviour means that it remains an appealing starting point for an attempt to describe information in transit in the 'federated organization'.

Accordingly we seek to apply the general principles of the information entity, whilst abstracting from some of the details offered in [11] and related programme documents.

Synthesis: information in transit

At this point in the paper, we are now ready to bring all of the threads together to consider 'information in transit', i.e. information being 'shared' or 'exchanged' by enterprise participants whose roles and/or viewpoints are not identical.



In the 'federated' model, information cannot be copied. However, some form of 'signalling', through the exchange of data with context, is clearly possible.

A general model of exchange is reflected in Figure 4. In this figure, the form of the template at the top (with the label 'Information in transit') is loosely inspired by the information entity of [11].

The model can accommodate both 'push' and 'publish and subscribe' exchanges. Addressing to the intended recipients is achieved through the transmitted 'context of safe use': this might reference specific recipients, a class of recipients, or could be property-based (i.e. anyone who satisfies the stated conditions can receive it).

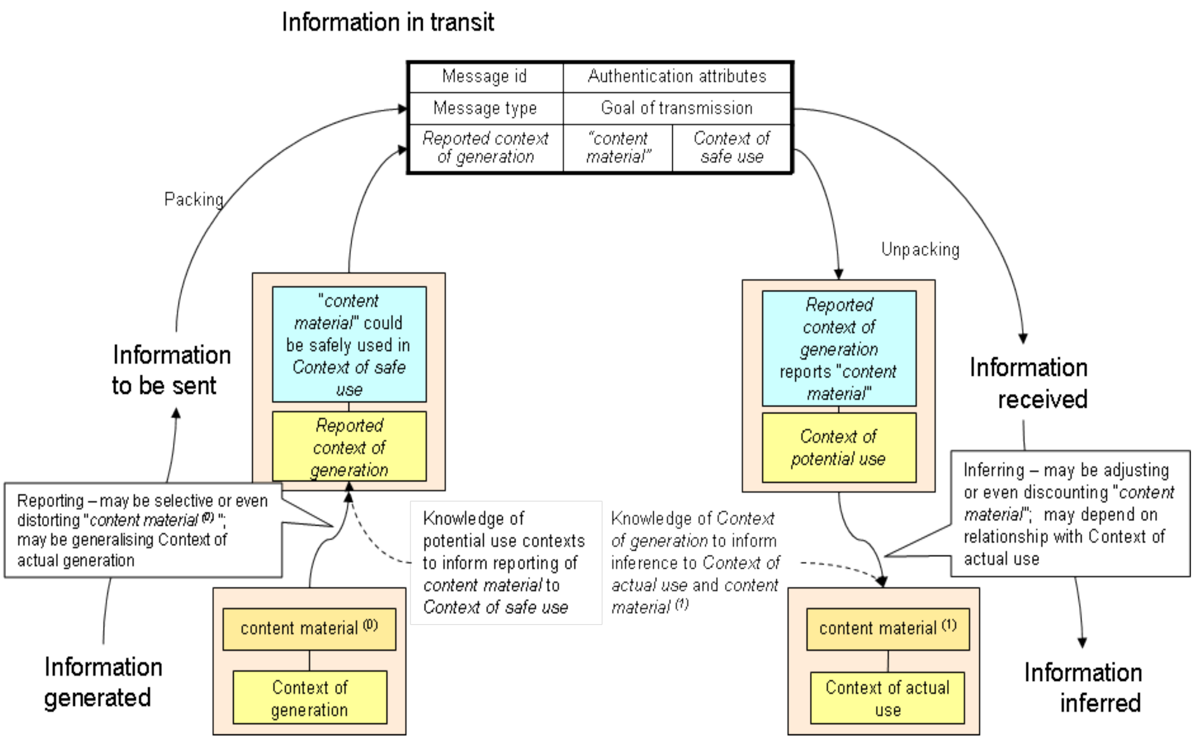


Figure 4: A general model of information exchange

Note that the original content material could be an observation report 'O', and yet:

- what is sent takes the form "X reports that 'O can be regarded as a usable observation' ";
- what is interpreted might be different again (i.e. O'≠ O), because of what the recipient already knows.

This model can now be specialised according to the relations which hold between the different contexts and the different parties' appreciation of context. These mechanisms can be crudely ranked on the following scale:

- simplistic – as pertaining to the 'unified' model of the enterprise;
- complicated – reflecting a structured model of functional divisions and pan-functional interactions;
- quasi-complex - pertaining to a form of localised complexity;
- complex.

This analysis is shown in Appendix B (Table 2), whose form is shown schematically in Figure 5. Clearly we would like to use the simplest mechanisms possible (e.g. the 'simplistic' column), but what drives us rightwards across Figure 5 are the following factors:

- informatic distance;
- conditionality of information;
- requirements for adaptability and agility to address operational dynamics (as opposed to familiarity and stability implied by unchanging procedures).

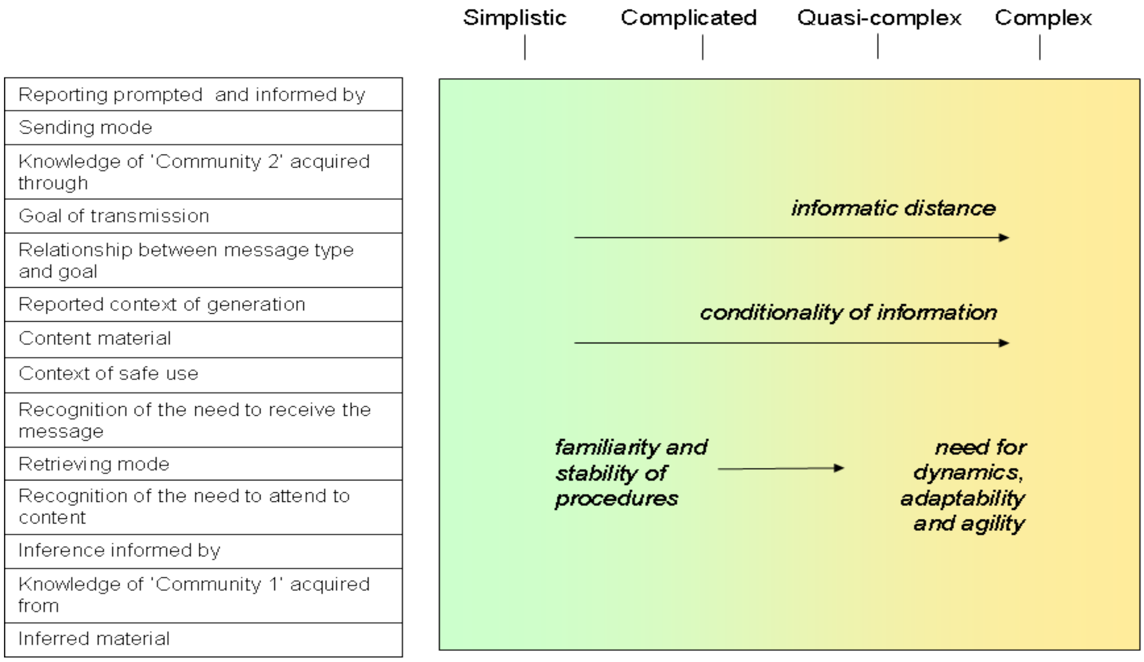


Figure 5: Analysis of mechanisms and their dependence on conditions

In moving from left to right, the interpretation of the information exchange becomes less mechanical and less deterministic. The entries in Table 2 towards the right are by no means exotica which can be ignored for most forms of enterprise communication. In fact all of the previous context-laden examples discussed earlier (missing information, sampling effects, information incest and procedural gaps) will require the mechanisms to be found in the 'quasi-complex'. The Liaison Officer in a conventional military organization operates in the 'quasi-complex': he is a conditioner and interpreter of information flows, not a post-box.

Even in the 'quasi-complex', any translations of information content are still pre-determined. This is not the case for the fully 'complex' organization: here information exchange requires learning and adaptation, and any translations of content are *not* pre-defined.

Reflections: why can't we resolve all this on to meta-data?

As we move across Figure 5 (and equivalently across Table 2 in Appendix B), there are increasingly entries which, for anything beyond the most static and proceduralised of organizations, point to the need for collateral information flows between 'Community 1' and 'Community 2'. Examples (from Table 2) include:

- reporting (i.e. selective information push) being prompted and informed by (prior or current) knowledge of a specific exploitation community and the usage they might make of this information, giving confidence that it will be correctly interpreted;
- inference (i.e. information interpretation) being informed by knowledge of the conditions of generation and reporting (e.g. "Why would we have been sent this?").

To be sure, the conveyance of this collateral contextual information might be achieved in part by further substantial *explicit* flows of information. But increasingly (in moving from left to right across Figure 5 and Table 2) there will remain a significant need for information whose codification is simply not possible (e.g. the basis on which the content material which is actually transmitted is determined, as a selective interpretation of the original informatic content whose generation has stimulated the exchange[12]).

This sort of appreciation may be grounded in training and previous experience, and will need to be maintained in the current operational situation through rich interaction facilities (such as voice and/or face-to-face communications). Generally, the need for 'information in transit' to be supported by organizational constructs[13], such as cross-affiliation (e.g. exchange of Liaison Officers) or live collaborations, increases along the organizational complexity axis in Figure 5 and Table 2.

The futility of pursuing 'wall-to-wall codification' is expressed in a particularly succinct manner by Dourish [19], from which the following quotations are taken directly:

> "Matthew Chalmers made the observation that computer science is based entirely on philosophy of the pre-1930s. Computer science in practice involves reducing high level behaviours to low level mechanical explanations formalising them through pure scientific rationalisation; in this computer science reveals its history as part of a positivist, reductionist tradition […..]. However [these earlier philosophical positions] have been under continual assault since the 1930s, when philosophers such as Martin Heidegger and Ludwig Wittgenstein began to articulate radically new positions of cognition, language and meaning. This new approach abandoned the idea of disembodied rationality and replaced it with a model of situated agents, at large in the world, and acting and interacting within it. Practical action and everyday experience replaced abstract reasoning and objective meaning as foundations of a philosophical psychology."

Dourish [19] adds the further explanatory message that philosophy has moved on but computer science has tended to stay with the earlier stated positions.

Implementation avenues for information schemata

As originally described by Fitchett et al [11], the information schema principle could most naturally be implemented through the 'unified' concept of a common message repository, in which messages, though recognisable and fully-defined at the enterprise level, are only effectively used within certain communities, or within specific channels between communities (i.e. a 'half-complicated' approach). None of the other unified approaches to enterprise IM/IX can be practically implemented without sacrificing the critical associations between information, purpose and behaviour which the information schema captures[14].

The account of information in transit which we have provided in this paper allows for the progressive introduction (in moving towards the 'quasi-complex' and 'complex' columns in Table 2) of richer modalities in the relationships between information content, goals of transmission and intended actions (e.g. the influences on what is inferred on receipt of information). This generality serves to increase the range of applicability of the schema approach, but its implementation requires correspondingly more thought and the exercise of human judgement.

The natural setting for the employment of this approach is now the federated concept of multiple repositories with controlled flows of information between them. Essentially the schema provides a template for specifying the form and/or safe use of what [15] describes as Import/Export Services. These could be implemented in a number of ways, but the

[12] In other words, how do we *report* what we observe? This is simple for 'commodity' information, but increasingly problematic for conditional information and 'complicated' or 'complex' organizations.

[13] Of course, storing a pointer to such an organizational construct (like a collaboration) as meta-data may be both useful and necessary; but it does not remove the need for the organizational construct in its own right, e.g. we still need the collaboration itself to actually take place!

[14] In principle, one could attempt to encode these associations into an enriched form of data model, but it would be a formidable undertaking and one which, in turn, would sacrifice flexibility and agility.

obvious approach is to use a messaging style: for this option, the schema is effectively describing the structure of the message, including its header fields.

It is unlikely that all of the information implied by the 'quasi-complex' and 'complex' columns in Table 2 could be encoded into the properties of, or information content conveyed by, these Import/Export Services. However, they could provide the basis for procedural checks to establish whether a proposed Import/Export Service represents a safe way to pass a particular type of information between particular communities in a particular operational context. And (as we noted before) the answer could be that it is only safe provided that there are some additional channels of communication between 'Community 1' and 'Community 2', such as cross-affiliations or live collaborations.

Conclusions: 'complex' information and work patterns

Instead of trying to reduce informatics to the formality of language and ontology, we can recognise the intrinsic participation of social and organizational components as highlighted towards the right-hand side of Figure 5 (and Table 2 in Appendix B), e.g. the presence of Liaison Officers and the reliance on context-maintaining collaborations which support rich interactions.

Clearly further work is needed before satisfactory answers can be given to questions such as "How deterministic is the resultant system?" and "On what basis could a formal safety case be constructed?" Nevertheless, this paper suggests that the most profitable route would be to pursue a science of informatics in which organizational structures and practices are recognised as providing a palette of informatic components. Choreographed practices (c.f. [20]) need to be characterised essentially as 'transfer functions' between information inputs and information outputs.

Thus the meaning of information becomes relativised not simply to the identity of the community which generates or uses it, but also to the work patterns which they are employing. As a simple illustration, the safe use of a document described as a draft, or a contingency plan, clearly requires a knowledge of the generator's documentation production process (e.g. how mature would this draft be?) or the approach being followed to planning (e.g. does this reflect a genuine expectation, or is it an exercise in 'testing the limits'?).

Thus the 'complex' definition of information takes the form shown in Figure 6.

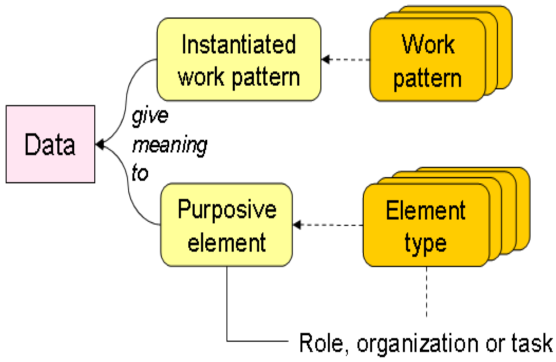


Figure 6: 'Complex' definition of information

In the complex model, element types and work patterns are defined at design-time; purposive elements and work patterns are instantiated at assemble-time; and sub-languages are created in an execution model, by purposive elements adopting instantiated work patterns.

Enterprises which exhibit social diversity require a 'complex' definition of information which is sensitive to the characteristics of the world of work and organization. In this perspective, the organizational configuration reflects the requirements of effective IM/IX, rather than the other way round.

Under this interpretation, extant principles of military organization reflect a highly-adapted contribution to information management / exploitation (IM/IX). Clearly we need to build on and extend these principles to accommodate non-military organizations; however, we ignore or abandon them at our peril.

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Thanks are also due to Dr Ann Fitchett (UK MOD SEIG) for re-injecting the earlier paper [11] on information design into the discussion. The liberties taken here with the interpretation of that paper are entirely the responsibility of the current author.

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Appendix A – Appreciation of information in the broader literature

An extensive review[15] of different definitions of information [1] reveals a diversity of definitions, and also some common features. No single extant set of definitions (of information and related terms, like data and knowledge) attempts to embrace all of these domains; each focusses on particular areas and aspects, according to its specific intended utility.

Different definitions can be characterised (Table 1) as providing different answers to the following questions:

- What do these symbolic representations refer to, and what form do the truth conditions on these representation take?
- Of what type is the purposive element, and when (in Design-time / Assemble-time / Run-Time (DART) terms) is the notion of 'purpose' assigned?
- What is the nature of the flow from the symbolic representation to the purposive element?

[15] The objective of this work [1] was an improved understanding of Coalition Situational Awareness. The study also generated its own preferred definitions, which are denoted by 'CSA' in Table 1.

Question	Possible answers	Exemplifying model	Contribution to definitions: *see italicisation*
What do these symbolic representations refer to, and what form do the <u>truth conditions</u> on these representations take?			
	Representations acquire truth through empirical observation.	Davenport, 1997 [2]	Data are *simple observations*.
	The truth (or otherwise) of symbolic representations is invested in their being, or their corresponding symbolically with, one or both of the following: • an encoding of external-world observables • an encoding (i.e. a partial representation) of epistemic facets of the world of Work and Organization (i.e. what is known within, and about, the human and organizational world).	CSA [1]	Representations are created in respect of: • Observable aspects of the external world ('data') • Knowledge (which is relatively situation independent) • Information, awareness and understanding, which are usually related to some specific situation in the real world. A representation is something that *stands in place of, or substitutes for, some aspect of reality* as we perceive it – *typically representations of sensed data*, or information or knowledge, in the form of symbols, signals, bytes, etc..
		Stenmark, 2001 [3]	By examining the structure of … *information, we may finally codify it into pure data*, which, from an IT perspective, is the most valuable [form] since only data can effectively be processed by computers.
	Representations are an encoding (i.e. a partial representation) of epistemic facets of the world of Work and Organization (i.e. what is known within, and about, the human and organizational world.	Tuomi, 1999 [4]	Data emerges as a result of *adding value* to information, which is *knowledge that has been structured and verbalized*. There is no "raw" data, since every measurable or collectable piece of fact has already been affected by the very knowledge process that made it measurable and collectable in the first place.
	The symbolic representations constitute a valid description of a situation or condition, in an abstract description language accessible to humans.	Wiig, 1993 [5]	Information consists of facts organized to *describe a situation or condition*.
	Linked {in some unclear way} to our capacity to understand the external physical world.	Boisot, 1995 [6]	Data are an energetic phenomenon *that links our capacity as knowing subjects to an external physical world*.
a. **Of what type is the <u>purposive element</u>?** b. **When (in DART terms) is the notion of 'purpose' assigned?**			
	(a) Human actor (b) Some design-time and assemble-time pre-conditioning, but essentially assigned at run-time.	Davenport & Prusak, 1998 [7]	Information is a message meant to change the receiver's *perception.* Knowledge is *experience, values, insights*, and contextual information.
		Nonaka and Takeuchi [8]	Knowledge is about *commitments and beliefs* created from … messages.

Question	Possible answers	Exemplifying model	Contribution to definitions: *see italicisation*
		Stenmark, 2001 [3]	*Knowledge Is a state of preparedness built up partly by personal commitment, interests, and experiences and partly by the legacy of the tradition in which we have been brought up; knowledge is therefore fundamentally tacit.*
		Choo, Detlor, & Turnbull, 2000 [9]	Knowledge is about justified, true *beliefs.*
		CSA [1]	Information is an interpretation that *people* make when exposed to data and symbolic representations, that makes a difference to the way they think about things and their disposition to act.
		Wiig, 1993 [5]	Knowledge is about truths, *beliefs, perspectives, judgements*, know-how and methodologies.
	(a) A model of the world which is constructed according to some human purpose (b) Design, assemble or run-time.	Shannon and Weaver [10]	Information = $-\Sigma p \log p$.
		Boisot, 1995 [6]	Information is an extraction from data that acts upon *our probability distributions* and modifies them - …..
	(a) An actor whose actions are informed by a model of the world (b) Run-time.		…. i.e. information makes a difference to the way *we think about things or to our disposition to act.* Knowledge is a *set of probability distributions that we deploy* with respect to the phenomena that we encounter.
What is the nature of the flow from the symbolic representation to the purposive element?			
	The attending to or receipt of the representation by the purposive element.	Nonaka & Takeuchi, 1995 [8]	Information is a *flow* of meaningful *messages.*
		Davenport & Prusak, 1998 [7]	Information is a *message* meant to change the *receiver's* perception.
		CSA [1]	Information is an interpretation that people make *when exposed to* data and symbolic representations, that makes a difference to the way they think about things and their disposition to act. Information is the meaning derived from the use of knowledge to make sense of *received* data and representations.
	The application of representational content to, and resultant modification of, a model of the world.	Boisot, 1995 [6]; also Shannon and Weaver [10]	Information is an extraction from data that *acts upon* our probability distributions and *modifies* them - i.e. information makes a difference to the way we think about things or to our disposition to act
	The organization of representations as pertinent to a situation or condition.	Wiig, 1993 [5]	Information is about facts *organized to describe* a situation or condition.

Table 1: A variety of definitions of information

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Appendix B – A rich account of 'information in transit'

This Appendix presents the tabular analysis which is summarised in the main body of the paper at Figure 5 and its supporting text. The four columns in Table 2 reflect increasingly-complex (i.e. increasingly less mechanical and deterministic) mechanisms to get information from the Context of actual generation to the Context of actual use.

In the section of the main body of the paper headed 'Implementation avenues for information schemata', there is a brief discussion of the ways in which the entries in this table might be used in the implementation of information transit mechanisms.

	Simplistic	Complicated	Quasi-complex	Complex
Reporting prompted and informed by:	Context of generation	Context of generation and knowledge of ‘Community 2’, required in order both to express the ‘Context of safe use’ with confidence that it will not be misused	Context of generation and knowledge of ‘Community 2’, including Context of potential use, required in order both to express the ‘Context of safe use’ and to have confidence that it will be correctly interpreted	Context of generation and knowledge of ‘Community 2’, including Context of potential use, required in order both to express the ‘Context of safe use’ and to have confidence that it will be correctly interpreted
Sending mode:	Publish	Publish / Push	Push or Stimulated Push (could be initiated by an embedded ‘Community 2’ representative)	Push or Stimulated Push (could be initiated by an embedded ‘Community 2’ representative)
Knowledge of ‘Community 2’ acquired from:	N/A - the sender may have no knowledge of the specific contexts in which possible recipients are operating; the ‘safe use’ conditions are built into the message type, and who actually picks up and acts on the message not material to the sender	Message type definitions and/or procedures	Local knowledge of ‘Community 2’, or affiliation of ‘Community 2’ representative	Local knowledge of ‘Community 2’, or affiliation of ‘Community 2’ representative
Goal of transmission	To achieve effect consequential on ‘Context of generation’, through any agency within the enterprise	To achieve effect consequential on ‘Context of generation’, through the agency of ‘Community 2’	To allow ‘Community 2’ to consider whether effects are appropriate consequent on ‘Context of generation’	To allow ‘Community 2’ to consider whether effects are appropriate consequent on ‘Context of generation’
Relationship between message type and goal	Message type = goal	Message type is appropriate to goal (and strongly typed)	Message type is appropriate to goal (and may be strongly typed)	Message type is appropriate to goal but only weakly typed (i.e. may use vanilla message types)
Reported context of generation	N/A – meaning to recipient should be clear from message type and authentication	Reported context of generation $\supseteq$ Context of actual generation	Reported context of generation $\supseteq$ Context of actual generation	Reported context of generation is selective interpretation of Context of actual generation
Content material	Content material $\subseteq$ Context material$^{(0)}$	Content material $\subseteq$ Content material$^{(0)}$ or pre-determined translation of $\subseteq$ Context material$^{(0)}$	Content material $\subseteq$ Content material$^{(0)}$ or pre-determined translation of $\subseteq$ Context material$^{(0)}$	Content material is selective interpretation of $\subseteq$ Content material$^{(0)}$

	Simplistic	Complicated	Quasi-complex	Complex
Context of safe use	Addressees not identified, conditions of safe use may be part of message type definition and/or related procedures and may not need to be supplemented	Addressees identified; conditions of safe use may be part of message type definition and/or related procedures, and may not need to be supplemented	Addressees identified, plus conditions of safe use as properties (supplementing any conditions cued by message type and/or related procedures); may include a pointer to broader 'Communities 1 and '2' discourse (e.g. "only to be used in the context of what we have discussed")	Addressees identified, plus conditions of safe use as properties (no reliance on message type and/or related procedures); may include a pointer to broader 'Communities 1 and '2' discourse (e.g. "only to be used in the context of what we have discussed")
Recognition of the need to receive the message	Triggered by message type and matching of own context with Context of safe use'	Addressees identified in Context of safe use	Addressees identified in Context of safe use	Addressees identified in Context of safe use
Retrieving mode:	Subscribe / Pull	Receipt of push	Receipt of Push or Stimulated Push (could be initiated by an embedded 'Community 1' representative)	Receipt of Push or Stimulated Push (could be initiated by an embedded 'Community 1' representative)
Recognition of the need to attend to content	Goal	Goal and Context of actual use	Goal, content material, recognition of sender (in Reported context of generation), Context of actual use	Goal, content material, recognition of sender (in Reported context of generation), Context of actual use
Inference informed by:	Message type = goal, reinforced by authentication attributes	Message type = goal, reinforced by authentication attributes and knowledge of 'Community 1'	Goal, content material, Reported context of generation, broader knowledge of 'Community 1' (including Context of actual generation) and Context of actual use	Goal, content material, Reported context of generation, broader knowledge of 'Community 1' (including Context of actual generation) and Context of actual use
Knowledge of 'Community 1' acquired from:	N/A - other than that contained in goal and Content material	Message type definitions and/or procedures, plus Content material	Local knowledge of 'Community 1', or affiliation of 'Community 1' representative	Local knowledge of 'Community 1', or affiliation of 'Community 1' representative
Inferred material	Content material$^{(1)}$ $\subseteq$ Content material	Content material$^{(1)}$ $\subseteq$ Content material or pre-determined translation of $\subseteq$ Content material	Content material$^{(1)}$ $\subseteq$ Content material or pre-determined translation of $\subseteq$ Content material	Content material$^{(1)}$ is selective interpretation of Content material plus collateral information from Context of Actual Use

Table 2: Some specialisations of the general model of Figure 4

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