EXPRESS

ISO 10303-11

A White Paper on Enabling Open Information Systems

2010-04-14

The International Organization for Standardization (ISO) approved the EXPRESS language as an International Standard in 1994. The language was a product in the work programme of the ISO subcommittee for Industrial Data (ISO TC184/SC4) as part of developing STEP (Standard for the Exchange of Product Model Data). The subsequent years have seen many deployments of EXPRESS, delivering tangible business benefit from effective and efficient data exchange, sharing and archiving.

The EXPRESS capability has enabled ISO subcommittees to develop ready-to-use models for various types of information. These models have successfully become the foundation of open information systems that embody data independence and, thus, solve the requirements for long-term data retention.

EXPRESS is a formal specification language for information requirements and is complementary to enterprise solutions such as database management systems. This language is unique and, by enabling model-based system development, fit for the purpose of analysing and resolving the information dimension of organizations.

The language is rich but easy to use and understand during information analysis. This analysis will typically deliver explicit, comprehensive insight into the information perspective. Such insight is the necessary foundation for interoperability and integration solutions, including exchange file formats and common data repositories. These solutions are the prime target of the EXPRESS capability.

In summary, the EXPRESS language is a proven foundation for high-quality information and, thus, a robust enabler for the Information Age.

Why should I read this White Paper?

My organization is concerned with interoperability & integration of information & I am:

- the CIO needing to understand how EXPRESS can deliver return on investment, especially by using open, neutral information models such as STEP, PLCS & IFC

- the team leader needing to understand how EXPRESS enables my software development team to be efficient & effective

- the software developer needing to understand the capability provided by EXPRESS & how this relates to other technologies

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Introduction

Organizations of any size achieve high performance by making timely, effective and efficient decisions. All decisions rely on a fundamental input: information. Organizations require capable people to make decisions but must also invest in the processes and technology that generate fit-for-purpose information. Such investment has led to information becoming a key enabler of the globally competitive market place and, thus, the world has entered the Information Age.

Every information set possesses characteristics that determine the success of the decisions possible using the information content. Of these characteristics, the most critical are timeliness, accuracy, completeness and provenance. These are the characteristics of high-quality information.

High-quality information is most typically achievable through computer-based solutions. These solutions benefit from implementation using an information model, which rigorously defines the information content. Such models require a formal requirements specification language in which to state the definitions. EXPRESS is such a language.

This White Paper explains the ways in which EXPRESS addresses the requirements of the Information Age, describes the EXPRESS language and related technologies, positions the language with respect to enterprise solutions such as database management systems and presents some examples of how EXPRESS has delivered business value to existing users of the language.

The needs of the Information Age

Organizations achieve high-quality information as the result of both processes and technology that are fit for purpose. However, organizations operate as a rich system of interacting components. These

> "The EXPRESS language was developed to provide the full range of capabilities needed to represent data, independent of any particular implementation technology. This is a critical element in protecting a company's investment in its information across changes in the underlying information systems & technologies."
>
> Howard Mason (BAE Systems)
> Chairman of ISO TC184/SC4, Industrial Data

Core data functionalities

data exchange – use of computer files to transfer data between software applications

data sharing – use of a single common repository to provide data access to more than one software application

data archiving – storage of data for possible later retrieval by software applications (either through computer files or a data repository & potentially by software applications that do not even exist at the time of creating the data)

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components include internal people, processes and technology, in addition to interfaces to the corresponding components in external organizations. If information passes between the components (internally and externally) without preservation of meaning then the organization will not sustain a coherent, high-quality set of information.

Another issue is the long life of some information. Product designs, patient records, cartographic data are just some of the examples where the information is valid and valuable for longer than the life of an individual generation of implemented information technology. The information has an owner who must act to ensure that access to that information is not lost when the technology is no longer operational.

Organizations implement information technology that includes the necessary mechanisms providing access to the processed and stored information. However, every organization has a strategic interest to know that these access mechanisms are not unique to a single information technology vendor. Such uniqueness would allow the vendor to control pricing unilaterally and cause the access to depend exclusively on the continued financial viability of the vendor.

Finally, each individual implementation of information technology is almost invariably a partial view of the total information landscape of an organization. For instance, information on people is necessary across applications related to salary, pensions, leave, training and so on. In all these applications, some common information will occur, such as name.

An enabler of the Information Age

The EXPRESS language addresses the challenges of the Information Age. The language provides capabilities that support achieving high-quality

information. These capabilities include formal data definition and constraint specification, thus, establishing the semantics (meaning) of the data (also known as data modelling). The language has associated technologies that also define the syntax of data sets. The syntax determines how to implement the information technology to process the data.

EXPRESS enables the definition of information models that create the common language to address both data **interoperability** and **integration** problems.

Data interoperability arises when two interfacing components comply with a common information model. These components can then create and access either exchanged or shared data sets.

Data integration arises when organizations build repositories containing unified, rationalized collections of data. These data typically come from many different individual information systems and are of interest to multiple parties.

Using EXPRESS also provides the basis for reliable **archiving**. The information model provides an explicit specification of data semantics and, thus, even without access to the original software, future users can analyse the model and understand the content of the corresponding archived data sets.

Software vendors create **open data** systems by using explicit, shared data specifications. By creating the information models in EXPRESS, vendors provide a basis on which customers can establish unconstrained access to the data sets within the system.

The EXPRESS language is part of an overall architecture that achieves a rich form of **data independence**. This independence ensures that information analysis is possible without reference to specific application functionality and implementation

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The challenges of the Information Age

interoperability of information technology, addressed by data exchange & sharing solutions

common enterprise-wide views of information, addressed by **data integration** solutions

obsolescence of information technology, addressed by **data archiving** solutions

freedom from vendor lock in, addressed by **open data** solutions

multiple viewpoints, addressed by solutions embodying **data independence**

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technology. Analysis becomes focused on the information problem, specializing the skill set of the analyst. The analysis results in an information model that users can review and validate from the perspective of the information requirements.

The EXPRESS architecture is able to resolve the complexity in making decisions requiring information that is broad in scope and rich in detail, including large numbers of relationships. For example, if the decision is whether an airline should replace or refurbish an aircraft then the information scope will include financial, engineering and operational perspectives.

The EXPRESS language

The EXPRESS language became an International Standard in 1994 through the publication of ISO 10303-11, titled "The EXPRESS language reference manual". The language was the result of extensive collaboration to develop a means by which to specify the exchange, sharing and archiving of engineering data. Since that date, many different International Standards have used EXPRESS to represent consensus information models, while other organizations have exploited the language for internal purposes.

The language offers two key capabilities: human readability, through an intuitive graphical layout (EXPRESS-G); and computer processability, through the lexical form, which is the subject of a formal specification in ISO 10303-11.

EXPRESS enables the information analyst to define the following key elements:

- **entity data types**, which represent information on objects that are of interest to the user (for example, *product*, *organization* and *person*). Each entity data type has a declared identifier, which should indicate what the object is;

- **attributes**, which represent properties of the information (for example, *name*, *length* and *startDate*). Attributes can establish an association between one entity data type and another (for example, *employer* as an association from *person* to *organization*). EXPRESS allows the definition of derived attributes, where the value depends on the values of one or more other attributes (for example, calculating *area* of a *square* as being *side_length* x *side_length*);

- **constraints**, with respect to uniqueness, cardinality or the values of attributes (for example, specifying that for *triangle* having the attributes *angle1*, *angle2* and *angle3*, these sum to 180°). The

- Part 21 (ISO 10303-21), a **clear text encoding** for data that are specified using an information model in the EXPRESS language. This encoding enables the exchange of data sets using a human interpretable and computer processable structure;

- Part 28 (ISO 10303-28), an **XML[1] encoding** for data that are specified using an information model in the EXPRESS language. This encoding enables the exchange of data sets using a core technology of the Internet;

- **Standard Data Access Interface (SDAI)** (ISO 10303-22), which provides a generic set of operations by which to process data conforming to an EXPRESS schema. The SDAI enables the development of data sharing capability, using programming language-specific bindings that are also part of ISO 10303. These bindings include ones for Java, C, C# and C++, enabling the creation of application programming interfaces in these languages[2] based on a defined information model in EXPRESS;

- **binary representation** (ISO 10303-26, under development), which uses HDF5[3] to provide a compact means by which to exchange the content of very large data sets;

- **conformance testing** (ISO 10303-31 to 35), which provides the means by which to assure that EXPRESS-based implementations meet the applicable information requirements.

In summary, the EXPRESS language provides a rich capability for developing information models, which are then suitable for implementation to achieve data exchange, sharing and archiving.

EXPRESS & other technology

The EXPRESS language is a tool for the purposes of information analysis, which is one vital task within the overall software development process. This process includes other tasks, each with corresponding elements of information technology. EXPRESS is complementary to the following elements:

- application programming languages;

- database management systems;

- software modelling languages;

constraint functionality in EXPRESS is as rich as a typical programming language, allowing the expression of complex rules (for example, with *if…then* constructs);

- **subtyping**, which specifies that one entity data type inherits the attributes and constraints of one or more others and possesses additional attributes and constraints (for example, declaring *circle* as a subtype of *ellipse*, adding the constraint that attribute *minDiameter* shall equal *maxDiameter*);

- **schemas**, which collect together elements into logical collections (for example, *projectPlanning* could include all the definitions of entity data types specifically relevant to the project planning process).

In addition to the core language, the complete EXPRESS-related capability includes:

- EXPRESS-X (ISO 10303-14), a structural **data mapping language** that enables the user to convert data conforming to one EXPRESS schema into those conforming to another. EXPRESS-X provides a capability by which to build translators to enable data exchange and sharing;

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[1] Extensible Markup Language <http://www.w3.org/standards/xml/>

[2] Some EXPRESS toolset vendors also support Visual Basic.

[3] Hierarchical Data Format 5 <http://www.hdfgroup.org/HDF5/>

- service-oriented architecture;

- Web technologies.

Application programming languages benefit from combination with EXPRESS. An application programming language provides the functionality by which to process data according to the information perspective, EXPRESS being an ideal means for specifying this perspective. This data processing functionality can make use of the SDAI and, thus, achieve standards-based information interoperability between different software applications.

EXPRESS provides a capability with parallels to that of object-oriented programming languages such as C++ and Java. These languages include data structures that are similar to entity data types in the EXPRESS language. Thus, object-oriented languages offer a ready means by which to implement input and output functionality on top of EXPRESS-defined information models.

EXPRESS includes some constructs (such as multiple inheritance) that are not common even in object-oriented programming languages. However, while these constructs enrich the information perspective, they are not critical at the data processing level and developers can implement the information model using alternative structures to compensate for these constructs.

Database management systems offer the means by which to store data sets. Two types of system are relevant to EXPRESS:

- those that make use of EXPRESS in native form and, thus, offer a direct route to implementation;

- those that make use of Structured Query Language (SQL) and are prevalent in many existing information technology implementations.

Direct implementation of EXPRESS ensures no gap exists between the information model and the data set in the database. However, EXPRESS models are independent of implementation technology and capture requirements from an information perspective.

This independence is what enables such models to specify how database developers shall convert the model into, for example, corresponding SQL statements. This conversion can take account of requirements specific to the implementation technology (for example, identifying appropriate indexes to improve database performance).

Software modelling languages are similar to EXPRESS, supporting analysis but for software functionality rather than the more specific information perspective. Software modelling has been a focus for the Object Management Group (OMG); the result is the Unified Modeling Language (UML).

UML supports the complete software development process and only the Class Diagram is comparable to the EXPRESS language. The similarities include graphical representation, a formal basis for interpreting the language and the capabilities to define classes (similar to entity data types in EXPRESS) and rules (using Object Constraint Language, OCL). However, OCL does not match EXPRESS for richness in defining rules for information integrity. UML also has no equivalent to the exchange encodings for EXPRESS (Part 21 and Part 28).

EXPRESS complements UML in terms of providing the information perspective but no organization will want to maintain unconnected models in two different languages. Thus, the EXPRESS-related capability includes the standard ISO 10303-25, which defines a mapping from EXPRESS to XML Metadata Interchange (XMI). The XMI specification provides a means by which to represent an information model in non-graphical form, establishing the mechanism for transferring the model from EXPRESS to UML (although this capability does not solve the problem of transferring the content of data sets).

Further to ISO 10303-25, the OMG has developed a metamodel[4] that establishes a formal basis for generating UML models from those in EXPRESS. This metamodel establishes EXPRESS as a part of the OMG approach to software development.

Service-oriented architecture (SOA) is a means to implement enterprise-wide solutions through federation of software applications. The federation relies on an enterprise service bus to establish communication between the applications. However, this service bus requires a common data model to define the content of messages to and from the data services in the federation. These models are an ideal use for EXPRESS.

> "The capabilities of EXPRESS both to define the complex rules needed & to allow data models to be extended ensures there is a single, unambiguous definition of the data. Given that, for archiving purposes, the data models will still be needed in fifty years, a stable language definition of the models is essential."
>
> Sean Barker (Advanced Technology Centre, BAE Systems)

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[4] Reference metamodel for the EXPRESS information modeling language specification

Web technologies are without doubt a major component in most up-to-date implementations of information systems and include XML, which has become the main focus for the information perspective of Web-based solutions. XML provides the means by which to represent data sets, making use of XML Schema to specify the valid content for the data set. However, XML results in the data sets being a verbose representation and XML Schema is less rich than EXPRESS, which offers a more appropriate means for capturing the information perspective in a model. This model enables Web-based implementations by using the Part 28 data encoding.

Web technologies include those that support the Semantic Web, which, in particular, has raised the potential for ontologies to be the means by which to exploit semantic content within information systems. However, an ontology is only an information model with some additional features and, thus, if an organization chooses to invest in information modelling using EXPRESS then the organization is building a suitable foundation for a more complete ontology at a later date[5].

Proven business benefits of EXPRESS

Since 1994, EXPRESS has delivered benefit in enabling the exchange of data between computer-aided design (CAD) systems. All of the major CAD systems include import and export functions using EXPRESS-based data models. In addition to this capability for CAD, other implementations of EXPRESS have delivered business benefit, as detailed below.

EADS & Eurofighter

The Eurofighter aircraft is a joint development by four partner companies. These organizations resolved the challenge of harmonizing non-geometric design data every night through the use of an EXPRESS-based information model from within ISO 10303. This model has already served for more than ten years as a single common specification and, by reducing the number of required translators, is ensuring cost-effective and high-quality data exchange.

The construction industry

Multiple technical disciplines contribute to the construction of a building. Each discipline uses discrete specialist software applications and, thus, organizations responsible for building maintenance face the problem of receiving data in many different formats. This problem has led to creation of the Industry Foundation Classes (IFC) using EXPRESS and, subsequently, the buildingSMART consortium putting forward the IFC for publication as ISO 16739. The standard enables the integration and re-use of building and construction data, reducing costs.

European Space Agency (ESA)

ESA has pioneered the use of concurrent engineering to achieve considerable acceleration of space programme development. Such engineering requires the integration of the constituent activities through efficient exchange and sharing solutions to get the right data at the right time to the right stakeholders. ESA is using EXPRESS-based information models to allow different information systems to interoperate.

Long Term Archiving & Retrieval (LOTAR)

The worldwide aerospace industry is designing products as three-dimensional digital models. The contents of these models are not available in paper form. However, paper has been the traditional medium by which to achieve long-term archiving of data. The European and the American aerospace industry associations (ASD and AIA[6]) have selected EXPRESS as the open, maintained standard information language for the purpose of digital archiving. LOTAR allows the re-use of existing designs in both new products and updates to existing products and ensures successful retention of data for legal purposes.

Criteria for successful exploitation

The EXPRESS language delivers business benefit through implementation when organizations take account of the following critical success factors:

- use of a robust software development process;

- exploitation of standard information models;

- identification of an appropriate deployment option for the language;

- selection of an external partner to provide specialist EXPRESS-related capabilities.

The EXPRESS language offers greatest benefit when fitting into an overall **software development process** that embodies a systems engineering approach. This approach is a general framework and the specific details within the framework are a matter for each individual organization performing the implementation. However, the organization will

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[5] ISO 12006-3 demonstrates the capability that EXPRESS can provide when developing an ontology.

[6] <http://www.asd-europe.org/> & <http://aia-aerospace.org/>

benefit from using a best practice approach such as the Model Driven Architecture from the OMG and The Open Group Architectural Framework (TOGAF). Both of these examples benefit from use in conjunction with EXPRESS.

TOGAF covers the entirety of information technology solutions including the role within this solution architecture of data entities and the related logical and physical data components. EXPRESS is ideal for defining these entities and components. TOGAF, furthermore, identifies the architecture deliverables to support the approach and these deliverables include class and class hierarchy diagrams. These diagrams are an appropriate application for EXPRESS-G.

The systems engineering approach should include early identification of the functional requirements corresponding to the user requirement. If these functional requirements include the exchange, sharing or archiving of product data then, in addition to the general relevance of EXPRESS for addressing the information perspective, the ISO 10303 series of standards also includes application protocols that define **standard information models**. Such standard models offer interoperability beyond even the immediate requirement (avoiding re-engineering the solution to achieve compatibility with information systems that become relevant at a future date) and save the effort of developing an alternative model to achieve the same effect.

The EXPRESS language offers a spectrum of **deployment options**, from simple to comprehensive. The simplest option is to use EXPRESS and EXPRESS-G purely for human interpretation (potentially even using pencil and paper to capture and communicate the information model). This option requires investment in training analysts and providers of the user requirement to understand the language but no other changes to the existing

Reducing interface requirements to achieve interoperability of four enterprise applications

12 point-to-point interfaces

8 neutral interfaces

the EXPRESS-based hub (repository or exchange file format)

development approach in use by an organization. Human interpretation depends on the skill of the people who are reading the models to transform the information requirements into implemented features of the solution.

At the comprehensive end of the deployment spectrum, organizations make use of software toolsets that can process the EXPRESS language and provide development and implementation capabilities. The capability for development will enhance and manage the creation of information models (textual and graphical forms). The implementation capability will enable data storage according to the information model, generation of Part 21 and Part 28 files of the data, access conforming to the SDAI, processing of mappings in EXPRESS-X, compilation of functionality into standalone executable files and access to all of these functions through an application programming interface and web services. This implementation capability will deliver particular benefit when interpreting the rules in the information model and applying these rules to enforce integrity of data sets, which often originate from different sources before coming together in an enterprise repository.

Comprehensive deployment eliminates manual intervention in the implementation of the content within the information model. Such intervention could include converting a model from EXPRESS to SQL, creating a gap between the specification and the implementation form and adding cost and risk due to non-automated configuration management.

In between simple and comprehensive are other deployment variations. These variations are typically appropriate when an organization has already implemented enterprise applications. These applications include database management systems, as well as those providing more specific functionality for activities including finance, document management, master data management, product data management and enterprise resource planning.

When enterprise applications already exist, analysis is necessary to determine the degree to which the applications under consideration are subject to the challenges of the Information Age: interoperability, data integration, data archiving, open data and data independence. The degree of challenge will determine how much financial benefit will arise from investment in EXPRESS.

External partners offer a route to EXPRESS-based implementation without either building in-house skills to cover all the details of the EXPRESS-related technology or creating new infrastructure delivering EXPRESS capabilities. Such partners provide software in the two main categories of
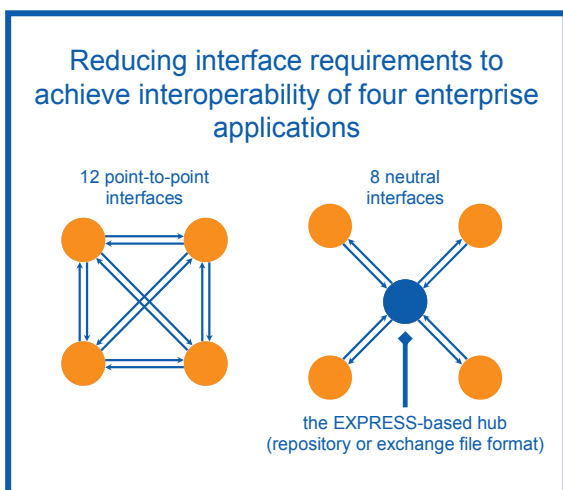
> "Industry has reached a major milestone in agreeing on EXPRESS as a common information language for describing products & facilities. By enabling data integration & long-term data retention, the language supports organizations in achieving both innovation & cost-efficient production & product support."
>
> Jorulv Rangnes (Business Director, Jotne EPM Technology)
> <http://www.epmtech.jotne.com/>

EXPRESS-based toolsets and end-user applications that exploit EXPRESS-based information models.

Conclusions

The EXPRESS language is a tool by which to address the key challenges of the Information Age: interoperability, data integration, data archiving, open data and data independence. These challenges affect the combined capability of people, processes and technology in organizations. All organizations can, however, overcome these challenges through developing a coherent information perspective. This perspective is the one in which EXPRESS provides a unique and robust capability.

The EXPRESS capability covers information models and a layered approach to software application architectures. This approach ensures that organizations can gain a clear information perspective independent of specific implementation technologies and then proceed to building and/or using end-user solutions that are consistent with this perspective.

The EXPRESS language provides a capability not only for data definition but also for rich rules that specify data integrity. The rules become visible to the information owners in an organization, no longer being hidden away within the code of application software. This visibility allows the owners to more easily validate and, as necessary, enhance the rules.

The EXPRESS language has attracted authoritative international support. This support involves ISO maintaining the standard and organizations such as OMG developing exploitation. The support is effective because the participating individuals possess many years of experience gained through deploying the language to solve multiple real business problems.

The EXPRESS capability offers definable business benefit. This benefit can arise from information models that establish a common view of data across multiple systems. Such models are available ready for use from ISO and if systems require data interoperability then the fundamental cost saving is not only to re-use the previously developed model but also to reduce the number of translators (to and from the common model rather than point-to-point between all systems).

EXPRESS has attracted support from various software vendors. Some of these vendors offer toolsets providing the bridge between the EXPRESS language and an implementation infrastructure that integrates with the enterprise applications that provide the major decision support capability of organizations in the Information Age.

Further information

The ISO catalogue includes standards that specify and use EXPRESS:

www.iso.org

The ISO/TC184/SC4 website provides background on the development of EXPRESS:

www.tc184-sc4.org

PDES Inc. encourages the development and implementation of EXPRESS-based solutions:

www.pdesinc.org

The Open Group website provides information on enterprise architecture development:

www.opengroup.org

The OMG website provides information on software modelling languages:

www.omg.org

The W3C creates the standards for Web technologies:

www.w3.org

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