

## 2.4 Product Environment

The product environment model specifies the relevant information content of the ecosystem in which the product operates. This is the aggregate of the information space of the environment (treated for convenience as an entity in its own right) and of each associated entity. Optionally, this model may specify the behavior of an entity as support for product evaluation or for various other purposes discussed below.

The basic purpose of the product environment model is to provide developers with an accurate portrayal of the environment as a dynamic information space within which the product will operate. The environment being specified exhibits properties and phenomena that can be detected by appropriate entities and may change under the influence of selected entities. This model specifies how each of the various entities are able to detect or initiate changes in the information content of the environment. These entities are the means by which the product is able to obtain data to maintain its representation of the environment's information content and initiate actions that influence that content.

Each entity is described as a logical device that represents its own information space and the means it provides for interaction to share information or coordinate action as appropriate.

The product environment model describes an environment that may be physical, virtual, or hybrid, as appropriate. A physical environment is that which exists in the real world, a virtual environment is one that is simulated in software (and which may or may not approximate physical reality), and a hybrid environment is a physical or virtual environment in which entities are some combination of physical, emulated, and virtual. The product environment model can be viewed as specifying either a product's actual environment or an artificial environment in which the product can operate as if it were in its actual environment.

For products built to operate in the same ecosystem, they may share a product environment model. The relevant aspects of the model for a particular product may be limited by the context element of its product requirement model.

This model encompasses three elements (the context element of the product requirements model specifies the entities of interest that operate in the environment):

- (information) what is the product-relevant information content of the each entity of interest?
- (interfaces) what are the associated conventions for interacting with each entity in order to (1) coordinate or share information or (2) monitor or effect changes in information content?
- (behavior) what is the behavior of each entity that can cause its information content to change independent of product activity (for the purpose of simulating an adequate approximation of an entity's expected behavior)

This model provides a basis for:

- Developing software that will interact with the environment and entities as specified, obtaining and sharing information and initiating actions via related devices to effect the product's intended behavior
- Developing empirically-based scenarios (capture history of inputs and resulting effects as a basis for regression testing as product evolves or comparative evaluation of alternative product versions or implications on product behavior of changes in behavior of the environment or entity)
- Building a virtual world (a simulated environment and entities that represent an artificial/ non-physical or augmented/hybrid reality) in which a product can operate (e.g., a game or other fictional endeavor; or as a contained training platform for users; or to evaluate effects on product of changed/ different configuration of environment/entities)
- Building an alternative reality model (a reality-based model of the environment and entities in which selected properties and phenomena can be modified to analyze resulting effects on behavior of the environment or entity)
- Building a temporal projection (a reality-based model that guides understanding by capturing and analyzing the chronology of changing information (and

resulting product reaction) over a span of time or informs decision-making by projecting and comparing outcomes of alternative options; an aid to understanding (rationale for) product behavior or effects of potential actions on that behavior)

- Ability to inject anomalous ecosystem conditions to evaluate product behavior

## Product Information Space Element

The product information space element specifies the product-relevant information with which each product-engageable entity is concerned. Information is expressed in terms of the data form in which each entity defines it. Information is specified in terms of a set of discrete or aggregate values expressed in an encoding in a digital or analog representation.

{define info model of environmental monitored/controlled variables; models for behavior (how values chg)} {relevant info content that changes naturally or due to ecosystem effects} {also info assoc (sent/received) with related systems}

The element specifies the data that each of the accessible entities in the product's ecosystem provides.

## Interfaces Element

The interfaces element specifies the information and actions supported by each ecosystem-associated entity. Each entity is characterized as being one of three types: edge, user, or system. An information space is associated with each entity that defines access to corresponding data that it shares. Information and action interactions with an entity is specified in a form appropriate to its type. An edge entity is a logical device that has direct access to the environment, monitoring or effecting associated properties. A user entity characterized according to specified "roles" that define an associated set of capabilities to obtain or provide information or initiate actions related to the environment, other entities, or itself. A system entity is a source of information or effector of actions.

### *Edge Entities*

An edge device interface is specified in terms of data that it can convey between the physical world and computation, including translations between analog and digital representations. A device may operate independently or as an agent of the product. A device's intrinsic interface may be encapsulated and enhanced within a software-defined abstract interface.

### *User Entities*

A user interface is specified in terms of a user role that has associated information and action capabilities. It is a composite of a physical device interface and abstract mechanisms required to enact supported user-system interactions.

### *System Entities*

A system interface is specified in the guise of one or more associated logical devices.

## **Behaviors Element**

The behaviors element specifies the observable behavior that an entity is expected to exhibit. Behavior is specified as discrete events that an entity initiates and is expressed in terms of enabling conditions, potential effects, and criteria for which effects result. Types of behavior include initiating action that modifies the environment's information content, transforming and/or storing information obtained from the environment or other entity, or transferring information to another entity.

### *Relevant Operation of the Customer Enterprise*

(products, processes, user roles)

### *Device Behavior*

### *User Behavior*

### *System Behavior*

DRAFT

## **A Basic Product Environment Model**

(what dev needs to interact in ecosystem, messages (actions/info) coming in & messages (actions/info) going out)

A basic product environment model specifies the ecosystem information space in which a product operates. This model defines a natural environment and entities that operate within that environment.

### *The Natural Environment*

The natural environment is the changing information space with which the product is concerned. This space represents the observable phenomena and properties of the environment that can be expressed as measurable quantities. The content of this space can be monitored by associated entities and can change as a result of naturally occurring processes or due to the effects of entity actions.

### *Entities of Interest*

(entities represented as devices including as proxy agents for users & systems; what information does each device monitor/affect)

## **A Physical Environment Model**

A physical environment has many aspects, both natural and constructed, some of which correlate with software capabilities (e.g., defining devices needed to monitor or act on the environment, considering effects of terrain and buildings on mobility, how communications is affected by environmental conditions). Processes integral to the environment induce phenomena that influence the expected behavior of the product. Entities operating in the environment may enhance or inhibit the ability of software to obtain needed information or to operate as intended (e.g., devices that monitor environmental phenomena, entities that threaten safety or security of product-critical devices or information). Requirements model constraints may identify assumptions about physical environment characteristics that limit choices about the product's realization, such as communications protocols, hardware selection, or other aspects of infrastructure.

## **A Dynamic Environment Model**

A dynamic product environment model is a basic product environment model extended with specifications of the behavior of the environment and associated entities.

dynamics (processes that produce behavior): simple state model or simulation

## **A Scenarios-Enhanced Environment Model**

{define related/addressable elements of ecosystem & transactional interface specs: systems & devices?; info content/communication specs/perf specs; how elements chg envr vars} {maintain as elements evolve} {how ecosystem operates on the envr or as a distinct source or target of info} {scenarios that portray how other systems are behaving + simulation of other systems sending/receiving messages} {simulate people / business processes?} {scenarios that portray how the envr is behaving, in terms of envr vars; simplification: vars are static except due to sys effects}

## **An Instrumented Environment Model**

### **Ecosystem Simulation**

{incl simul of ecosystem envr and entities behaviors within which product can operate in lieu of actual envr/ecosystem}

### **An Artificial Environment Model**

An artificial operational environment can be needed either as a simulated reality in which a product will operate or as a platform for evaluating a product within an approximation of its actual operational environment. The provision of an artificial operational environment is the realization of a product in its own right, having its own underlying environment, associated devices, and capabilities that define its expected behavior. A product can be built to operate in such an environment without any

knowledge that the environment is not natural or physically realized beyond its computational mechanisms.

In extended form, this model defines a framework for creating a software platform that approximates the envisioned operational environment. Such a platform can be built to accommodate actual or artificial (emulated or simulated) realizations of entities as may exist in the actual environment. Interactions with entities can be instrumented to provide experimental monitoring and control of their behavior, supporting analyses of product behavior. If a product is being built to operate in a virtual environment (e.g., games or scientific simulations), this platform would become the actual operational environment for the product. Building such a platform would entail a recursive application of the activities of software product engineering. In any case, the operational environment model must be verified as a sufficient approximation of the actual environment to the degree that it is an adequate basis for ensuring that the product will operate correctly in the actual environment.

### *Product Engineering for an Artificial Environment*

(either a virtual openv for a product or a simulated environment product)

### *Injecting, Exercising, and Monitoring a Product in an Artificial Environment*

## **A Product-Embedded Virtual Environment Model**

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Alternatively, a product can be built to operate in a simulated realization of an envisioned environment (e.g., as a medium for game or scientific experimentation



products) rather than in an actual physical environment. In this case, the operational environment model is the basis for constructing an environment simulation within which a product is injected for its intended use.

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A product is injected into a system to transform its behavior within a containing ecosystem. A product operates by obtaining information from the ecosystem and initiates actions via devices that may change that information. The operational environment model is a representation of the ecosystem within which that system operates. An environment and systems that operate within it consist of information and agents by which such information changes. This representation specifies the means by which a product is able to interact with the environment and other elements of the ecosystem. It can also be elaborated as a specification for creating a facsimile of the actual ecosystem into which the product can be experimentally deployed and evaluated.

A product relies on a suitable facsimile of / verisimilitude to / accurate tracking of relevant aspects of the ecosystem information space to guide its behavior. Its ability to foresee changes, either organic or as the effect of entity actions, depends on the product's model of ecosystem behaviors. Environment and related entity processes express as dynamics of change.

- formulate an infrastructure that represents the composition and working of the ecosystem as a whole, identifying hardware devices and other (black-box) systems / elements, that serve as a product's operational environment
- provide a model that defines the information content of the operational environment and simulates associated natural processes that determine values
- formulate a means to represent data / control channels that provide connections between infrastructure elements

- provide the means to inject a software object as the behavior of any designated element of the infrastructure; provide software objects that emulate the behavior (including timing and errors; normal/expected and abnormal/unexpected behaviors) of black-box systems operating in the environment
- formulate the means to connect hardware devices or to inject software objects that emulate the behavior of devices (that sense environmental data and effect changes in that data)
- formulate the means to emulate business process and the associated expected behavior of human users in scenarios that correspond to their performance of responsibilities in designated working roles within the system
- provide the means to instrument virtual (simulated or emulated) elements for observability (to monitor actions and collect data)

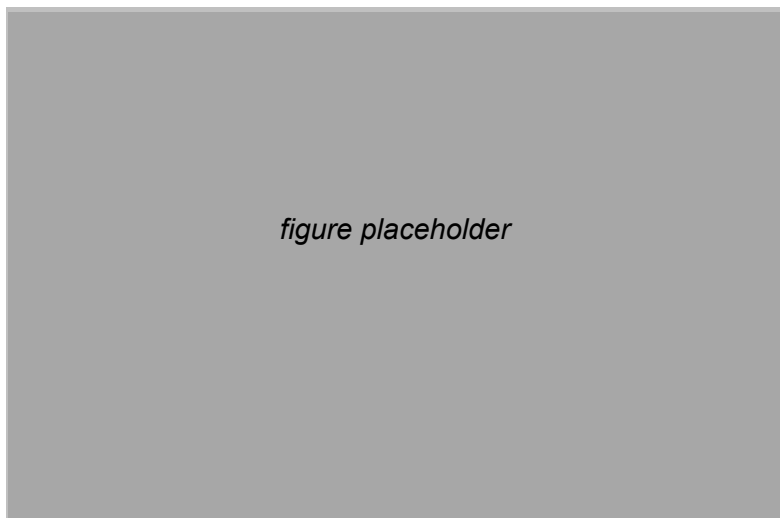
This includes specifications of (1a) the physical environment (an abstract data model) (1b) hardware devices that map data (a concrete data model), (2) user roles and scenarios for performing customer business processes, (3) other systems with which the product will need to interact, and (4) capabilities that users need in a product to monitor or modify the ecosystem to better meet their needs. This includes as-is models of the environment and potential to-be models that might better support the envisioned product.

*an infrastructure that simulates the ecosystem, emulating hardware devices and other systems/elements, that serves as a product's operational environment {what are the relevant elements and behavior of the operational environment (product context) within which the business process/procedures/practices/capabilities are applied to pursue business objectives?}*

- *representation of environment (ecosystem?) into which the product will be injected to operate*
- *basis for defining product interactions (monitoring or controlling) with relevant real-world data values (an information model of externally occurring values)*

- *basis for creating software encapsulations that emulate supporting hdw devices (to what degree of fidelity: how accurate and precise is the device to reality, match that in virtual space and time)*
- *basis for creating product elements that model the environment to predict potential changes or action effects*
- *basis for creating a simulated environment for pre-deployment testing*
- *basis for simulating business/user/operator processes (operator interacts with hdw devices, user performs data processing functions) based on scenarios representing product usage and utility*

*In describing the operational environment, the envisioned product is a black-box from the perspective of other elements. Interactions with it are “conceptual”: information and acts that are directed into or out of the product. (how much is the OpEnv specification just descriptive of relationships? Interactions should be expressed in processes/scenarios only, which are inherently limited/anecdotal; does the OpEnv need to be a mirror of the Rqmts or more statically descriptive? Scenario describes a process that user or system performs with effect on the product.)*



**Figure 2.3-1. Conceptual Structure of the Operational Environment Model**

## Specifying an Operational Environment

This elaboration of requirements context must properly cover all aspects of operational context but may encompass aspects of the actual operational environment beyond what a particular product needs. In this way, an operational environment model may support the development of multiple products that can operate in the same or similar environments. An operational environment model may be created as a collaborative effort among multiple projects that are intended to operate in the same or sufficiently similar operational environments. The environment model will accommodate all entities related to any product whereas each product is built to interact only with those entities that are specified in its requirements model context.