

INCORPORATING THE ELEMENTS OF THE MASE METHODOLOGY INTO AGENT OPEN

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Abstract: Enterprise-wide, web-based systems can be assisted in their construction by the use of agents and an agent-oriented methodology. As part of an extensive research programme to create such an AO methodology by combining the benefits of method engineering and existing object-oriented frameworks (notably the OPF), we have analysed here contributions to the OPF repository of process components from the MASE agent-oriented methodology, identifying three new Tasks, one additional Technique and two new Work Products.

1 INTRODUCTION

Construction of an enterprise-wide, web-based system can be assisted by using agents and an agent-oriented methodology. While there are an increasing number of stand-alone methodologies (e.g. Gaia: Wooldridge *et al.*, 2000), none supports all process elements across the full lifecycle.

Many agent-oriented methodologies extend the ideas already established in the field of object-oriented methodologies, adding agent-specific issues such as social interaction, autonomy and reasoning processes and modifying and extending other existing OO support to apply also to agents. For example, Gaia (Wooldridge *et al.*, 2000) takes as its basis the Fusion methodology of Coleman *et al.* (1994); ADELFE (Bernon *et al.*, 2002) starts with RUP (Kruchten, 1999)¹ and Agent OPEN (Debenham and Henderson-Sellers, 2003a,b) extends the OPEN Process Framework or OPF (e.g. Firesmith and Henderson-Sellers, 2002).

It is also increasingly being recognized (e.g. Cockburn, 2000) that the idea of a single process to suit all kinds of software project is an unattainable "holy grail" since software projects vary greatly depending on many factors, such as organizational constraints, business constraints, technology issues and application factors (Firesmith and Henderson-Sellers, 2002). Creating a suite of processes can best be undertaken using the concepts of method

engineering (Brinkkemper, 1996; Ter Hofstede and Verhoef, 1997; Ralyté and Rolland, 2001).

Combining these two threads, we propose here a further extension of the OPF, based on method engineering, to construct a wide range of process instances. Preliminary work has been undertaken to create initial support for agents (Debenham and Henderson-Sellers, 2003a). Here we report on the continuing research project that aims to ensure that *all* current mainstream AO methodologies can be supported via method engineering and the OPF by careful analysis of each AO methodology in turn. Here, we focus specifically on ensuring that concepts from the MASE AO methodology of DeLoach (1999); Wood and DeLoach (2000); Wood (2000) are either already supported in or provide candidates for new process components in the OPF repository.

Section 2 outlines the ideas behind method engineering (ME) whereas Section 3 describes the basic characteristics of the OPEN Process Framework or OPF (Firesmith and Henderson-Sellers, 2002). In Section 4, we describe the basics of the MASE methodology and then in Section 5 describe the elements of the agent-oriented methodology MASE (DeLoach, 1999; Wood, 2000; Wood and DeLoach, 2000) that not currently supported in the OPF and which we therefore propose for addition to the OPF repository.

¹ Although the citation is actually to the Unified Software Development Process of Jacobson *et al.* (1999)

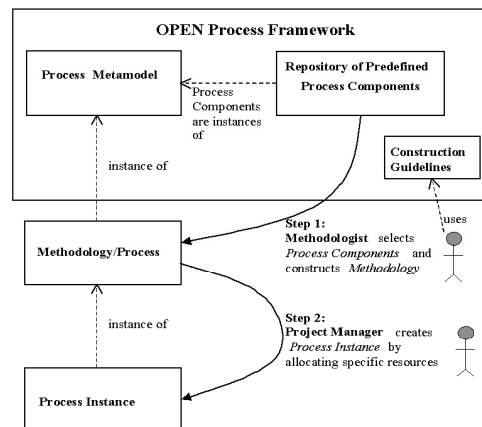


Figure 1 The OPF defines a framework consisting of a metamodel and a repository of process components (after Henderson-Sellers and Hutchison, 2003).

2 METHOD ENGINEERING

A method (or methodology) is a combination of a process and a set of products. The product side is generally described using a modelling language such as the UML (OMG, 2001) and a suite of appropriate diagrams. Consequently, a major interest in method engineering is in fact the process-focussed elements. Thus, we will use terms such as method engineering and process engineering essentially as synonyms and similarly refer to the method fragments in the repository as either method chunks (Rolland and Prakash, 1996) or process components (e.g. Firesmith and Henderson-Sellers, 2002). The discipline of method engineering (ME) itself (e.g. Brinkkemper, 1996) provides a rational approach to the construction of methods from method fragments, which are typically stored in a repository. The method itself is then constructed by selection of appropriate method fragments (Brinkkemper *et al.*, 1998; Rolland *et al.*, 1999) followed by their configuration in such a way as to satisfy the requirements for the method (Ralyté and Rolland, 2001) and create a meaningful overall method (Brinkkemper *et al.*, 1998). A method targeted at a particular project or environment is known as a situated or situational method and the means of its derivation known as situational method engineering (SME) (Ter Hofstede and Verhoef, 1997).

Method engineering implicitly relies on the existence of a process/method metamodel. By using the OPF we make this metamodel explicit since a major characteristic of the OPF is its underpinning metamodel. It is then easy to both generate method

fragments from the metamodel in a consistent way and also to ensure that repository-stored process components have been rigorously defined. In other words, a metamodel imposes some rules upon how a method should be constructed. Such rules also automatically impose some granularity constraints as noted in Brinkkemper *et al.* (1998). A second set of rules is needed to assist in process construction.

3 A BRIEF OVERVIEW OF THE OPEN PROCESS FRAMEWORK

The OPEN (Object-oriented Process, Environment, and Notation) Process Framework (OPF) (Firesmith and Henderson-Sellers, 2002) exemplifies the use of ME within, at least initially, an object-oriented software development context. Its metamodel defines five major high level metaclasses: Work Product (inputs and outputs to Work Units), Work Units (describing what jobs need to be undertaken and how), Producers (the actors, usually human, expending the effort), Languages (to communicate ideas and results) and Stages (to impose an overall temporal sequencing).

From each metamodel class/subclass, instances can be generated and stored in the OPF repository (Figure 1). The OPF calls these process components, from which a selection is made specifically based on the current project or organizational demands. This results in a situational method. Rules for this situational method engineering are also contained within the OPF repository. This gives a high degree of flexibility to the process engineer in undertaking

process construction and tailoring to local conditions. A company-customized OPEN version is then “owned” by the organization, becoming their own internal standard, while retaining compatibility with the global OPEN user community.

Initially, the OPF repository contained about 30 predefined instances of Activity, 160 instances of Task and 200 instances of Techniques (the three main kinds of Work Unit) as well as multiple instances of Role, Stage, Language etc. Some of these are orthogonal to all others in their group and some overlap. For example, there are several Techniques in the repository for finding objects e.g. textual analysis, use cases simulations, CRC card techniques. Consequently, during process construction both association and integration strategies (Ralyté and Rolland, 2001) are needed.

4 MAJOR ELEMENTS OF MASE

MASE (DeLoach, 1999; Wood, 2000; Wood and DeLoach, 2000) aims to guide the designer through the multiagent-system development process from an initial system specification to a set of formal design documents. It includes two phases: analysis and design. The former deals with the specification of system goals, use cases, sequence diagrams, roles, and tasks, while the latter uses the analysis phase’s outputs to design agent classes, agent interactions, and agents’ internal components.

MASE is drawn from the legacy of object-oriented methodologies such as Rumbaugh’s Object Modeling Technique (OMT) and the Unified Modeling Language (UML). It also builds upon the pre-existing work in the realm of agents and multiagent systems e.g. Kendall and Zhao (1998) and Kinny *et al.* (1996). MASE is independent of any particular agent architecture, programming language, or communication framework. It is also capable of tracking changes throughout the development process. Every model created during the analysis and design phases can be traced forward or backward through the different steps to other related models. However, various limitations of the methodology are the assumptions that the agent system is closed, static, and involving only one-to-one inter-agent conversations.

MASE is supported by *agentTool* – a graphically-based, fully interactive software engineering tool that supports all MASE’s steps as well as code generation and automatic verification of inter-agent communications.

4.1 Stages used in MASE

Cycle: MASE is iterative across all phases with the intent that successive “passes” will add detail to the models until a complete and consistent system design is produced. This description fits OPF’s “Iterative, Incremental, Parallel Life Cycle” model.

Phases: MASE covers Analysis and Design. In terms of OPEN’s phases, MASE supports “Initiation” and “Construction”.

4.2 Tasks characterizing MASE

- ‘*Capturing Goals*’: includes 3 sub-tasks
 - ‘*Identifying Goals*’
 - ‘*Creating Use Cases*’
 - ‘*Structuring Goals*’
- ‘*Specifying Roles*’ involves identifying and modelling a set of roles required for the achievement of the captured goals. In MASE (and in many other MAS methodologies), role is considered as a “first-class” concept of analysis and design, a major focus of modelling. In many OO approaches, including UML V1.x, role is downplayed. However, role is pre-eminent in an OO methodology like OORam (Reenskaug *et al.*, 1996) and this more significant importance for role is echoed in the OPF.
- ‘*Identifying Tasks*’ involves associating each role with a set of tasks to detail how the role can fulfil a goal.
- ‘*Applying Use Cases*’: involves transforming use cases into sequence diagrams.
- ‘*Creating Agent Classes*’: involves identifying agent classes from roles and constructing an Agent Class Diagram that shows agent classes and conversations between them.
- ‘*Constructing Conversations*’: A MaSE conversation defines a coordination protocol between two agents. Conversations can be built by adding all the possible states and transitions derived from the sequence diagrams and tasks.
- ‘*Assembling Agents*’: involves identifying and constructing the internal components of each agent class. A designer can either define components from scratch or use pre-existing components.
- ‘*System Deployment*’: involves instantiating agent classes with agents, and allocating the agents to nodes.

4.3 MASE Techniques

- For 'Identifying Goals': MASE suggests analyzing detailed technical documents, user stories, formalized government specifications, and scenarios.
- For 'Creating Use Cases': MASE recommends standard 'Scenario Development' techniques.
- For 'Structuring Goals': MASE suggests hierarchically organizing goals in the order of importance. Each level contains goals that are roughly equal in scope, level of detail and importance. All sub-goals must relate functionally to their parent.
- For 'Specifying Roles': MASE derives roles from goals via a generally one-to-one correspondence. Similar or related goals, and goals that share a high degree of cohesion, may be combined into single roles. Some goals that involve distribution may imply distributed roles.
- For 'Identifying Tasks of each role': MASE does not discuss techniques for task identification. However it denotes that different roles should not share the same task. Shared tasks are a sign of improper role decomposition, and should be placed in separate dedicated roles.
- For 'Applying Use Cases': MASE follows standard OO techniques for transforming use cases into sequence diagrams. A few adaptations made to the conventional techniques are that every participant in a MASE's sequence diagram should be a role, and information flows

- between participants should represent instances of events occurring between the two roles.
- For 'Creating Agent Classes': MASE derives agent classes from roles via a generally one-to-one correspondence. In some cases, multiple roles may be combined into a single class, or a single role mapped to multiple agent classes.
- For 'Constructing Conversations': MASE suggests deriving inter-agent conversations from inter-role Sequence Diagrams and Task State Diagrams.
- For 'Assembling Agents': MASE recommends three methods for assembling components to define an agent class: 1) to select a pre-defined agent architecture and either instantiate the components as is or modify their attributes and methods; 2) to use pre-defined components and assemble them into a user-defined agent architecture; or 3) to define both components and agent architecture from scratch.
- For 'System Deployment': The instantiation and allocation of agents in MASE are guided by the considerations of communication traffic and processing powers.

4.4 MASE Work Products

- *Goal Hierarchy Diagram*: this is a simple tree structure where goals are represented as boxes and goal-subgoal relationships as directed arrows from parents to children.
- *Use Case Diagrams*: (identical to UML)
- *Role Diagram*: MASE adopts the Role Diagram

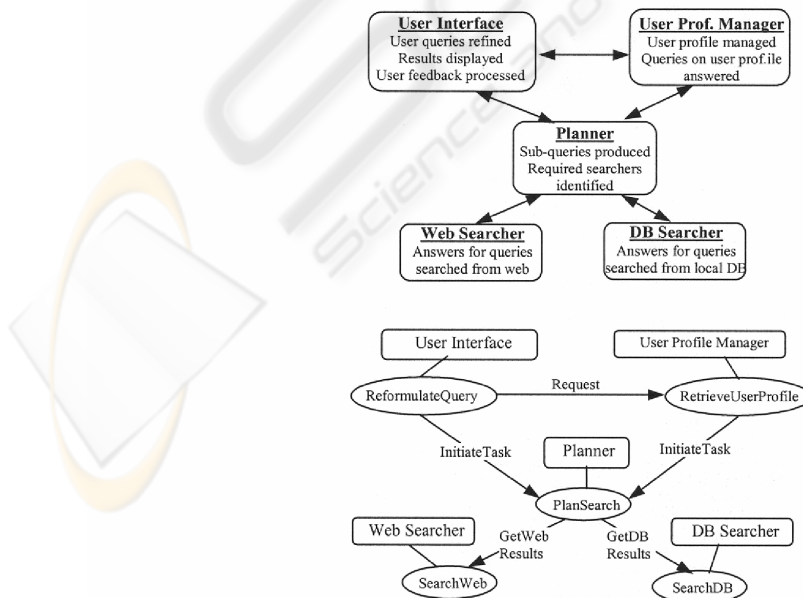


Figure 2 MASE's role diagram and extended version thereof

- from Kendall's (2000) Role Model (Figure 2). Lines between roles show possible communication paths between roles. Goals associated with each role are listed under the role name. An extended version of the Role Diagram shows the set of tasks associated with each role (denoted as ellipses attached to the role).
- *Task State Diagram*: (corresponds to UML State Transition/Statechart Diagram)
 - *Sequence Diagram*: (corresponds to UML Sequence Diagrams, with actors being roles.)
 - *Agent Class Diagram*: different from UML Class Diagram in terms of
 - Class interface: Each OO class has attributes and operations. Each MASE agent class has a goal and may or may not provide services to other agents.
 - Semantics of relationships between classes: in a UML Class Diagram, the connections represent association, composition, aggregation or inheritance relationships between classes. In MASE, the connections between classes denote conversations that are held between agent classes, and the label next to each agent class represents the role the agent plays in a conversation. An example of a MASE-recommended Agent Class Diagram is shown in Figure 3.
 - *Communication Class Diagram*: corresponds to UML State Transition Diagram. However, a Communication Class Diagram focuses on the states of an agent *during a particular conversation*. Two state diagrams are required for each conversation (one for the initiator and one for the responder). The labelling on the arcs follows conventional UML notation *rec-mess(arg1)[cond]^trans-mess(arg2)*. The actions specified within a state represent

processing required by the agent.

- *Agent Class Architecture Diagram*: MASE does not impose any template for this diagram, although a UML Component Diagram seems to be a good substitute, based on MASE's use of CBSE. MASE also suggests using a State Diagram to model the sequence of events passed from one component to another.
- *Deployment Diagram*: different from UML Deployment Diagram as follows:
 - The three-dimensional boxes represent nodes in UML, but agents in MASE
 - The connecting lines represent physical connections between nodes in UML, but conversations between agents in MASE
 - MASE uses dashed-line box around agents to indicate that these agents are housed on the same physical platform.

[Note: DeLoach (1999) suggests a Communication Hierarchy Diagram, which is not mentioned in other references. This diagram simply defines the relationships between the various conversations within MAS. The conversations themselves are described in Communication Class Diagrams.]

4.5 Languages discussed in MASE

MASE proposes its own modelling languages but claims to be independent of any particular implementation language, recommending:

- *AgML* (Agent Modelling Language): a graphically based language which describes the types of agents in the system and their interfaces to other agents. Although AgML diagrams look similar to OMT or UML diagrams, they have additional features and have modified traditional OO semantics to capture notions of agency and cooperative behaviour.
- *AgDL* (Agent Definition Language): based on

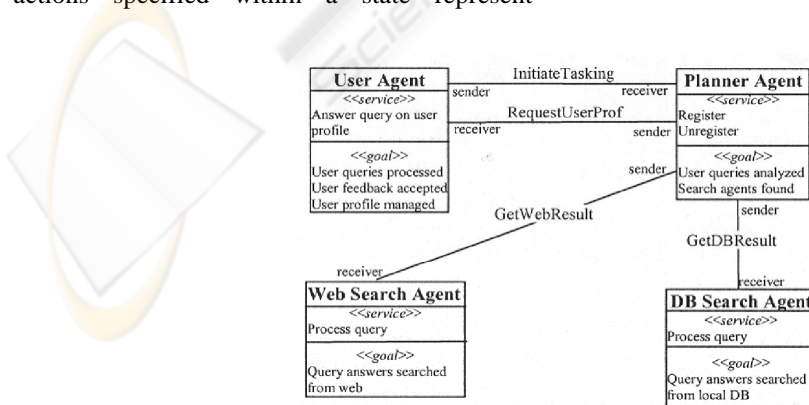


Figure 3 Exemplar agent class diagram in MASE

first-order predicate logic to describe the internal behaviour of each agent (not supported in the current OPF repository).

In this section, we outline the various Tasks, Techniques and Work Products that are proposed in this paper as additions and modifications to the OPF repository in order to incorporate agency concerns as identified in MASE. These new process components

5 ADDING SUPPORT TO THE OPF DERIVED FROM MASE

Table 1: Mapping between MASE and OPF

MASE	Supporting OPF Tasks	Supporting OPF Techniques
<i>Capturing goals</i>	Model goals	OPF user requirements techniques Tropos techniques Hierarchical task analysis
<i>Specifying roles</i>	Identify agents' roles Construct the Object Model Identify CIRTs	Role Modelling
<i>Identifying tasks</i>	Model agents' roles Determine agent reasoning	Hierarchical task analysis Responsibility modelling
<i>Applying use cases</i>	Construct the Object Model	
<i>Creating agent classes</i>	Model agents' roles Map roles onto classes Construct the agent model (new)	Intelligent agent identification Agent internal design (new)
<i>Constructing conversations</i>	Construct agent conversations (new)	Interaction modelling State modelling
<i>Assembling agents</i>	Design agent internal structure (new)	Agent internal design (new)
<i>System deployment</i>	Create a software/system architecture	Coding Distributed systems partitioning and allocation

have been identified directly from the MASE literature and are summarized in Table 1.

5.1 Existing support and mapping between OPF and MASE

The capture of goals is supported in Agent OPEN through the Task: 'Model goals' (Henderson-Sellers *et al.*, 2003b). Roles are covered by Task: 'Identify agents' roles' (Debenham and Henderson-Sellers, 2003b) and standard tasks of 'Construct the Object Model' and 'Identify CIRTs' which, together, cover the identification and modelling of roles.

MASE's Task 'Identifying tasks' is mirrored by Agent OPEN's "Model agents' roles" and "Determine agent reasoning" (Debenham and Henderson-Sellers, 2003b) because tasks in MASE represent the functionality of agent roles. 'Construct the Object Model' Task of OPF covers the MASE Task of 'Applying Use Cases' although it should be noted that actors in the sequence diagrams should be roles rather than classes and objects.

OPF's Tasks 'Construct the Object Model' and 'Identify CIRTs' only cover the identification of OO

classes. Therefore a new Task: 'Model agents' roles' was introduced by Debenham and Henderson-Sellers (2003a). Using this and the existing OPF Task: 'Map roles on to classes' offers adequate support. While the linkages between objects in the Object Model represent association, aggregation, and inheritance relationships, the relationships between agents in the Agent Class Diagram represent *inter-agent conversations*. Thus, we need to consider whether the conventional relationships in the context of OO systems are relevant to AO systems. We thus propose three new Tasks: 'Construct the agent model', 'Design agent internal structure' and 'Construct agent conversations' plus a new Technique: 'Agent internal design'.

With respect to techniques recommended by MASE, goal identification is supported in the OPF by several standard user requirements techniques as well as the Agent OPEN techniques "borrowed" from Tropos (Henderson-Sellers *et al.*, 2003b), together with techniques for structuring goals. In addition, the pre-existing OPF Technique: 'Hierarchical Task Analysis' is also available.

For MASE's 'Specification of roles' techniques, OPF offers the Technique: 'Role Modelling', which covers various aspects of role modelling, although is weak on guidance for the identification of roles. MASE's 'Identifying tasks of each role' technique corresponds to 'Hierarchical Task Analysis' and 'Responsibility modelling' techniques in the OPF, even though these techniques need to be extended to cater for roles/agent classes. MASE also suggests producing a State Diagram for each task, not mentioned in these two OPF techniques.

For techniques to support MASE's 'Creating Agent Classes', the OPF offers Technique: 'Intelligent agent identification'. This technique, however, currently covers only the need for agents and agent modelling notation. Much extension is required. OPF also offers various techniques for OO class identification/modelling (such as 'Abstract Class Identification' and 'Class Naming'), which can be extended to support the identification of agent classes, taking into account the major differences between OO and agent classes – e.g., agent classes are generally more coarse-grained than OO classes. (The OPF 'Granularity' Technique, in particular, should be extended to account for this difference). Consequently we propose here a new Technique: 'Agent internal design'.

Conversations can readily be constructed using OPF Techniques: 'Interaction modelling' and 'State modelling', perhaps with minor extensions. Techniques to support the assembly of agents in MASE are found in OPF's new Technique: 'Agent internal design'. Finally, system deployment issues are supported by Technique: 'Coding' and distribution allocation issues through Technique: 'Distributed systems partitioning and allocation'.

Overall, three new Tasks are identified together with one new Technique. Additionally, two new Work Products are recommended for inclusion into the OPF repository (see below).

5.2 New Tasks

An OPF Task describes something that needs to be done. Its name is verblike, describing an action to be undertaken. The three new Tasks are described formally as follows.

TASK NAME: Construct the agent model

Focus: Static architecture

Typical supportive techniques: Intelligent agent identification, Control architecture

Explanation: An analogue of the "object model" as the main description of the static architecture needs to be constructed. This model will show the agents, their interfaces and how they are connected both with other agents and other objects within the system being designed.

TASK NAME: Design agent internal structure

Focus: Internal structure of agents

Typical supportive techniques: Agent internal design, 3-layer BDI model, Reactive reasoning

Explanation: Using an appropriate model for the internal agent architecture, such as the BDI model, the internal structure of each agent needs to be determined. If a hybrid architecture is used, both ECA rules (event-condition-action rules) and I-rules (inference rules) may be needed. If using a BDI architecture, then goals and plans will be needed (see Agent OPEN Tasks: Model Goals and Models Plans: Henderson-Sellers *et al.*, 2003b). When using Prometheus, high level capabilities are identified and iteratively decomposed, finally resulting in plans, internal events and data.

TASK NAME: Construct agent conversations

Focus: Detailed agent-agent interactions

Typical supportive techniques: Scenario development, Collaborations analysis, Interaction modelling, State modelling

Explanation: Interactions and their protocols are modelled in agent-oriented systems by conversations that formally define the coordination protocol between any pair of agents. The construction of agent conversations can be accomplished by identifying all possible states and transitions which are themselves in turn derived from an analysis of the sequence diagrams and tasks.

5.3 New Techniques

An OPF Technique describes how a Task is accomplished i.e. "how" something is done. One new Technique is identified and described here.

TECHNIQUE NAME: Agent internal design

Focus: Internal features of an agent

Typical tasks for which this is needed: Design agent internal structure

Technique description: The fine detail of an individual agent must be described in terms of its attributes and operations (as for objects) but more importantly in terms of its goals, plans, capabilities, responsibilities, events responded to and pre- and post-conditions.

Technique usage: Document each of these internal characteristics (or features) of every agent in the system. The detail should be sufficient for coding to take place easily from these design specifications.

Deliverables: Capability diagram

5.4 New Work Products

An OPF Work Product describes the input or output of a Task.

NAME: Goal hierarchy diagram

OPF CLASSIFICATION: Architectural set

RELATIONSHIP TO EXISTING WORK PRODUCT: None

BRIEF DESCRIPTION: A graphical description of the hierarchical or tree structure of goals. Goals and subgoals are represented by boxes and directed arrows run from each goal to each of its subgoals.

NAME: Role diagram

OPF CLASSIFICATION: Architectural set

RELATIONSHIP TO EXISTING WORK PRODUCT: Class diagram but emphasizing roles rather than classes

BRIEF DESCRIPTION: Although a role diagram, as described in MASE, can be documented using UML, particularly Version 2, the increased importance of roles in agent technology as compared to object technology suggests that this should be a separate, named diagram type. It can be documented using standard UML role notation.

6 SUMMARY AND CONCLUSIONS

As part of an extensive research programme to combine the benefits of method engineering and the OPF to create a highly supportive methodological environment for the construction of agent-oriented information systems, we have analysed here contributions from the MASE AO methodology. We have identified three new Tasks, one new Technique and two new Work Products, but no additional Roles or Stages.

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