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Merit of Adaptable Pairing as an Agile Systems Engineering Knowledge Management Practice

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Context

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**Frequent modification of
on-board aircraft mission systems for new or different
intelligence, surveillance, and reconnaissance
technology and accompanying infrastructure.**

**Frequent refurb of aircraft structural integrity,
often with unexpected/unscheduled
surprises in need of attention.**

**All with increasing needs for decreasing schedules
in Quick Reaction Capability response**

Purpose

Systems engineers often experience dramatic project shifts and rapid technological advances, straining the engineering organization.

Project teams also deal with changing personnel, mistakes or rework, and slow engineering response times to unplanned needs.

These factors can lead to reduced quality, increased costs, and slipped schedules.

Due to constantly evolving projects and project teams, knowledge management must be able to adapt based on current needs and resources.

The purpose of this paper is to present knowledge management issues that must be addressed during an engineering project, and to propose a useful operational architecture for knowledge management.

This architecture will provide an image of how agile knowledge management can be used by systems engineers to counter the turbulence in today's technical work forces.

The proposed architecture is best described as *adaptable pairing,* where two or more individuals engage in knowledge sharing and assignment swapping to complete a specific project task.

Paper Content

This paper begins with a discussion of knowledge management issues and elements.

The second part of this paper addresses the dynamic environment where knowledge management decisions and activities take place.

Finally, an agile adaptable-pairing approach to knowledge management is presented. The operational architecture of the approach enables and facilitates effective transfer, assimilation, and application of knowledge in unpredictable and unstable systems engineering environments.

On Knowledge Management

The late management consultant, Peter Drucker, described knowledge as being the "only meaningful economic resource."

Indeed, organizations can be viewed most importantly as knowledge-creating entities who's most valuable resource is knowledge generated through human experience (Nonaka 2000).

Knowledge management within organizations seeks to provide some organizational structure to knowledge creation, transfer, and assimilation. It is described by (Malhotra 2001) as the management processes of acquisition, conversion, and application of knowledge.

Knowledge management decisions and activities are often reactions to changes in the environment, such as technology advances, shifting market demands, and workforce transitions. There is significant research into how workforces can be designed to respond effectively to change. The term *agility* has been applied to workforces that are in "a continual readiness to change" (Goldman 1995).

An agile work force is often a necessity rather than simply a particular approach (Alavi 2013).

Explicit and Tacit Knowledge

Explicit knowledge includes company standards, manuals, specifications, formulas, proofs, and data. Explicit knowledge is fairly easy to access and transfer between individuals, and should require minimal interpretation with respect to intent and application. (Kogut 1992) distinguishes information as a type of explicit knowledge, in that it can be "transferred without the loss of integrity." Explicit knowledge may comprise the majority of an organization's core knowledge, accessible to all employees as guidance for most day to day activities.

Tacit knowledge is derived from human experience. Kogut describes tacit knowledge as human "know-how". Tacit knowledge is not formally documented, and may not be part of the common knowledge available to all employees. It is accumulated skill or expertise (von Hippel 1988).

Tacit knowledge is more difficult to transfer between employees, because it can be subjective and may be difficult to describe or transfer as a concise knowledge package. Examples of tacit knowledge are beliefs, perspectives, mental models, and ideas (Nonaka 2000).

Generally, tacit knowledge comes from first-hand experience of how to handle a given situation. (Davenport 2005) claims that important decisions are more likely to be made using knowledge in the heads of staff rather than information from other channels. It is likely that the most significant technical challenges (complexity) faced by an organization do not have clean solutions that can be referenced in a document or book. Entire organizations, from the leadership team to the junior employees, rely heavily on tacit knowledge from key personnel.

Tacit Knowledge is Difficult to Capture

A common distinguisher between knowledge and information or data, is that knowledge involves human judgement. "Knowledge consists of truths and beliefs, perspectives and concepts, judgements and expectations, methodologies and know how" (Lefrere 1997).

Knowledge is also context specific (Nonaka 2000). It is not enough for an organization to have a library of available resources if it does not have the personnel to distinguish what information is necessary and how it should be applied to a given situation.

This is one reason tacit knowledge may be particularly difficult to capture and assimilate. As a consequence, tacit knowledge is often neglected in knowledge growth "blueprints" that explain what to learn, but contain little insight into how to apply it (Kogut 1992).

Mission:
Right Knowledge in Right Place at Right Time

The key output of knowledge management is readily available knowledge that drives the success of a project.

There must be a process that gains the right type of knowledge at the right time, and a process that delivers the right knowledge to the right place.

Companies acquire information and knowledge in many different forms.

Some forms, such as airworthiness directives for a commercial airline, may be delivered in a predictable form that allows routine and quick integration. Soon after the directives have been received, they are sent to the relevant people who know how to act on them.

Integration of other forms of knowledge may not be as straight forward. A company that is looking to branch off into a new technology market may hire new employees with experience in that field. The integration of that new knowledge into the existing organizational structure and culture may be the most significant challenge of the knowledge acquisition process.

Challenges

Work forces are not static. From a functional point of view, the movement of workers within an organization can add or subtract knowledge from a project team. From a numerical point of view, hiring and downsizing follows the organization's contract load, with potentially dramatic change in an organization's knowledge base.

Technology evolves. With new or evolving technology, existing knowledge bases become insufficient, irrelevant, or obsolete. There are competitive benefits for organizations that embrace change rather than rely on traditional "sweet spots" or "core competencies."

Shifting market opportunities. New market opportunities likely require unique knowledge that may not be well documented, and/or currently exists outside of the organization.

Need: Agility in Knowledge Management

In the context of a systems engineering project, any knowledge management architecture must be agile.

Agility is a system's ability to make strategic moves to counter or take advantage of a constantly changing environment.

An agile knowledge management system must account for the fluidity of the work force, technology progressions, and shifting customer wants.

This contrasts with a conventional knowledge management approach that gathers all the perceived knowledge necessary to complete a project and struggles to adjust to environment changes as the project progresses.

For an aircraft modification team, the baseline knowledge profile may consist of design, stress, aerodynamic, electrical, thermal, and systems engineers.

There will likely be a variety of backgrounds and experience levels.

There will generally be some level of functional and integrated leadership assigned and tasks will be delegated as deemed appropriate.

If this is the extent of knowledge management, then the project may suffer from many of the challenges discussed previously.

Adaptable Pairing

SE project knowledge management must operate in the present, facilitate rapid sharing of knowledge, fill sudden voids, and catch early mistakes.

Adaptable pairing has the potential to meet these needs.

Pairings should be based on a particular task and applicable knowledge.

Establishing and maintaining complimentary pairs maximizes benefits.

The management of pairing plans may be the responsibility of project leadership, or it may rely more on self-organization within the team.

Pairings should facilitate decision making, quick response times, and minimal rework.

Pairings may change between projects, or even multiple times throughout a project.

An individual may participate in multiple pairing relationships simultaneously.

The general pairing relationship will transfer knowledge through discussions to solve daily challenges, and through work checks with assignment swapping.

Proposal: Getting Started

How does a project engineer establish and maintain effective pairings throughout the life of a project?

The first step establishes a baseline pairing plan, founded on defined tasks and team members. This should occur immediately following the creation of project requirements.

Pairing plans require thought and understanding of the necessary tasks and available project knowledge. This contrasts manpower lists that simply ensure there will be an adequate number of engineers available to complete the entire scope of work.

The primary considerations of the pairing plan are to create pairs that will make sound decisions in relation to their tasks and minimize their mistakes or rework.

Effective pairing plans should:

- **Clearly define task boundaries for each pair.**
- **Create self-sufficient pairs – pairs that possess or have immediate access to the tools and knowledge necessary to complete assigned tasks.**
- **Create pairs with some common core knowledge – pairs that can engage in useful knowledge sharing and assignment swapping.**

Effective pairing plans should not:

- **be limited to engineers of the same title or functional groups**
- **consist of traditional mentor relationships that may hinder response times**

Maintaining & Sustaining Effectiveness

As a project progresses, required tasks and personnel evolve. These evolutions require modification to the pairing plan.

The project engineer needs to establish a feedback loop to constantly evaluate the performance of each pair and knowledge needs of each task.

Pairs should also be free to report any knowledge or task concerns to the project engineer.

At any point in time effective pairing plans should be maintained by the project engineer.

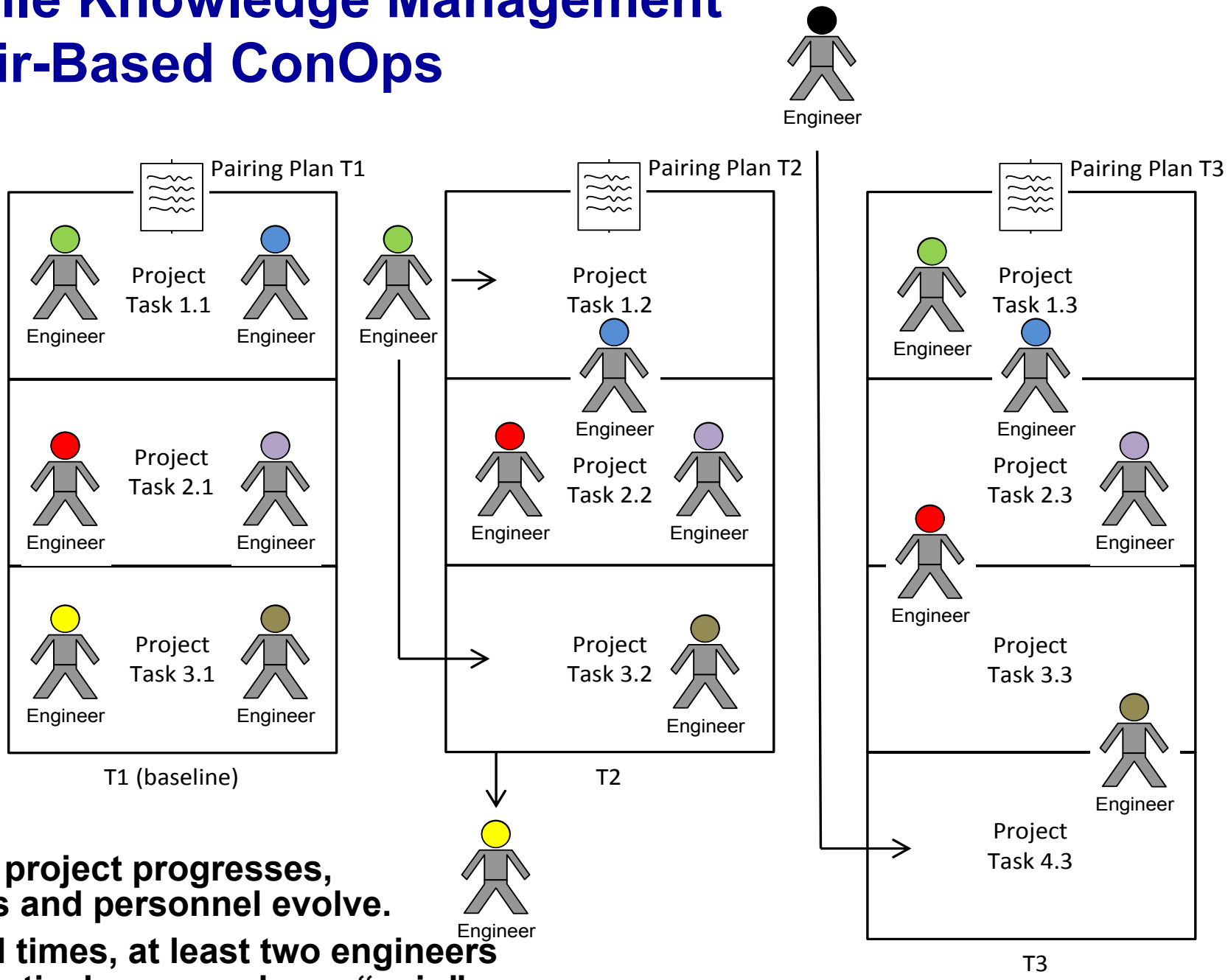
Individuals should be expected to fully engage in pairing activities and view them as a necessary to maximizing project success.

Within a pair, each individual should:

- **Leverage all available knowledge to solve daily challenges.**
- **Fully understand all assigned tasks and work performed by the pair.**
- **Create a work swapping plan.**

The activity of monitoring and adapting pairing plans should be performed throughout the project. as the cost of mistakes and poor decision making increases as a project progresses.

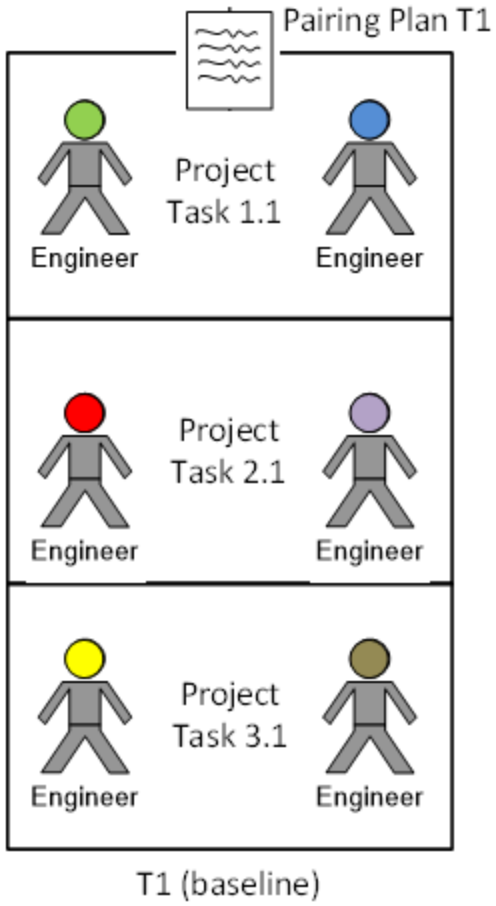
Agile Knowledge Management
Pair-Based ConOps



As a project progresses, tasks and personnel evolve.

At all times, at least two engineers are actively engaged as a "pair."

Project Time (Phase) 1

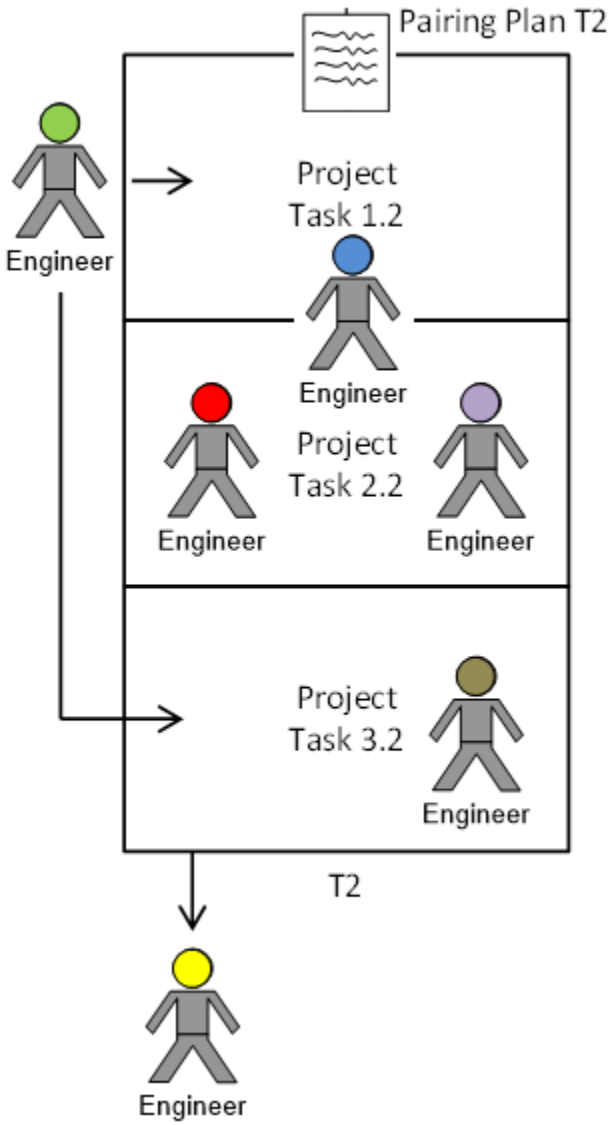


At the project onset (T1), three unique tasks are defined.

An initial pairing plan delegates each task to two engineers.

Each pair engages in knowledge sharing and assignment swapping to progress on their assigned task.

Project Time (Phase) 2



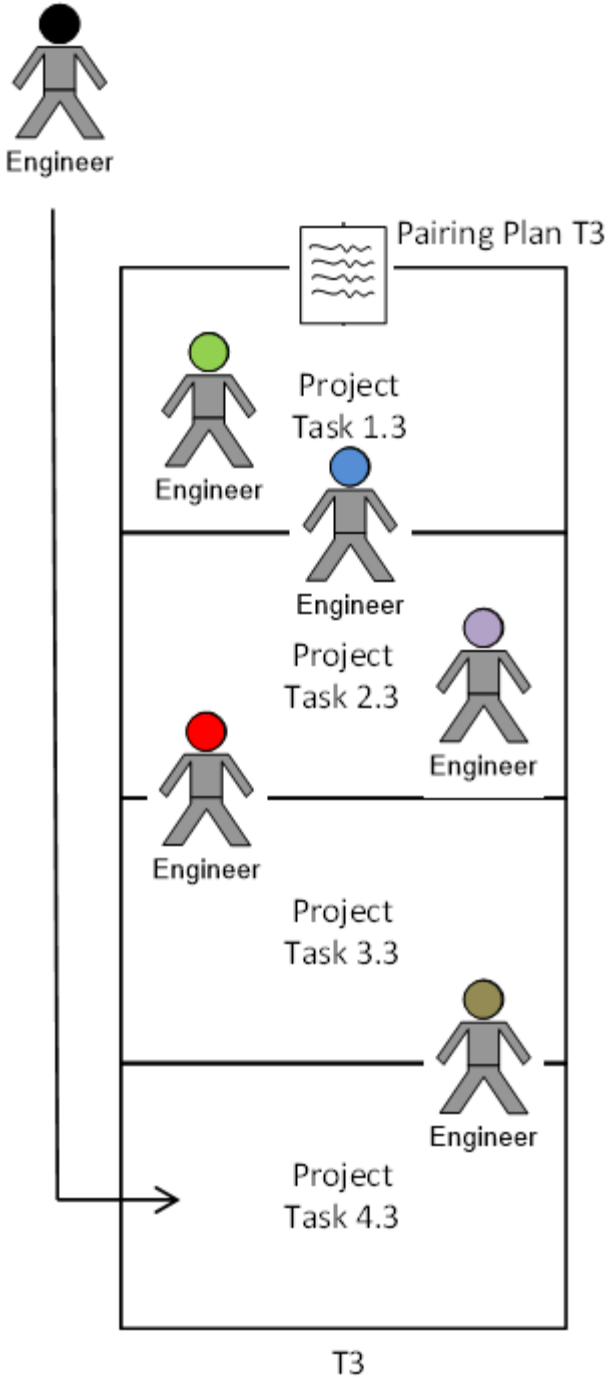
After a period of time (T2), the Yellow Engineer assigned to Task 3 is reassigned to a different program.

It is decided that the Green Engineer is the best fit to fill the open spot on Task 3, while still performing a pairing role on Task 1.

Also at T2, the scope of Task 2 increases and requires additional knowledge support that can be provided by the Blue Engineer.

The pairing plan has shifted to account for changes in personnel and knowledge requirements.

Project Time (Phase) 3



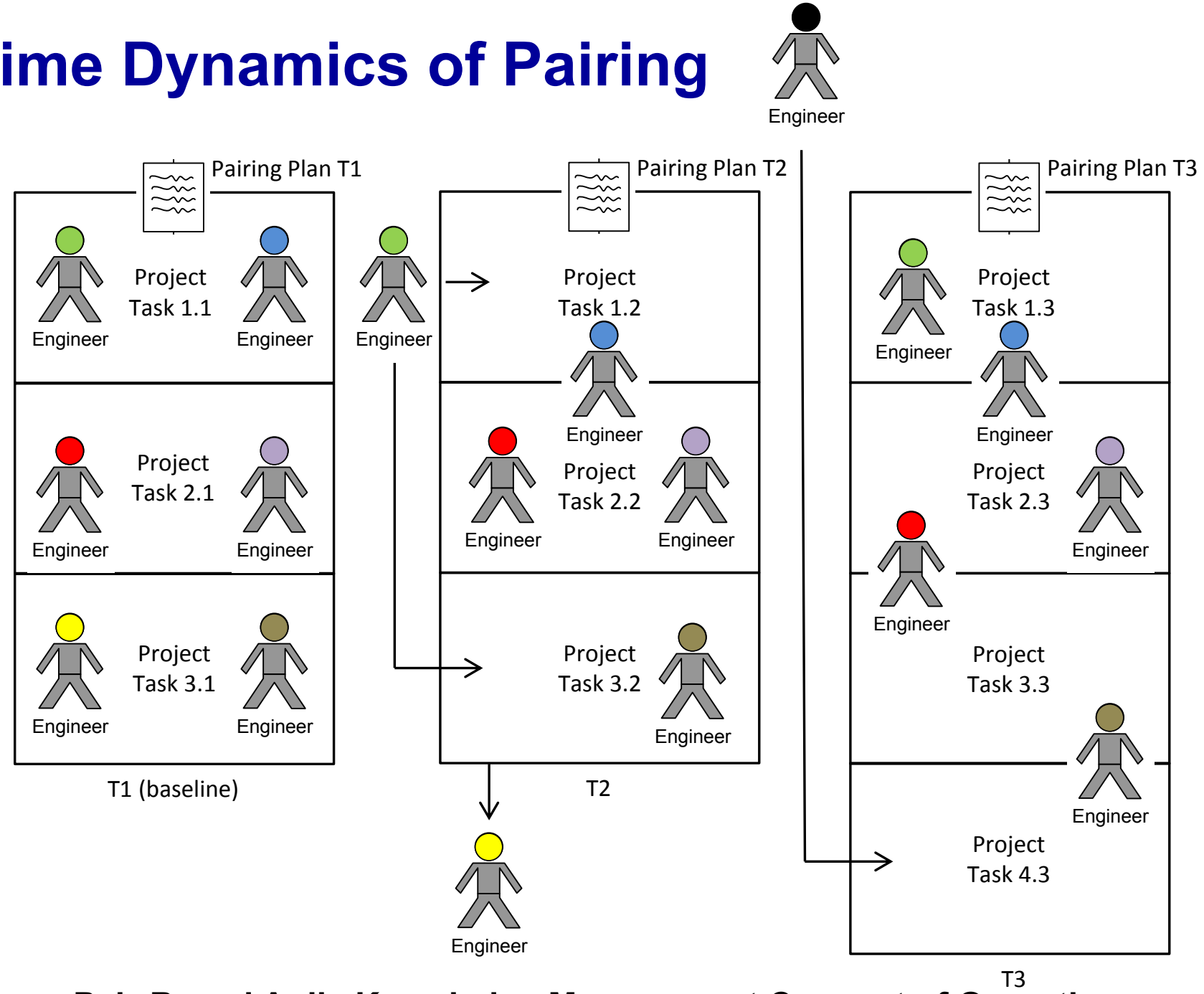
Towards the end of the project (T3), the customer has requested an additional amount of work to be performed (Task 4).

Pairing for this new task is accomplished by shifting the Brown Engineer to an additional Task, and introducing a new engineer (Black Engineer) to Task 4.

At the same time, Task 3 has progressed to a new stage where the expertise of the Red Engineer is desired.

The Green Engineer shifts back to working full time on Task 1.

Time Dynamics of Pairing



Pair-Based Agile Knowledge Management Concept of Operations

Where Does the Agility Come From?

A system architecture of:

- **drag-and-drop resources (a variety of engineer types),**
- **that readily interface according to a plug-and-play passive infrastructure (pairing plan),**
- **sustained by an active infrastructure of designated responsibility for resource evolution, resource readiness, pair assembly, and pairing-plan evolution.**

A system design concept of reusable, reconfigurable, scalable resources.

An operational behavior of real-time acquired and applied learning to deal with an unpredictable, uncertain, evolving environment.

Studies of Pairing in Software Development

Pair-programming is a practice for generating software. It can be described as "two programmers working side by side at one computer on the same problem" (Cockburn 2001).

There is evidence in both research and practice to support the claim that work pairs can be beneficial (Williams 2000).

The actual benefits of pair programming are no doubt task specific. For example, pair programming has shown to be more beneficial for higher complexity tasks (Dyba 2007).

There is evidence to suggest that pair programming can reduce project times. "By working in tandem, the pairs completed their assignments 40% to 50% faster".

Studies support pair programming benefits as:

- **Reduces the risk of errors and debugging time (quality & duration effect)**
- **Provides more in depth reviews (quality effect)**
- **Provides an opportunity to share knowledge (quality & duration effect)**
- **Improved personal job satisfaction (among those who accept it)**

Note: Referenced studies do not support lower development costs, as total person-hour effort appears to increase.

Pairing benefits appear to be
increased quality and reduced total duration

Wrap Up

Knowledge is grouped into tacit and explicit categories. Tacit knowledge predominately resides in the heads of individuals and is often difficult to quantify and transfer. Knowledge management operates in an unsteady and often fast paced environment where it may be hard to recover from a slow response or lack of foresight.

An agile approach is necessary to deal with the constant personnel, technology, and customer driven changes. The proposed agile architecture for knowledge management consists of adaptable pairs or working groups. The value proposition of constantly evolving pairs is increased project quality, lower project cost, and more predictable schedule performance.

Beneficial activities of pairing are assignment swapping and knowledge sharing. These activities lead to fewer errors and rework, faster resolution of issues, and organizational resiliency to changing personnel. Evidence from pair programming is used to support these claims.

The creation and management of pairing plans is vital to the success of knowledge management. Pairings should form primarily for the benefit of the project – increased quality, lower costs, and reduced schedule time.

Secondary benefits such as knowledge growth and work satisfaction are also important to the sustainability of a technology company. Over time, pairings will increase the skillset and experience of the workforce for successive projects. With each pairing experience, the knowledge base of the organization evolves and becomes more aligned with the current challenges facing the organization.

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