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COVES: an e-business case study in the engineering domain

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Abstract *The paper discusses how to succeed in the new economy by utilizing e-business in transforming business processes and strategy. The Collaborative One-Stop Virtual Engineering Services (COVES) portal provides users with collaborative engineering services for government agencies and private sectors involved in various areas like safety, health and environment. The portal helps in design through modeling and simulation over the Internet for the above sectors. The portal provides a Web-based environment for tackling the above issues during the design of a factory via the use of e-computational fluid dynamics. Besides the above, COVES has re-engineered the traditional business processes associated with construction industry by integrating various enterprises. The portal also improves competitiveness by installing a strong culture of knowledge collaboration and increased accessibility to expensive high-performance-computing (HPC) resources and tools. The integrated inter-enterprise workflow with various public and private parties has simplified the procedure and expedites building plan approvals.*

1. Introduction

The globalization of the market place has presented new challenges for co-operative working. In response, most enterprises have made significant investments in enterprise software for streamlining internal operations as well as for inter-enterprise cooperation and collaboration. As outlined in Bill Gates's book entitled *Business @ the Speed of Thought* (Gates, 1999), business in the year 2000 and beyond will be accelerated by the flow of digital information. To conduct business at the speed of thought, we need to provide a well-integrated flow of the right information to the right part of the organization, and also across extended enterprises. This paper presents a system that enables users to conduct e-CFD at the speed of thought.

This project, Collaborative One-Stop Virtual Engineering Services (COVES) can be likened to a small sheltered inlet or bay. It is a small, private and secure place where professionals from various areas can come together to work on a project. This sheltered inlet or bay is at the same time connected to the larger ocean, which is analogous to COVES being connected to the rest of the world via the Internet. In addition to a secure "place" to work, COVES also provides the tools necessary for engineers, architects and developers to design and test

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out ideas and concepts. This can be done with the help of visualisation and simulation tools such as computational fluid dynamics (CFD), computational structural dynamics (CSD) and computational thermal dynamics (CTD).

CFD is a method for solving complex fluid flow and heat transfer problems on a computer. CFD tools are used in a wide variety of engineering applications like aerospace, combustion, chemical, water, radiation, petroleum, marine, metallurgical etc., architecture and building science, and environment. The COVES system is a system that focuses on CFD. This system re-engineers the traditional business process of CFD associated with the construction industry by automating the submission and approval of the building plans, turning it into webCFD.

The COVES is a pilot project with the joint effort of the Ministry of Manpower, The Computational Fluid Dynamics and the Internet Computing Group of IHPC. Its project proposal has won "The Enterprise Challenge" (TEC) award from the Prime Minister's office of Singapore in the year 2000 (TEC: The Enterprise Challenge, n.d.).

The rest of the paper is organized as follows. Section 2 discusses the integration of inter-enterprise business processes, and an outline of the workflow paradigm used in COVES, as well as gives a general description of the automation of CFD business processes. System implementation details are explained in section 3. Section 4 presents a brief description of the business model used for COVES. Section 5 shows the savings offered by COVES system in terms of money and time. Section 6 briefly presents related works in this area. We conclude in section 7 with a summary and discuss future avenues of our work.

2. Business process integration

Figure 1 show the various enterprises involved in the system and the integration of inter-enterprise business processes. The enterprises included in the system are One Stop Submission Center (OSSC), COVES in Institute of High Performance Computing and various government agencies. OSSC facilitates electronic submission, processing and approval of building project documents over the Internet (for Singapore-based industry). OSSC is part of Construction and Real Estate Network (CORENET), an automated plan submission cum checking systems. This is a major initiative spearheaded by the Building and Construction Authority, a statutory board under the Ministry of National Development of Singapore. Approving agencies include Occupational Health Department, Fire Safety Bureau and Pollution Control Department. The CORENET in collaboration with COVES and several other public and private organizations aim to re-engineer the business processes of the construction industry to improve turnaround time, productivity and quality.

With the integration of the above enterprises the client can upload the draft plan via the CORENET/OSSC instead of personally going to the various offices

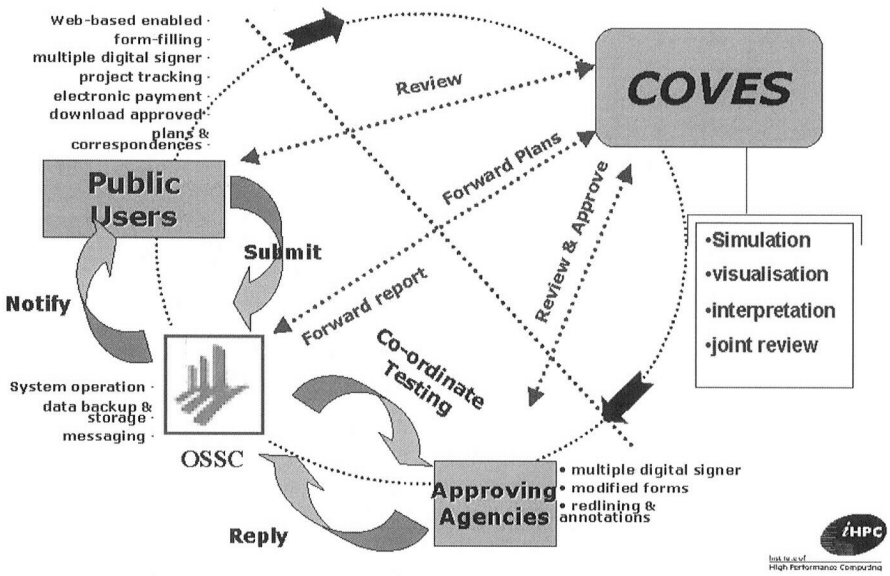

Figure 1.
COVES integration with other enterprises

to get the factory plan application approved. The client can upload the project plan directly to COVES HPC cluster if the nature of the work is consultancy. Among the project submitted by the clients to the OSSC, the projects that require CFD-related testing will be forwarded to the COVES system. The Web-based CFD (webCFD) workflow begins when the client upload the documents. Workflow is concerned with the automation of procedures where documents, information or tasks are passed between participants according to a defined set of rules to achieve, or contribute to the business goal. Workflow can be manually organized or organized using IT resources to provide process automation. The workflow model used for the integration of CFD internal business process is "group-centered workflow", i.e. the work management problem is tackled by the coordination and tracking of the activities of individuals. The design, development and workflow model of the portal is given in more detail in (Emilda et al., 2001).

The COVES system is Web-based, hence the engineer just needs to log into the system to see the project details. Every CFD engineer involved in the project will be able to see the current and new project in his worklist when he logs into the system. A worklist is a logical set of data that represents collection of activities to be performed by particular participant (role). Whenever any user of that role is logged into the system, the corresponding worklist will be presented to him and he can select any of the activity to start the job. Each user just needs a browser and does not require any software installed locally in his desktop. The user-friendly graphical user interfaces of the system avoids user training also. The screen layout of a typical worklist of an engineer is shown in

Figure 2. The worklist page shown displays a list of all the works that have been assigned to him.

Each project received by the system is handled by a combination of life cycles and workflow. Life cycle allows the administrator to define the various phases/states of evolution through which the project matures. Workflow or sub-life cycle is applied to each state to establish the specific events and tasks occurring within each state. Workflow also tracks all the activities associated with each state of the life cycle from the time each state is initiated until it comes to an end. The major life cycle defined for COVES is named "Auto Start Web CFD Life Cycle". Figure 3 shows the major states of this life cycle. The first phase of the life cycle is initiated by the online-submission of a draft plan relevant to CFD simulations by the client. The job request from the OSSC/COVES automatically triggers a Servlet, which uploads the project documents submitted by the customer and activates the workflow application. The workflow associated with this phase creates a project cabinet for each project uploaded. A software entity called "Project Document", which encapsulates all the details and documents submitted by the client is also

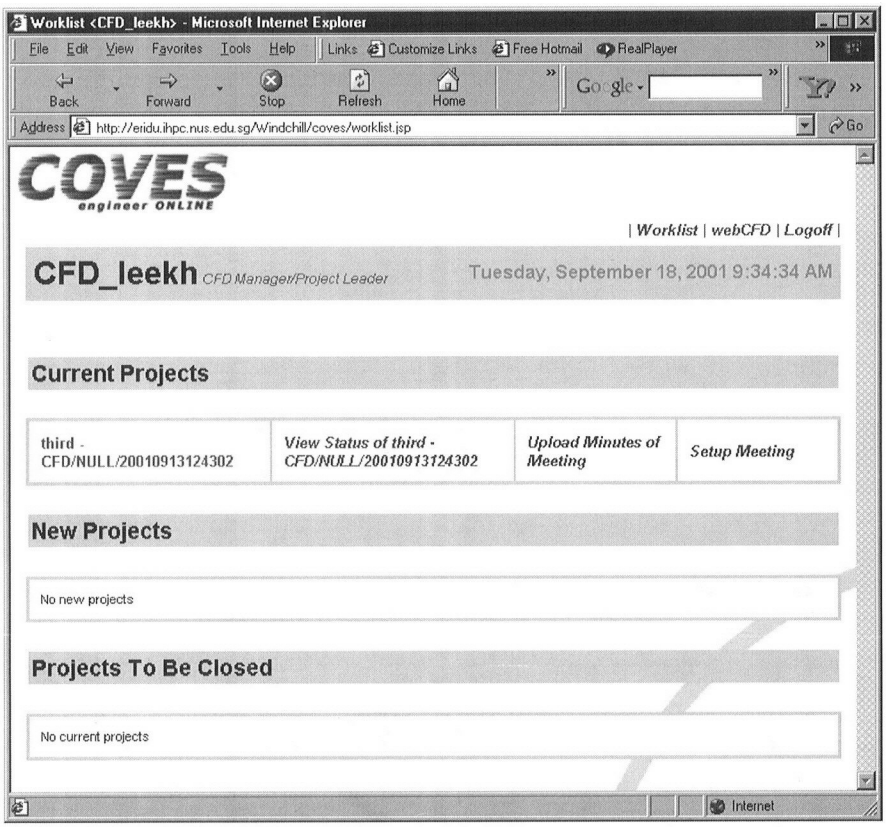

Figure 2.
Worklist of CFD engineer

created and stored in the project cabinet. This primary business object (BO) is a Java class defined for this purpose. Instantiation of the BO send email notification to the CFD manager about the new project.

The workflow associated with the "pending approval" phase provides the CFD manager with all the details necessary for him to evaluate/assess the relevance of the project. If the project is relevant to CFD it will be assigned to the appropriate engineers to carry out the necessary simulation or other tasks based on the factory plan submitted. In the "CFD in work" phase, CFD engineer carries out the necessary simulations to ensure issues such as health, fire safety and emergency response planning. During the design stage of factory, the above issues can be tackled by the use of three-dimensional visualization and simulation of the dispersion of airborne contaminants, spills and ventilation. A life cycle named "webCFD life cycle" is associated with this phase, which defines all the CFD internal processes. Acquiring of CAD data, geometry cleanup and fixing, model verification with client, post processing, CFD simulation, boundary conditions specifications or verification and meshing are some of the important internal CFD processes. Workflow applied to each process tracks all the activities and automatically forwards the task to the next user defined in the workflow, possibly dependent on the specific action or decision indicated by the current engineer. At each phase engineer is given access to all the required information and tools depending on the current phase to carry out the action required. The project status will be updated by all the individual workflow processing events onto the Oracle database. So it is possible to find out the current working phase of the project being handled. Each member of the project can view the current status of the project at any time by simply logging on to the system. The external parties involved in the projects can also login to the COVES portal (COVES: Collaborative One-Stop Virtual Engineering Services, n.d.) to view the status of the projects they have submitted.

The deadline/alarm-reporting module sends e-mail notification to the corresponding engineers when the work is approaching or past the deadline. The date set by the workflow designer can be either absolute or relative to the start of the workflow or particular job step. Calendaring system, meeting schedulers and conference system are some of the other modules available in the portal.

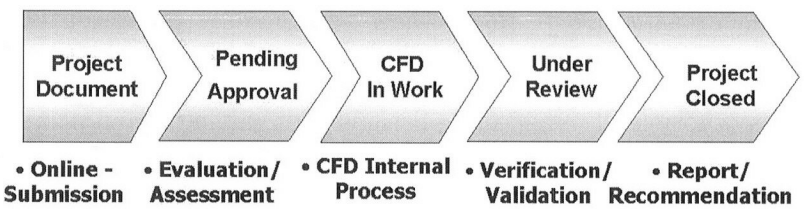

Figure 3.
Various states of evolution of the project

At each stage of the project engineer can make the necessary notes/comments and upload the screen shots or results of the simulation/visualization. Provision has been made to schedule meeting at any stage if the engineer wants to do so. Minutes of the meetings can also be uploaded. All the documents uploaded will be stored in the respective project cabinets. Once all the CFD processes are completed, the engineer calls for a collaborative discussion/interpretation and project review over the Internet with different government agencies. This can be carried out in the "under review" phase. Finally, in the "project closed" phase, the post-processed results and summary report will be returned over the Web to the client and to the relevant government authorities. OSSC notifies the client about the status of application once it receives the response of approving authorities and the testing results from COVES.

COVES is a sub-system riding on the infrastructure set up for e-Engineering Portal (The E-Engineering Portal, n.d.). e2-portal is a strategic initiative of the Institute of High Performance Computing (IHPC, Singapore). e2-portal provides a key infrastructure for hosting engineering application and facilitates collaborative engineering over the Web. The portal extends HPC services including design, modeling, simulation and visualization to the clients over the Web. The Portal is focussed on forming partnerships to jointly research, develop and deliver value-added services to local companies and institutions. In the long term, it aims to establish Singapore as an Internet Engineering, Manufacturing and e-Commerce Hub by providing universal access for local companies and solution vendors to HPC technology. CFD engineer logs on to e2-portal to use the CFD software. e2-portal hosts all the latest CFD software for design and analysis.

Before the implementation of the portal, the applicants need to personally go to various government agencies to get the building plans of factories approved. Now instead of the above, necessary documents are submitted over the Internet and is forwarded to the relevant authorities. The online submission is much cheaper, faster and more convenient for all. The system also offers collaborative high-performance computing and networking (HPCN) technology for virtual product/process design, thus enabling the enterprises to shorten design cycles. The above in-turn reduces the product development cycle time and provides monetary savings especially for smaller companies as government professionals and engineers can assist them directly in their design. The collaborative platform allows government professionals and engineers to share information among them and to work together with their private counterparts in a virtual project team. The system also contains a common repository of 3D engineering designs and building layout plans that can be accessed by all government agencies. Besides this the system also integrates the internal workflow of the CFD business process.

3. System implementation

The COVES portal is developed as a multi-tiered system as shown in Figure 4. The client tier is represented as tier 1, which is a thin browser based component, developed using Java Server Pages (JSP) technology. JSP is used as most of the pages are dynamically generated. Using JSP, no plug-ins or security files are needed on the client systems. The second tier consists of Web server and J2EE compliant application server including few third party components for workflow management. JavaBeans component is used for the communication between the client component and the server component. Servlets and Java Message Service (JMS) are also used. The third tier consists of the database server and file manager. The fourth tier consists of the HPC resources, cluster and other additional resources required.

The COVES system is based on the J2EE standard for developing multi-tier enterprise applications. This ensures smooth integration of legacy systems and transparent and seamless access for users. And as it is Web-based, the access is ubiquitous and pervasive. On the security front, a high-strength 128-bit encryption is provided to protect confidentiality of data transfer between COVES and remote users. Web based authentication and role-based access level control are also implemented to allow authorized access only.

Since the COVES system is developed using purely Java, it is platform independent. The Web-based, real-time, interactive communications provided by WebEx is used for the collaborative review with different government agencies (WebEx Online Meetings and Web Conferencing, n.d.). The service provided by WebEx (Webex, 5) is accessed by plugging into the WebEx Interactive Platform (WIP) through APIs. The COVES system layout is shown in Figure 5.

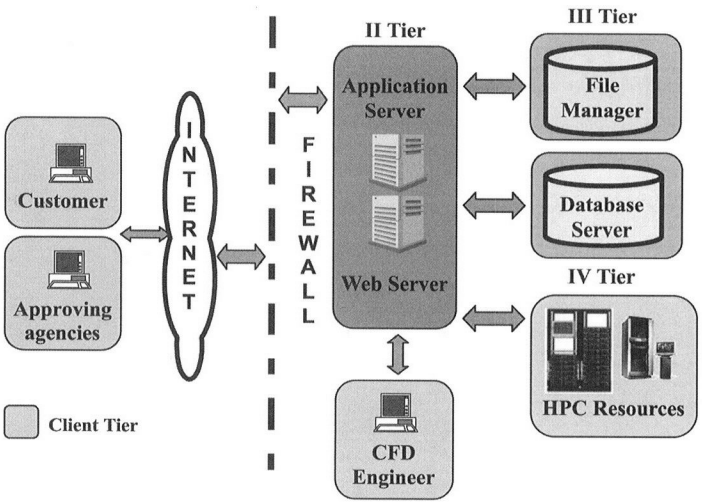

Figure 4.
Multi-tier Web architecture

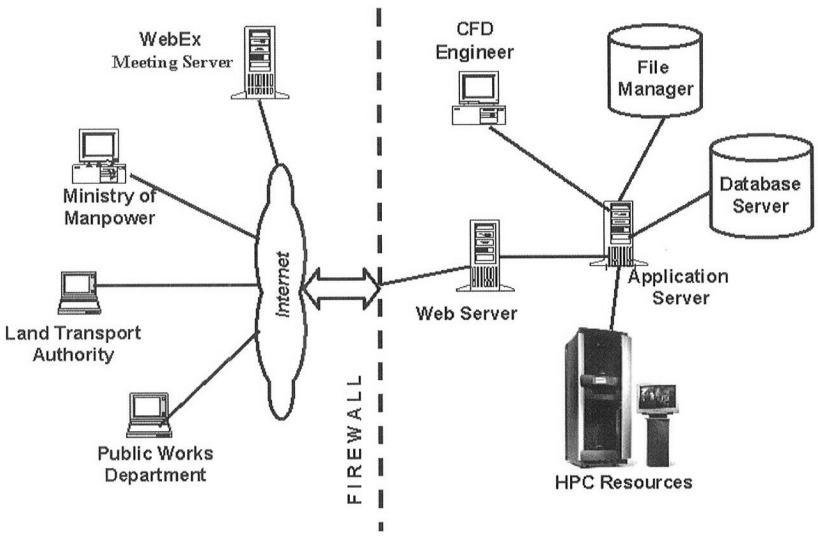

Figure 5.
COVES system layout

4. Business models

COVES system is a combination of two Internet based business models, collaborative platform and virtual community, as shown in Figure 6. Virtual community is composed of people who want to discuss their interest or specific questions/issues of mutual interest. A virtual community includes the following advantages:

- It provides project support with a virtual team of consultants and a collaborative learning/training environment.
- It promotes in the development and sharing of open standards and best practices among members.
- It helps in sending out news updates or technology advances faster.
- It helps in adding values to the business.
- It increases the reach and retention.
- Service quality can be improved based on the immediate feedback from the community.

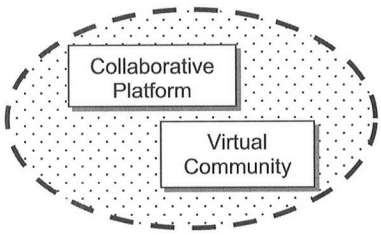

Figure 6.
COVES business model

Forrester research says: "sites view community as an element that generates repeat traffic". Amazon.com reports that repeat customers account for 72 per cent of total orders placed. EBay finds that the growth of its 2.1 million registered user base was directly attributed to the new additions of chat rooms and discussion areas. So based on the above views it can be concluded that business gain can be achieved by adopting virtual community as a business model.

Collaborative platforms provide users with a set of tools and information environment for collaboration between enterprises. The platform developed using above two models allows all the members of the virtual community (i.e. government, agencies, private professionals) to collaborate on a project (e.g. building a chemical plant, setting up an office/factory). These two models focus on specific functions, such as collaborative design and engineering, or in providing project support with a virtual team of consultants. Possible revenues are from membership fees, advertisement and from the utilization of tools (e.g. for design, workflow, document management).

The service focus and the target market identified for COVES are shown in Figure 7. The target market identified for COVES are heat ventilation and air-conditioning (HVAC), fire and smoke, pollutant dispersion and indoor air quality (IAQ). Modeling, analysis, simulation and visualization are the service focus identified by COVES.

5. Benefits of COVES

The process automation by COVES provides tremendous benefits that translate into cost savings and production gain. The following are some of the benefits offered by COVES in terms of money and time:

- Savings for factory/building owner due to avoidance of retrofitting and

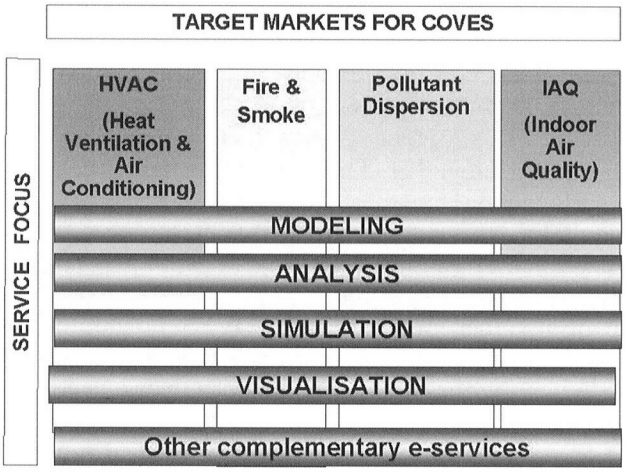

Figure 7.
Service focus and the target market for COVES

- Savings from operating cost due to more efficient design.
- Savings for government agencies for lower simulation costs and lower manpower costs.
- Reduced design cycle time.
- Reduced product development cycle time.

The benefits of COVES are plenty. It enhances collaboration and greatly reduces paper-based error and miscommunication. The CFD process involves piles of building plans and documents for each project. With the business process automation by COVES system, all the documents are neatly packed into the project, which results in productivity. CFD engineer can handle more projects, which also results in quick application approvals. Above results in a shared knowledge base of 3D simulation results, increased accessibility to HPC resources and tools, and domain expertise from anywhere and at anytime. All these translate to better design, shorter delivery time, substantial cost saving and a more technologically advanced and competitive industry.

6. Related work

There have been several initiatives around the world to study the feasibility of providing Web-based CFD products and services. Foremost among them is MICA (Model for Industrial CFD Applications), an EC-supported (MICA: Model for Industrial CFD Applications, n.d.) project. The project, involved fourteen partners (mostly industrial and some academic) from nine European countries was initiated in 1996. Its aim, which was successfully achieved, was to show that CFD calculations could be set up and their results can be inspected on PCs equipped only with "front-end" software of non-immerse "virtual-reality" character, while the computations were performed remotely.

Although similar in nature to MICA, COVES attempts to automate the entire CFD modelling process including meshing, solving and post-processing within a Web-based environment. In addition to MICA, COVES avoids the need for remote computations. It leverage on the ability of the Internet to eliminate work barrier due to distance by creating virtual project teams allowing professionals from various disciplines, different geographical regions, and approving government bodies to work together. This integration helps clients to avoid the need to travel to various government offices to get their application approved. This approach would be extremely useful for business processes dealing with government agencies as they can involve all the relevant government agencies such as Occupational Health Department, Fire Safety Bureau and Pollution Control Department together in a project. COVES is initially targeted at factories that are not traditionally users of CFD. It is hoped that these "new converts" (especially among the SMEs) will enhance their level of productivity and competitiveness by the use of High Performance Computing and Networking (HPCN) technology by allowing the enterprises to shorten the

design cycle using virtual product design via the Collaborative Virtual Engineering environment. This would also make the use of HPC more pervasive.

Other initiatives in this area includes developing infrastructure (both hardware and software) to provide Web-based/Web-enabled CFD services. There are a number of portals which provide engineering services on pay per use basis. COVES system is unique in its work that it integrates various enterprises including approving bodies.

7. Conclusion

To succeed in the new economy, organizations need to integrate business processes and technology within the enterprise and also across extended enterprises. The paper presents how streamlining information flow within and between enterprises creates new internal efficiencies as well as new way to better serve the customer needs. COVES portal has re-engineered the traditional business process associated with the construction industry by integrating various public and private enterprises. The portal enables a group of professionals from various organizations with diverse experience to work together as a group more effectively and efficiently. The paper presents how e-business can transform business processes and strategy. The portal provides an e-consultancy service for government agencies and private sector organizations that require performance-based approval or quality assurance for building plans. The system is now in the trial phase with some of the participating agencies. We believe that COVES is a blueprint and a turnkey technology to be replicated, albeit with modifications, to other simulation and compliance-based engineering processes that involves multiple government agencies. Already, the on-going development of the One Stop Submission Centre (OSSC) by the Building and Construction Agency is accelerating towards the obvious trend.

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