

Virtual Office, Community, and Computing (VOCC): Designing an Energy Science Hub Collaboration System

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Abstract. ¹The Consortium for Advanced Simulation of Light Water Reactors (CASL) implements a management strategy that imbues physical collocation; community; collaboration; central leadership; multidisciplinary teams executing a single milestones-driven plan; and integrated, co-dependent projects. The CASL-streamlined management structure includes collocation at CASL, use of technology to achieve multidiscipline collaboration, video conferencing for meetings, and a VOCC project that integrates both the latest and emerging technologies to build an extended “virtual one roof.” CASL is headquartered at ORNL, where the CASL leadership and a majority of the multidisciplinary, multi-institutional scientists and engineers will be located. Work performed at partner sites will be seamlessly integrated across the consortium on a real-time basis via community and computing (VOCC) capability that integrates both the latest and emerging technologies to build an extended “virtual one-roof” allowing multidisciplinary collaboration among CASL staff at all sites. The paper describes the VOCC collaboration system.

Keywords: User Centered Systems Design, Collaboration, Collaborative Virtual Environments, Collaborative Computing, Human Computer Interaction, Energy Science Hub.

1 Introduction

The United States (U.S.) is currently focused on energy independence and energy efficiency. The Department of Energy (DOE) is making major investments into innovative approaches to improving nuclear reactor energy efficiencies. To realize measurable improvements, DOE needs to optimize its current nuclear power production capability by reducing capital and energy costs per unit, reducing nuclear waste, and enhancing nuclear safety. DOE has funded a consortium of scientists, led by Oak Ridge National Laboratory (ORNL) to develop transformational nuclear computational science models for identifying, understanding and solving nuclear reactor safety and performance issues. These critical virtual reactor models and predictive simulations will not only contribute to extending the life of current reactors, but will be instrumental in supporting future commercial reactor designs.

¹ www.casl.gov

To optimally harness the collective conscious of the consortium, ORNL needed to cognitively bring together under “one-virtual-roof” the best nuclear and light water reactor (LWR) scientists, engineers, designers, and industrialists to solve complex alternative energy efficiency designs. The consensus was to construct a physical one-roof space, but extend its reach through a connected virtual collaborative environment. The environment was defined as Virtual Office, Community Computing” and is the first DOE energy hub to use human centric, immersive, and visually analytic design techniques and principles to build a physical work space for the purpose of virtually unifying geographically distributed computational scientist and high-performance computing (HPC) resources.

VOCC is a system of systems integrated in a special way to promote collaboration and critical thinking amongst its users. Critical thinking is presumed to lead to insight and insight to innovation. VOCC’s “innovation at the speed of insight” means a more rapid deployment of predictive simulation capability to the LWR industry. A direct consequence of the design is not only reduced current energy costs, but expedited delivery of LWR innovations to industry.

The major components of VOCC include virtual collaboration and design labs and presence and visualization systems. The presence systems provide the primary and essential support for virtual interactions (face-to-face collaboration) amongst teams and consortium members, from scientist to managers. Complimentary collaboration systems provide spaces for ideation and co-creation activities. The Ideation space includes interactive sketching and drawing tools which assist team members in expressing ideas. The space also serves to facilitate stimulation of “collective ideas” and solutions. The visual immersive spaces allow team members to interact with other people, simulation data, and textual information. Lastly, 2d and 3d visual environments permit collective analysis of virtual reactor objects and reactor operation simulations. Defining capabilities contained in these systems was left with project members because we generally feel collaboration is driven by an individual’s scientific activities. The CASL collaboration and Ideation Officer (CIO) used the capability to also drive the search for suitable existing technology. The state of technology drove initial collaborative system designs. The three most dominant consortium activities influencing design included agile code development, modeling and simulation, and visual data analysis.

The optimal reactor design strategy exists only when cognitive systems for design are closely coupled with physical engineering design systems inside collaborative virtual spaces. These unique virtual spaces allow researchers to represent holistically diverse components of reactor knowledge in such a way that quick convergence to an understandable solution space is inevitable (*“design at the speed of insight”*). Convergence of the disparate knowledge spaces is facilitated via Collaboration. Collaboration takes place when you can co-locate physically or virtually human dynamics [1] (human perception, perspective, and cognition) and information or data with visually immersive, 3-D design modeling systems. Modeling systems must go beyond static display walls and include ad-hoc, dynamic visual spaces like 3d tele-immersive environments or advanced telepresence communication systems, and interactive touch modeling systems. These devices must be located in or near collaborative spaces so individual team members can be “collectively creative”, kick around ideas (‘ideate’). Telepresence systems not only serve as advanced spaces for

real time visualization, but they are also critical for pervasive collaborative communication amongst creative teams and customers. Collectively these components form a virtual cognitive laboratory representing a collective design conscious of reactor design knowledge and capability. By singularly locating this design knowledge and insight we can guarantee rapid movement of technology and engineering practice into the U.S. energy industry's reactor design centers.

2 Energy Science Hub

In June of 2010 the U.S. Department of Energy (USDOE) launched (CASL), an Energy Innovation Hub. Hubs are new R&D structures created by the USDOE to address the most pressing U.S. energy problems. After reviewing many excellent proposals, the Secretary of Energy identified only three energy innovation focus areas that would be researched under the hub structure 1) building efficiency, 2) fuel from sunlight, and 3) nuclear energy. CASL was selected as the nuclear energy hub. The CASL Hub's end product is a code suite and methodology that industry and regulators will use directly in LWR reactor design and licensing practice, and/or indirectly to justify along with experimental results their proprietary modeling and simulation capabilities.

The Hub research concept will effectively remove current R&D barriers which have historically prevented USDOE from achieving national energy and climate goals. Hubs comprise a highly collaborative team, spanning multiple scientific, engineering, and where appropriate, economics, and public-policy disciplines. Hubs will seek to rapidly drive energy solutions to their fundamental limits. Each Hub will support cross-disciplinary R&D focused on the barriers to transforming its energy technologies into commercially deployable materials, methodologies, and technologies. The ultimate goal of each will be to advance a highly promising area of energy science and technology to the point that the risk level will be low enough for industry to deploy solutions into the marketplace. In the case of the Simulation and Modeling for Nuclear Reactors Hub the USDOE strongly emphasized the "one roof" concept. Co-location of scientists in a single structure was not the only concern for collaboration. It was achieving distributed, effective collaboration using a centrally led "integrated" model of research towards a challenge goal.

2.1 Science Mission and Hub Goals

The Consortium for Advanced Simulation of Light Water Reactors is an exceptionally capable team that will apply existing modeling and simulation capabilities and develop advanced capabilities to create a usable environment for predictive simulation of light water reactors. This environment, designated the Virtual Reactor (VR), will incorporate science-based models, state-of-the-art numerical methods, modern computational science and engineering practices, and uncertainty quantification and validation against data from operating pressurized water reactors. It will couple state-of-the-art fuel performance, neutronics, thermal-hydraulics, and structural models with existing tools for systems and safety analysis and will be

designed for implementation on both today's supercomputers and the advanced architecture platforms now under development by the USDOE.

To accomplish this vision for the VR simulation tool, CASL will focus on a set of challenge problems that encompass the key phenomena limiting the performance of pressurized water reactors, with the expectation that much of the capability developed will be applicable to other types of reactors. Broadly, CASL's mission is to develop and apply modeling and simulation capabilities to address three critical areas of performance for nuclear power plants:

1. capital and operating costs per unit energy, which can be reduced by enabling power uprates and lifetime extension for existing nuclear power plants and by increasing the rated powers and lifetimes of new Generation III+ nuclear power plants;
2. nuclear waste volume generated, which can be reduced by enabling higher fuel burnups; and
3. nuclear safety, which can be enhanced by enabling high-fidelity predictive capability for component performance through failure.

3 Hub Innovation Strategies

CASL provides a unique opportunity not only to advance the use of nuclear power in the United States but also to advance the state of distance collaboration in the process – a key element in an increasingly global research society. CASL has a clear commitment to the use of state-of-the-art technology and frequent virtual meetings to enable long distance collaboration.

CASL will undertake a Virtual Office, Community, and Computing (VOCC) Project. The VOCC project will deliver (1) commercially available and when necessary custom web-based virtual office and collaboration technology; (2) advanced telepresence or net-presence technology; and (3) methods and technology for scientific study, analysis, and remote CASL computing on HPC systems. The final deliverable will implement and leverage DOE HPC investments such as Leadership Computing and the National Nuclear Security Administration ASC Program. VOCC's efforts create an integrated multidisciplinary, multi-site collaboration and integration and a singular CASL focus, thus significantly enhancing the opportunity for innovations in nuclear energy.

3.1 A Unified Collaboration Platform

The Virtual Office, Community Computing (VOCC) project is focused on designing a unified collaboration platform and general creative work environment to support the advanced simulation of light water reactors (LWR). The CASL hub concept has two monumental tasks: (1) to cognitively bring together under "one virtual roof" the best LWR scientists, engineers, and industrialists and (2) to create a state-of-the-art scientific collaboration space that not only supports, but also optimizes joint LWR design, fabrication, and assessment. VOCC is the first Department of Energy (DOE) hub project to use human-centric, immersive, and visual analytic design techniques and collaboration principles to build a physical work space for the specific purpose of

unifying—virtually—geographically distributed computational scientists and high-performance computing (HPC) resources.

The VOCC platform will be a video-based integrated electronics environment; its primary purpose is to support both CASL's synchronous and asynchronous communications and visualization needs. VOCC will contain the core traditional elements of a collaboration platform like group communication tools, messaging, social networking and computing tools, as well as collaboration tools for modeling and simulation, two-dimensional (2D) visualization, and 3D information manipulation. VOCC must possess virtual collaboration tools that can be accessed by anyone, at any time, from anywhere on any device. Most online virtual tools will be accessible via rich interactive applications (RIAs) on the web. VOCC will leverage existing virtual productivity spaces designed for information sharing such as Wire, Google Sites, SharePoint, Groove, SOSIUS, and Think Free².

The VOCC platform is a “system of systems,” with each subsystem referred to as a “venue.” Each venue has been selected based on a documented CASL user requirement. Once a capability requirement has been established, a technology search is initiated to configure the venue. A candidate set of technologies are identified and an evaluation performed. Technologies are evaluated on many factors, including but not limited to cost (*initial procurement and maintenance/legacy operational costs*), efficiency, mobility, scalability, interoperability, and ease of use. Efficiencies are examined from both a computational and an efficiency point of view, where the latter ranges from sharing of information (data) and knowledge to venue energy consumption.

“Mobility” and “scalability” describe the adaptive nature of a venue to communicate with CASL partners and stakeholders when and where necessary. For synchronous and asynchronous communication, this implies CASL venues scale from room-size voice and video nodes to mobile-size voice and video nodes. Scalability of this nature ensures diverse productive landscapes from venue productivity (groups) to small-scale, handheld smart device (single-user) productivity (“productivity in the palm of your hand”,[2]). Interoperability standards for CASL mean that each venue must easily talk to other venues and connectivity is afforded to multiple operating systems (OS), minimally Windows, Mac, and Linux. These types of efficiencies ensure creative collaborative CASL venues are available to users, partners, and stakeholders any time and any place, from any device. Ease of use ensures that no matter how little a user may use a certain collaborative venue or application, he or she can quickly start reusing it in a meaningful way without spending much time retraining (reduced cognitive load on user).

3.2 Human Dynamics and Computing

CASL’s vision to create a virtual reactor (VR) for predictive simulations of LWRs necessarily means building a virtual technical team, a community comprising engineers, designers, scientists, researchers, and industry experts. The community

² Mention of specific commercially available hardware or software does not constitute an endorsement of the items. USDOE does not endorse any commercial products.

members need a virtual-one-roof to engage one another to evolve solutions and approaches to real, difficult, and necessary scientific alternative energy needs.

CASL's one-virtual-roof is VOCC, and it will consist of layered networks, architectures, and communications (including social networks). The networks will provide trusted collaborative computing to enable organizing, distributing, and routing of sensitive data between CASL partners (e.g., intellectual property, export-controlled information, etc.). Cybersecurity is an integral part of CASL. Multiple, redundant resources and tools will be devoted to protecting sensitive digital information inside the sensitive CASL enclave. Additional protocols will be established to ensure there is no transfer of data from sensitive CASL enclaves to CASL open enclaves.

Defining collaboration and collaboration venues and tools is not something for the information technology (IT) group to define on the CASL enterprise level. Such a prescription for enterprise collaboration tools only creates resentment on the part of users because they typically do not truly address users' scientific technology needs. Collaboration is driven at the personal level by individuals. Selection of collaboration tools and venues must be closely coordinated with end user workflows and outcomes. Workers must intuitively see the value of using collaboration tools and they *must* be engaged in their development and build out. However, deployment and secure access to such venues must include organizational information technology resources.

4 VOCC Collaboration Needs Assessment

To understand what CASL's creative collaboration needs are, CASL performed an initial needs assessment. First, a repeatable methodology for information collection was established. We started with the proposal-based concepts of "virtual one-roof" and worked toward reality and eventually to a full initial understanding of stakeholder and user technology needs. We focused on optimizing collaboration in the CASL activity space (speeding up innovation) while simultaneously reducing operating cost (improving CASL's business value). It became quite clear during this assessment that VOCC was not just a milestone in a science proposal; rather, *it is the way CASL would most effectively operate and innovate.*

Next, other key operational considerations were identified that would be critical in establishing the venue-based needs for the assessment process. Among the most important was the need to share data and access on HPC systems such as the Cray Jaguar at ORNL. There are also needs to share intellectual property and tech export control information. Additionally, core computational use cases for evaluation were identified. An initial survey of partner sites was performed to determine the extent of their institutional contributions and limitations (space, bandwidth, firewalls). Great thought and discussion were given to performance measures and how those might be measured in relation to the collaboration venues. Finally, the interoperability issues partner sites might have with selected technologies were considered, along with the infrastructure modifications, if any that would be necessary to accept the technology. VOCC in general does not seek to be prescriptive about collaboration tools or venues, but rather to prepare for being optimally interoperable for the unanticipated use of each organization's resources. It does, however, require that at least one identical

form of synchronous communication exist at each core partner site. At this point, it is assumed that the only prescribed venue is immersive telepresence.

4.1 CASL Activities

The needs-based assessment assisted CASL in identifying four primary activities for technology requirements evaluation: (1) Business/Program Management, (2) Agile Code Development, (3) Modeling and Simulation (M&S), and (4) Lectern (Educational)/Research Partnerships. Table 1 lists some of the use cases gathered for each category.

Table 1. Four Main Activities Planned for VOCC

Business/Program Management	Agile code Development	M&S and Analysis	Lectern/Research Partnerships
<ul style="list-style-type: none"> • B2B partner discussions • Reviews w/sponsors, partners, FA leads, collaborators, etc. • Holistic/Iterative cost estimations for SW development • Technology transfer/sharing • Cooperative agreements, presentation/publication material development • Technical exchange, PowerPoint, MS Office, Primavera, etc. • Sometimes audio only connects 	<ul style="list-style-type: none"> • Daily Stand-ups • SCRUM Sessions • Code assembly and Sketch up • Distributed code development forward & reverse SW engineering • Remote pair programming • Co-authoring SW/user documents and manuals • Distributed configuration management and version control (shared code storage) • Distributed Test Environments • Multiple participants, single interactive session exchange • JAZZ, Eclipse, other IDE's, Rational Asset manager, etc. 	<ul style="list-style-type: none"> • Sharing hi res. Viz. via true telepresence or augmented reality (direct view and manipulation of reactor models) • CRUD – Impact Analysis (Rod vibration, LOCA accidents) • Model validation • Multiple participant, multiple session exchanges • View 3d video objects, share control and edits • Using Access & Para View w/telepresence system • CFD, STAR-CCM, etc. 	<ul style="list-style-type: none"> • Interactive & Immersive classroom instruction • Augmented Reality presentation of guest speakers • 3D learning environment (visual tutors) • Social Software and “shared study & research environments” • Building partnerships, virtual university extensions • Democratizing information access • Expanding human to machine interaction • Simpodium, blackboard, etc.

Business/Program management technology needs to primarily include telepresence or video connectivity and a persistent digital work plan to track document changes and updates. Telepresence would provide a high degree of personal interaction with the senior leadership team (SLT) and focus area (FA) technical team leads. Collaborative document spaces provide a place to share documents involving processes, protocols, and technology exchange agreements. Uses for these document spaces are most needed in the startup phase of the program.

Code development is initially one of CASL's largest user communities in support of the VR. CASL has decided to employ an Agile software development approach to the VR. IBM describes Agile development as a collaborative, incremental, and iterative approach to software development that can produce high-quality software in a cost-effective and timely manner. Unlike traditional software development, Agile development emphasizes flexibility, continuous testing and integration, and rapid delivery of functionality.

The traditional approach to Agile software development is co-location (locating two or more team members in one physical place). Co-location can provide participants immediate coherent visual and auditory feedback from code development team members. The visual feedback is very important, as the majority of collaborative communication and hence understanding is visual [4].

CASL code development teams will need two key technology venues to support agile code development. Scrums are processes for developing such complex software applications as Virtual Reactor Integration (VRI). Scrum teams are relatively small and consist of 5–7 cross-functional team members. Their iterative development life cycle runs every 30 days. They develop code in pairs and as teams. Many coders prefer to design Unified Modeling Language (UML) in an interactive and intuitive touch application space. This requires hardware that is multi-touch enabled and a software development environment designed to emulate traditional interaction like keystrokes and mouse clicks. Code teams have daily Scrum sessions that last approximately 15 minutes. These meetings require telepresence for optimal execution and, minimally, desktop video exchange in remote paired programming instances. Ultimately, augmentation to the telepresence system is desired so that three-dimensional (3D) real-time code modeling/meshing change can be examined in a real-time 3D format. This would give developers a clearer understanding of the impact of code changes on 3D VRI models.

The third activity is M&S and Analysis, which includes visual object analysis. One instance of visualization calls for 3D visualization and analysis, and another, calls for interaction and immersion. Visualization may involve multiple participants and multiple exchanges of data at varying levels of resolution. Information analysts would like to view and share control of 3D objects in cave-like facilities and in advanced telepresence systems. A typical use case for a C3 or C5 venue is to view a slice of a 30 foot reactor or to walk around inside a reactor to view the impacts of corrosion-related unidentified deposits or even to evaluate rod vibration simulating a loss-of-coolant accident.

The last activity evaluated was the lectern or speaker environment and research partnerships. The primary need for having guest speakers, whether for technical exchanges or educational outreach, precipitated the deployment at CASL of an augmented reality (AR) podium using a transparent image plane. This venue is ideal for speakers, teachers, or trainers. The interactive touch venue is also desirable for exchanging instructional information or sharing desktops for collaborative research. The AR podium represents a very advanced form of immersive telepresence. This use case has needs for a telepresence venue and touch environments to support various research workflow activities.

Generally, all users described a need for an ideation space where users can think or “ideate.” Ideation is typically done in non-VR and 3D modeling environments. Tools used to ideate usually include the basic ability to sketch and draw, tools not inherent to VR environments or general visualization venues.

5 Challenges to Collaboration System Design

Without question the most difficult task in designing the VOCC system of systems was getting users to clearly identify and/or communicate their true collaboration needs. Most scientists deal with capability and thus technology requirements in a truly adhoc fashion. As a normal course of work execution scientists and researchers do not stop and take inventory of capability or even critically assess their approaches to innovation. It is clearly beneficial for collaborative systems designers to socialize their collaboration strategy, to teach users basic requirements definition and management, and to let users “share in the burden and risk” of choosing technology solutions. Getting users involved in all aspects of technology evaluation will result in their quicker adoption of the collaboration strategy [5].

Secondarily, the most difficult task to collaborative system selection is demonstrating and more importantly quantitatively characterizing the business value afforded by the collaboration venue (“collaboration metrics”). A 2010 Salire Partners (a technology value path provider) report states that 80% of companies see a positive return on investment (ROI) on collaboration technologies [6]. The average payback in months for government organizations is ~33 months. At the end of five years payback should exceed 100%. Frost & Sullivan, the industry research and growth consulting firm, looked beyond the more obvious return on investment (ROI) calculation a company may make before investing in these tools, such as the cost of operating the solution against savings derived from travel avoidance [7]. VOCC will be in the months ahead seriously focused not only on developing meaningful collaboration metrics to quantify typical cost savings, but also those associated with characterizing innovation ROI.

6 Summary

VOCC is a very unique system of systems collaboration platform that will facilitate and expedite desperately needed innovation in nuclear LWR design. Its physical one-roof will provide an optimal co-location environment for industry designers and researchers to more quickly solve complex energy problems. Its extensibility via the virtual one-roof will permit ORNL to share computational and visualization resources with industry in a manner that has never been done before. VOCC wants to democratize its capabilities in high performance computing, visualization, and modeling and simulation with its core partners via collaborative venues. Lastly co-location, whether physical or virtual, spurs collaboration resulting in a convergence of these two disparate yet complementary knowledge spaces.

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