Co-Optimization of Fuels & Engines

Building and Executing Aggressive Research Plans in a Large National Laboratory Consortium

Insights from the Co-Optimization of Fuels and Engines Initiative

September 30, 2022

Prepared by Pacific Northwest National Laboratory, National Renewable Energy Laboratory, Oak Ridge National Laboratory, and Sandia National Laboratories

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About the Co-Optimization of Fuels and Engines Initiative

This is one of a series of reports produced as a result of the Co-Optimization of Fuels & Engines (Co-Optima) initiative, a U.S. Department of Energy (DOE)–sponsored effort initiated to simultaneously investigate advanced engine designs and the enabling fuel properties. This first-of-its-kind effort is designed to provide American industry with the scientific underpinnings needed to maximize vehicle performance and efficiency, leverage domestic fuel resources, boost U.S. jobs, and enhance energy security.

Co-Optima brings together DOE's Office of Energy Efficiency & Renewable Energy (EERE), 9 national laboratories, 13 universities, and more than 20 industry and government stakeholders in a collaboration exploring solutions with potential for near-term improvements to the types of fuels and engines found in most vehicles currently on the road, as well as to the development of revolutionary engine technologies for a longer-term, higher-impact series of solutions.

In addition to the EERE Vehicle Technologies and Bioenergy Technologies Offices, the Co-Optima team includes representatives from the National Renewable Energy Laboratory and Argonne, Idaho, Lawrence Berkeley, Lawrence Livermore, Los Alamos, Oak Ridge, Pacific Northwest, and Sandia National Laboratories. More details on the project—as well as the full series of reports—can be found at www.energy.gov/fuel-engine-co-optimization.

Availability

This report is available electronically at no cost from http://www.osti.gov/bridge.

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Abbreviations and Acronyms

ACRONYM	Definition
AOP	annual operating plan
BETO	Bioenergy Technologies Office
DOE	U.S. Department of Energy
VTO	Vehicle Technologies Office
TRL	technology readiness level
MD	medium-duty
HD	heavy-duty

Executive Summary

This report describes lessons learned in the establishment, execution and termination of a large, multi-institutional consortium, derived from the Co-Optimization of Fuels and Engines experience. The decision to form a consortium comes with benefits (in advancing challenging multidisciplinary research) and costs (in time and additional management funds). Once the decision is made, key elements to a strong start include establishing a shared vision and goals; engaging an experienced project manager early; instituting feedback and oversight mechanisms to ensure relevance, strong performance, and situational awareness. Once a consortium is up and running, DOE and leadership should strike the right balance between competition and collaboration; foster an environment that builds trust; and adjust the organizational structure as needed to maintain collaboration. Finally, DOE and the labs can plan effectively for a smooth transition as a consortium winds down. This report provides some additional lessons and details on these lessons that we hope future DOE and lab leaders will find useful as they contemplate standing up new consortia.

1. Introduction and context

When is bigger also better and faster? When does combining capabilities of the Department of Energy's 17 national laboratories make sense? The national labs steward and apply important capabilities to help the Department execute its mission – *"to ensure America's security and prosperity by addressing its energy, environmental and nuclear challenges through transformative science and technology solutions."* In many cases the labs steward complementary, and sometimes even competing or overlapping, capabilities. There has been a trend for the labs to band together into a consortium, with or without academic or industry partners. This report seeks to define lessons learned on the formation, operation and winding down of a consortium – the Co-Optimization of Fuels and Engines (Co-Optima) Initiative. Co-Optima started as a nine-lab, 6-year, $132M initiative funded and overseen by the Bioenergy Technologies and Vehicle Technology Offices within the US DOE's Office of Energy Efficiency and Renewable Energy. DOE and the labs brought in universities to address capability gaps and industry to increase market appropriateness.

What Are the Key Elements of a Successful National Laboratory Consortium?

- Shared longer-term strategic science/technology goals
- DOE leadership
- Trust, either preexisting or a willingness to develop it, is essential
- Robust feedback and oversight mechanisms
- Planning and project management processes that drive integration
- A structure that encourages and drives innovation

2. Establishing a consortium

When does it make sense to pull together a broad set of resources into a consortium? What are critical steps to take to increase the likelihood of success? This section aims to answer these questions.

2.1. Consortium or no consortium?

Standing up and managing a consortium necessarily requires additional resources. Scarce resources, particularly DOE funding and the time of talented senior researchers, are required to stand up and manage a consortium. What are the conditions that make a consortium worth the additional effort? Our experience with Co-Optima suggests the following are useful guidelines:

2.2. Establish shared vision and goals

The DOE and consortium leadership set the vision to address a challenge that is key to DOE missions and the United States. The leadership team set concrete long-term and interim goals to achieve that vision. Ultimately, DOE led the way on the high-level goals by ensuring the consortium was explicitly tied to elements of the BETO and VTO strategic plans (or conversely that the goals of the consortium were reflected in the Office strategies). Setting long-term and interim goals was an inclusive process – it required input from different sets of technical experts, iterating as limits and opportunities of each sub-field (engines, fuels, analysis) became clearer. Iterating on consortium goals continued throughout the lifetime of the consortium.

Determining which lab capabilities to include and who would work on what occurred during the initial planning. DOE and the labs identified capability needs based on consortium goals and matched lab capabilities to address those needs. This process was also iterative and led eventually to inclusion of 9 labs, starting with all 17 labs in the initial discussions at the 2015 EERE Big Ideas Summit, then 11 and finally nine who ended up comprising the consortium.

The annual planning process was an effective forcing function to drive this integration process. Co-Optima found it most effective to engage senior leaders (steering committee, team leads, a few additional technical leaders) from across the member labs on these annual updates, iterating after feedback from DOE and advisory bodies. Tasks were aligned with goals, modified to be aligned, or did not make the priority for funding. New information (research results, external circumstances) influenced the annual process, but was also incorporated throughout the year as warranted. In all cases, it is important for the consortium leadership and DOE to guard against funding "pet projects", which may be interesting but not fully aligned with consortium goals. How? While we do not have the perfect answer, we believe the key is robust discussion and engagement between the consortium leadership and DOE, as well as internal discipline and leadership at the individual labs. During the execution of Co-Optima, both of these mechanisms led to termination of proposed or active tasks on multiple occasions. DOE program managers may lack the deep technical expertise in a given area, but are experienced in seeing how the pieces fit together and can ask probing questions to trigger discussion. Co-Optima leadership held each other accountable where needed and, by maintaining a critical and questioning attitude throughout the conduct of the project, also identified tasks that were not well-enough aligned.

Finally, re-programming existing funds increased the challenge of aligning staff and tasks to short and longer-term goals but enabled quick momentum to get the consortium moving. If existing projects or funding are to be rolled into a new consortium, deliberate efforts to align tasks and task leads to consortium goals must be incorporated. It may make sense to develop a transition plan for key capabilities to wrap-up pre-existing work and ramp up efforts on the new consortium over some months to a year and/or ramp up funding for the overall effort over the first one to two years (as DOE often does with large new efforts).

2.3. Engage a qualified project manager early

It may seem obvious, but still bears saying – engage a strong and experienced project manager as early as practicable. Leverage the experience of that project manager to incorporate efficient and effective processes. Utilize traditional project management methods to tie all planned research and development activities to the high-level goals; develop quantitative metrics and update as new information becomes available; and help establish regular updating and course correction mechanisms.

2.4. Build in robust feedback and oversight mechanisms

As with any project, several standard review (VTO Annual Merit Review, BETO Merit Review) and oversight mechanisms (regular meetings with DOE PMs, regular reporting requirements, annual reporting) were used by DOE to evaluate performance and progress. These mechanisms provided the usual benefits – continuous improvement, course correction, improved prioritization, linkage to other DOE projects and programs. Large consortia, though, need additional sources of input to ensure awareness of external developments, vet strategies and plans, develop advocacy for the consortium, and expand awareness of science and technology outputs. Co-Optima used an external (industry and other stakeholder) advisory board to provide that external set of voices to guide the project. Choose the specific members of the advisory board carefully – if the consortium is focused on longer-term research, it is important that the members are accustomed to thinking on that time scale. Co-Optima did not include a mechanism to replace members or fixed term limits, so adjusting the composition of the advisory board

required significant effort. Include a mechanism for regular turnover of some fraction of the advisory board (maybe every two years). Of course, it is incumbent on the consortium leadership to listen to the external input while balancing what are often short-term (industry) agendas against long-term consortium goals.

Finally, the consortium needs to develop internal feedback mechanisms, including reviews and frequent (monthly for the Co-Optima leadership team in the beginning) regular meetings, to build trust, teamwork and accountability. Given advances in remote collaboration tools over the past few years, the frequency and duration of in-person meetings may be lower than when Co-Optima was assembled. Nonetheless, some regular face-to-face meetings to build trust and foster open dialogue are important in the first year or two. The specifics for each consortium would be different, but common elements should include top-down guidance, bottom-up generation of ideas and (critical or otherwise) feedback, and engagement with DOE and external advisors. A calendar incorporating the full set of meetings can reduce redundancy and meeting proliferation.

3. Running a consortium

Transitioning from standing up a new consortium to executing on the research and management plans requires a new set of skills; the assistance of an experienced project manager can help make the shift seamless. The Co-Optima team found several key elements to strong program execution.

3.1. Balance competition and collaboration

The labs compete for funding but also collaborate regularly on small and large projects. With the labs as "competi-mates", the DOE must weigh the benefits of competition between labs vs. broad collaboration and integration of capabilities. It was our experience managing Co-Optima that maintaining some elements of competition within the work planning process helped drive innovation, while simultaneously providing incentives to collaborate across labs, capabilities, and DOE funding offices together ensured collaboration. Specifically, holding an annual (or other appropriate cadence) competition of ideas to ensure the most relevant, impactful R&D was conducted. Of course, R&D approaches must align with the vision and appropriate to achieve the desired outcomes.

It is tricky to achieve the right balance between new ideas and continuing efforts, lower

technology readiness level (TRL) and higher TRL research, etc. To (attempt to) achieve this balance, Co-Optima used an annual review that included an interative review of each team's plans by the initiative leadership, team leads, and steering committee. Each of the proposed tasks were tied to specific Co-Optima outcomes. Integrated plans to achieve specific Co-Optima objectives were developed off-cycle so that the appropriate tasks could be proposed during the annual scope review process. Cross-team activities were identified during the review. During this process, it was very clear to the assembled leadership when a proposed task did not address Co-Optima goals or otherwise looked like a "pet project". This approach ensured all labs were represented, each team knew what the others proposed, and the proposed work would (theoretically) achieve the intended outcomes. This approach was less successful at focusing on those elements that were on the critical path to achieving Co-Optima goals. Implementing a stage-gate process with the right criteria, adjusted for changing program circumstances perhaps, might have addressed this gap.

The availability and timing of funding may also influence how a consortium functions. In some cases, existing funding may be re-programmed. This can cause friction as staff and capabilities are shifted and legacy projects may be ended. Maintaining a base level of funding for each participating lab, combined with competition for the remaining resources can help maintain trust while ensuring the best ideas move forward. Within Co-Optima, some funds were new (BETO) and others were re-programmed (VTO). We found inefficiencies in some VTO-funded tasks during the first years, as activities continued that were only peripherally related to the core technical objectives of Co-Optima.

Co-Optima project management was complicated by government and laboratory budget planning processes in several ways that will be relevant to other consortia. First, changing priorities within and between administrations increase the difficulty of maintaining focus on long-term goals, and may require shifts in direction, appropriate for a large consortium. Second, more upfront coordination was required to develop lab-specific annual plans. Third, the annual planning cadence meant that shifts in direction during the year happened on a more *ad hoc* basis, which meant agile adjustments to new knowledge were also made in an ad hoc fashion. It may appear that this point contradicts the earlier on regarding changing priorities – it does! All consortia will have to balance agile responses to external and internal changes against longer-term thinking and planning. Finally, not all work proposed or conducted within Co-Optima necessarily aimed at Co-Optima goals. Some research "popped up" along the way as researchers followed interesting threads and therefore conducted work that did not quite fit into the Co-Optima vision. Some research like this is inevitable and could be productive. It is incumbent on the consortium leadership (DOE and labs) to monitor such work and make sure it is (1) worthwhile, and (2) does not detract from achieving critical path activities. In these cases, more frequent review by the leadership team and DOE with specific interim targets or outcomes are valuable.

3.2. Build trust

Effective teams require trust. Without trust in the competence, integrity, and values of other team members, unproductive actions waste time and money. Researchers spend time and energy wondering if others will steal their ideas, rush to publish something that will make their own work less worthy or propose work to DOE (through the consortium or outside) that threatens their funding. These have all happened in research consortia, though not in Co-Optima to our knowledge. Co-Optima built trust through three primary elements. First, and most important, was

strong DOE leadership. The DOE program managers worked with the labs to ensure funding followed performance, drive collaborative practices, and hold labs accountable when issues arose. This was particularly challenging in cases where existing projects were moved into Co-Optima. DOE and Co-Optima leadership worked hard to consciously create buy-in from staff – listening to them, working to identify pathways to transition their previously planned work, and ultimately finding common ground.

Second, transparency in lab-level funding, tasks, and milestones helped to build trust. This unprecedented level of transparency was codified by, for the first time, sharing annual operating plans (AOPs) among the labs. Interactions at annual and quarterly meetings helped build morale, transparency, and teamwork. This level of transparency meant that researchers from each lab could see what other labs were doing, identify potential areas of overlap and complementarity, and be assured that decisions were being made in the best interests of the DOE and the consortium.

Third, consortia are staffed by people, not all of whom are focused on collaboration with peers from other organizations. Engaging and retaining collaborative, non-parochial staff in leadership and technical roles was crucial to the success of Co-Optima. Each lab was responsible for providing a member of the steering committee and staffing technical tasks. Prioritizing collaborative technical tasks in the annual scope development process both rewarded multi-lab cooperation and incentivized future collaborations, thereby ensuring technical activities went beyond what would be achieved by a more traditionally managed program.

3.3 Organizational Structure Drives (or Breaks) Integration

Co-Optima organized in teams, which were roughly aligned with capabilities in engine simulation, engine/combustion experiments, fuel properties experiments, analysis, fuel production and characterization, and (initially) market transformation. The teams were also roughly aligned by sponsoring office (VTO, BETO) with some overlap, particularly in fuel properties and market transformation. This structure was a convenient way to organize but created two specific issues. First, the capability-based teams did not inherently drive to specific outcomes (the way an activity- or project-based organization would), which required additional work between the leadership team, team leads and steering committee members to ensure activities were aligned and sufficient to meet consortium goals. Second, the separation of complementary capabilities into teams put the onus on individual researchers to develop the specific collaborations that were a critical element of Co-Optima. Ultimately, these

collaborations did form, but could have happened more quickly with a different structure. For instance, aligning researchers based on an integrated project team aimed at one of the early Co-Optima technical goals (as was done in, for instance, the National Advanced Biofuels Consortium) would have linked up researchers with different backgrounds and driven earlier detailed technical discussions. The consortium would still provide value by providing explicit access to extended lab capabilities, links to other integrated and cross-cutting consortium projects, and a mechanism to exploit new linkages between technical fields.

One key advantage of the team structure became apparent as Co-Optima needed to shift gears when administration priorities changed. The shift to medium-duty and heavy-duty (MD/HD) transportation and to lower TRL was more easily accommodated by the collected capabilities in the team structure, than if integrated projects were required to change direction or focus.

4. Bringing it home

All things come to an end. Consortia are like any other organization – they evolve and sooner or later end. Planning for the end of the consortium and the transition of lab capabilities to address new challenges is best done with a longer runway (months to a year), if possible. Nonetheless, DOE and consortium leadership should develop and communicate clear guidance on the end-state and transition or sunsetting plan, including knowledge and technology transfer to industry or other R&D programs, with enough time for the labs to plan capability transitions.

With the right leadership and disciplined execution, consortia can achieve big aims that would be impossible to address via a collection of projects within a traditional DOE program portfolio. Co-Optima was fortunate to have had dedicated visionary leaders at DOE and the labs who launched the program, incorporating these principles or adjusting course based on new learnings. We hope these observations arising from Co-Optima will be useful in the conception and execution of future consortia.

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