56534
P-8

NASA
Technical Memorandum 106962

Army Research Laboratory
Technical Report ARL–TR–793

A System Simulation Development Project: Leveraging Resources Through Partnerships

Colin K. Drummond
Lewis Research Center
Cleveland, Ohio

A. Karl Owen
Vehicle Propulsion Directorate
U.S. Army Research Laboratory
Lewis Research Center
Cleveland, Ohio

Milt W. Davis
Sverdrup Technology, Inc.
AEDC Group
Arnold Air Force Base, Tennessee

Prepared for the
Aerospace Atlantic Conference
sponsored by the Society of Automotive Engineers
Dayton, Ohio, May 23, 1995

National Aeronautics and
Space Administration

U.S. ARMY
RESEARCH LABORATORY

A System Simulation Development Project: Leveraging Resources Through Partnerships

Colin K. Drummond, *NASA Lewis Research Center*
A Karl Owen, *Army Vehicle Propulsion Directorate*
Milt W. Davis, *Sverdrup Technology, AEDC Group*

ABSTRACT

Partnerships between government agencies are an intellectually attractive method of conducting scientific research; the goal is to establish mutually beneficial participant roles for technology exchange that ultimately pays-off in a stronger R&D program for each partner. Anticipated and current aerospace research budgetary pressures through the 90's provide additional impetus for Government research agencies to candidly assess their R&D for those simulation activities no longer unique enough to warrant "going it alone," or for those elements where partnerships or teams can offset development costs.

This paper describes a specific inter-agency system simulation activity that leverages the development cost of mutually beneficial R&D. While the direct positive influence of partnerships on complex technology development is our main thesis, we also address on-going teaming issues and hope to impart to the reader the immense indirect (sometimes immeasurable) benefits that meaningful inter-agency partnerships can produce.

INTRODUCTION

It has been said that when Santos-Dumont made the first airplane flight in Europe, Britain's Lord Northcliff declared: "The news is not that man has flown, but that England is no longer an island." It is as true today as it was in the early 1900's that changes in technology alter the environment in which we must operate. In the context that modern propulsion systems reflect advances of and coupling between propulsion, airframe, and control system technologies, then component simulations developed in **isolated** environments (technically and programmatically) are clearly self-limited. Today, we suggest that: "The news is not that interdisciplinary technology is complex, but that R&D projects are no longer islands."

Current (and expected) budget shrinkages among federal labs have fostered an atmosphere where organizations are more willing to explore cooperative relationships (communication between islands) than, say, as recently as the late 1980's. This openness brings with it the realization of possible redundancy in existing R&D activities and the subsequent requirement for participants to re-examine their basic research goals and portfolios. As such, partnership exploration activities are not only iterative (technically), but also ask researchers to think in terms of their core competencies (specialized skills they have which can't be readily matched by others).

Highly coupled with the partnership technology discussion are two important aspects of the relationship-building process:

1. Effective partnerships do not occur overnight, and
2. healthy partnerships will often outgrow themselves.

Thus, the financial attraction of R&D teaming makes it easy to miss important non-technical dimensions of the teaming process.

Gas turbine system simulations have a central role in many types of analytical and experimental propulsion research projects and are used in one form or another at many Government R&D labs. At first pass, then, advanced system simulations are technically logical as a focus for identifying inter-agency partnership possibilities.

Two important factors to consider in modern system simulation are (a) that advanced aeropropulsion performance requirements push conventional discipline boundaries such that interdisciplinary problems (e.g., aero-elasticity) need to be incorporated in system simulations; and (b) functionally, interdisciplinary technology reaches across organizational lines. In other words, modern simulations are complex technically *and* organizationally.

As a practical matter, R&D labs just beginning to effectively conduct internal research programs with a matrix-type organization have taken the first step in the process of teaming with external organizations.

Given the increasingly interdisciplinary nature and extended development time of new engine simulation technology, the NASA Lewis Research Center, the Army Vehicle Propulsion Directorate, and the Arnold Engineering and Development Center (AEDC) began discussions about three years ago to form a Joint Technology Development Effort (JTDE). The JTDE is designed to be a cost-effective, cooperative investigation of advanced compression system stability issues. The technical thesis of the work is that the fidelity of existing *system* simulations can be increased by numerically blending in selective *component* codes of higher fidelity. This is presumed to be a competitive approach to the strategy of rewriting the system simulation so that every component's fidelity is raised to the desired level of the critical component.

The Joint Technology Development Effort (JTDE) is the result of a formal contractual relation between NASA, the Army, and AEDC on specific compression system simulation deliverables. It is important to note, however, that the idea for the JTDE extended directly from each organization's participation in a more general working group called the Joint Dynamic Airbreathing Propulsion Simulation (JDAPS) partnership. In contrast to the JTDE's contractual focus on a specific technology, JDAPS is a more informal consortium that entertains a much broader range of gas turbine system simulation issues. JDAPS was formed in 1991 in response to the recognition of gas turbine simulation needs which appeared to be common among numerous Government, Industry, and University projects. The goal among the JDAPS partners is "to develop state-of-the-art dynamic airbreathing propulsion simulation technology and transition to JDAPS partners for application." Ultimately, improving U.S. Industry's aeronautics capabilities and competitive strength are of central interest, thus, industry membership in JDAPS has been extraordinarily beneficial in the past and will continue to be important in the future.

Although JDAPS is presented in more detail elsewhere (Davis et. al., 1995), it is worth mentioning here that the rapid growth in JDAPS membership over the last four years speaks directly to the need and value of JDAPS to participating organizations.

The discussion to follow is focused on:

(i) Three issues which may impede the *launch* of collaborative work,
(ii) The concepts of "mutual gain" and "risk sharing" as essential to the *on-going* health of a partnership, and
(iii) Our views on the importance of the (often understated) *indirect benefits* of R&D partnerships.

Remarks are directed toward the general area of simulation for gas turbine compression system stability, but the hope is that a more general relevance of the discussion should be evident.

THREE COLLABORATION ISSUES

Despite the appealing technical and financial leverage the initial JTDE partnership concept presented, it took a surprising amount of time (almost two years) to get the project off the ground. Hamel, Doz, and Prahalad's (1989) work on collaboration helps in articulating issues surrounding the JTDE start-up activity:

1. A partnership is a form of collaborative competition.
2. Core competencies must be identified and protected.
3. The ability for partners to learn from each other (the so-called "shared learning" experience) is as important as resource sharing.

In hindsight, these three critical issues were not immediately obvious or explicitly discussed during the JTDE teaming process; nonetheless much can be gained by sharing a discussion of these issues with others (providing examples wherever possible). Having overcome initial partnership barriers, the current JTDE teaming now represents a successful inter-agency venture for the development of critical technologies associated with gas turbine system simulation research.

Partnership as Competitive Collaboration

Emphasis on the technology transfer facet of JDAPS underscores that the development of simulation technology must be mutually beneficial for all participants. Given the broad membership base of JDAPS -- it currently involves five government labs, four universities, and four industry participants -- the concept of a partnership as a form of collaborative competition becomes apparent. Thus, while JDAPS serves a very effective common ground for the presentation, debate, and sharing of general simulation technology, the informal JDAPS structure recognizes and encourages more formal relationships between participants on specific technology development efforts. The NASA-Army-AEDC JTDE activity is precisely such an effort.

Specifically, the JTDE work consists of the following three main elements:

1. Integration of a high-fidelity (dynamic) compressor *component* code with a lower-fidelity (transient) gas turbine *system* simulation.

2. Assess the resulting hybrid (length and time scale) simulation on the Army T700 engine.

3. Assess the technique for a two-spool turbo fan engine of commercial interest.

The view of the formal JTDE activity as a subset of the informal JDAPS consortium does not erode the value of JDAPS to other participants. We propose that technology transfer benefits and influence on the detailed scope of work are (appropriately) a function of the barriers to entry (investment required) in the relationship.

Core Competency Identification

One view of the relatively open forum of the JDAPS umbrella is that the technology focus remains at a fairly "pre-competitive" level. This requires participants to have an acute sense of the unique and specialized skills which reside within their organizations -- the so-called core competency[1].

An important dimension to engaging in teaming activities-- especially at the technical working level -- is the need to know when a more rigorous tracking mechanism of technical and financial resource exchange (e.g., a contract) is necessary. One needs to be flexible enough to invoke the appropriate teaming framework for the situation at hand.

Successful collaborative research is a temporary "means" and not a long-term "end" in itself -- each separate organization utilizes the technology to address different (but complementary) weaknesses in existing capabilities. It is precisely the idea that technology will transfer between collaborators which leads to the thought that core competencies must be carefully defined. It takes a solid understanding of the industry and the knowledge of players to hit this on the mark.

Some research centers are more willing than others to expose those elements of work -- currently performed internally -- that can be "bought" or performed more effectively elsewhere. Research activity leading to codes that are *not unique* or are *easily duplicated* is fundamentally *not proprietary*. However, this does not mean the R&D task is easy or that the required research skills are quickly developed. Thus, activity which is actually quite meaningful to "outsource" can have the mistaken identity (to those close to the work) of a core competence -- such a judgement is a project management call which is not always so clear or easy to make.

A "make" or "buy" decision can be difficult to reach. Consider, for instance, a problem whereby a classic Euler solver code is required for a compressor inlet simulation, but for which the solver may need adaptation to an inlet system simulation at hand (as would be needed for a downstream compressor boundary condition). A commercial code may have extra features and be validated, but revision for the turbomachinery application would be required. To start from scratch will require some "re-inventing" of the wheel and take time for validation of high-fidelity features; however, the in-house simulation codes would most likely have a well-coordinated interface with other in-house simulation subroutines (internal definition of COMMON and EQUIVALENCE blocks).

A tendency exists for R&D organizations to fund what they can afford (the so-called "strategic fit" to program planning). Interdisciplinary technology goals make this strategy increasingly obsolete, since increasing costs are evident at the junctures of increasingly higher component-fidelity and an increasing comprehensive interdisciplinary coupling . A more competitive approach is to afford what is needed -- when budgets are tight, teaming can potentially expand affordability.

Shared Learning

Extensive discussion on the financial benefits of teaming will miss the subtle, motivating effect of the shared learning process. Clearly a fundamental role of research organizations is the expansion of scientific knowledge[2]. Knowing that a competitive (and proprietary) advantage results from the skill in transforming scientific knowledge into technology (for business purposes) the purchase or sharing of technology is difficult, if not a paradox, for many organizations. Nonetheless, an effective learning experience results from an arrangement whereby one organization has the opportunity to interface with the "cranked-up" R&D activity of another organization.

Consider, for example, the use of object-oriented programming for modern simulation. A significant barrier to making the "jump" from a procedural language to an object-oriented language lies in

[1]See the work of Thompson and Strickland (page 89) for an enlightening discussion of an organizations "core competency" in the context of a strategic situational analysis.

[2]Thomas Kuhn (1962) defines the expansion of scientific knowledge as the point at which a scientific anomaly can be understood in enough detail to become an expected phonomema.

the learning curve associated with an object-based language. NASA has a considerable base of experience in the application of several object-based languages (LISP, C++) for a variety of aeronautics problems and applications. The ability of the Army or AEDC researchers to rapidly come up the leaning curve on relevant problems is easily afforded through a partnership. On the other hand, NASA stands to benefit from AEDC's continued investment in real-time engine system health monitoring. The reversible "student-to-teacher" roles provides shared learning for each organization.

MUTUAL GAIN

Leveraging resources through teaming is a balancing act in which **mutual gain** must be provided for all participants.

An important metric for the JTDE is that the activity be mutually beneficial. Hamel, Doz, and Prahalad(1989) describe several conditions for which mutual gain is possible between partners; two items applicable to the present work are that:

1. Partners' strategic goals converge while their competitive goals diverge.
2. Partners can learn from the each other without compromising critical or proprietary skills.

The first item suggests that each partner will continue to prosper once the partnership ends. In other words, an improved high-fidelity simulation capability is the strategic goal of both AEDC and NASA, but the application of simulations for test and evaluation at AEDC is considerably different that an application of simulations at NASA for advanced control design.

A mutual goal to move to object-based simulation is an example of the second item. Here, it is expected that AEDC can learn a great deal from NASA's experience in developing object-based simulations and graphic user interfaces; conversely, the development of standardized object interfaces will allow NASA to more easily access unrestricted AEDC engine data.

Clearly, mutual gain must be measured more than through the balance sheet: Intellectual *and* resource sharing should both be factored in the measures of successful accomplish of scientific goals.

RISK SHARING

A customarily self-evident benefit of partnerships is the opportunity they present for the sharing of "risk." A closer examination of risk reveals that risk can take several forms:

1. Financial exposure,
2. Reputation risk, and
3. Transaction costs.

Reduced financial exposure is one of the most obvious benefits of a partnership. Figure 1 illustrates this point. Suppose that risk is perceived as the sum of the probability of technical success and financial exposure. A partnership can reduce the financial exposure tremendously and potentially transform a "possibly good" R&D investment into an "excellent" investment opportunity.

As an example, consider an on-going JTDE activity involving the integration of a high-fidelity dynamic compressor simulation with a lower fidelity, transient, component level model (CLM). Also known as "zooming" (increasing or decreasing simulation fidelity on-demand), it was not clear initially whether the inherently iterative blending of semi-empirical control-volume codes would be more computationally efficient approach than a (less empirical) Euler-solution approach with a body-force approximation to mimic the rotating machinery . The JTDE experience to date suggests that the Euler-solver approach is more effective than the semi-empirical control-volume approach, a lesson much less expensive to learn together than for each partner to find out on its own.

For extremely high-risk technical ideas, a partnership can be an excellent vehicle to reduce reputation risk. Organizations can use a partnership as a way to avoid the appearance of a misunderstanding of the "state-of-the-art." Partnerships can also assist in overcoming the "giggle factor" associated with innovative ideas or simulation concepts -- once considered on the fringe of feasibility -- whose implementation has been made possible by technology advancements (e.g., distributed computing, high-speed networked workstations, object-based compilers).

An overlooked aspect of joint projects is the possible reduction in transactions costs to a project. As an example, identifying the state-of-the-art can be expensive in a rapidly changing technology field. In a related vein, a partnership can produce the same benefits as a very exclusive technical symposia.

INDIRECT VALUE-ADDED ELEMENTS

Several indirect added-value elements are associated with effective aeronautics R&D partnerships:

1. Reduced researcher isolation in potentially sensitive (technical) areas.

2. Increased opportunities for new customer contact.

3. More realistic categorization of R&D risk (whether the R&D is incremental, radical, or fundamental).

4. Increased ability to influence related standards development (geometric, ARP's).

5. More meaningful role definition for University, Government, and Industry R&D laboratories.

6. A check on an organization's "perceived" versus "real" assessment of their core competencies.

Indeed, one could argue that the sum of the indirect effects may be of greater value than the direct effects. For instance, research in technically sensitive areas (proprietary or highly competitive situations) reduces the number of external researchers than an in-house researcher can compare notes with. A properly structured partnership can provide a setting for increased communication and thereby reduce researcher isolation.

Data and information standards development is another area where technical discussions and data format agreements among team participants can be exceptionally fruitful. For instance, the SAE Aerospace Recommended Practice (ARP) standards evolve over time in conjunction with changes in the technical landscape. Partnerships in which, say, object-oriented CLM protocols are developed can provide useful and timely information to on-going committees which oversee such standards.

Teaming arrangements also provide participants the opportunity to reflect on the appropriate roles for University, Government, and Industry R&D laboratories in the Aerospace field. The individual researcher may not need to think in such global terms on a day-to-day basis, but it is an exercise that can assist a researcher to refine their view of customer needs and the research their organization conducts to meet those needs. Such strategic thinking is a great asset to organizations today, but is clearly an indirect benefit to the teaming process.

YES, BUT ...

It behooves the reader to appreciate the authors' awareness of the potential downside of partnerships and, more generally, collaborative activities as a whole. We propose that the following issues must be recognized:

1. Potential for an increase in bureaucracy and a subsequent *increase* in transaction costs.

2. Inadvertent loss of proprietary information.

3. Misalignment of participant objectives, leading to significant erosion of potential benefits.

These are often the position of the "yes, but .." members of a potential participant organization. We do not claim these risks are non-existent, only that we believe they can be managed! It becomes quite clear that partnership planning and the strategic value of the partnership must be extensively worked beforehand.

CONCLUDING REMARKS

In light of the potential pitfalls of partnerships, skeptics can claim that cooperative R&D efforts simply lead to an increase in bureaucracy, the possible loss of proprietary information, and the atrophy of in-house resources. Without a doubt, these weaknesses do exist and become dysfunctional to the team if not managed properly. It is clear that participants must maintain an awareness of their role in the team and intervene when necessary to protect the health of the partnership.

Furthermore, there must be the commitment of the partners to make the process work effectively. All told, the skill one must take to manage a partnership is not too far away from the skill to successfully invoke a matrix-based project A fundamental difference, however, is that management of the partnership will be under the microscope of several organizations -- existing organizational weaknesses will certainly get magnified in the partnership process.

We propose that the potential weaknesses are more than compensated by the benefits. When properly managed, pursuit of increased cooperation among government agencies is a strategically sound method for conducting mutually beneficial R&D.

REFERENCES

1. Davis, M.W., A.K. Owen, W.F. O'Brien, and W.T. Cousins, " Joint Dynamic Airbreathing Propulsion System (JDAPS) Partnership," to be presented at the 40th ASME International Gas Turbine Institute Conference, Houston, Texas, June 1995. ASME Paper 95-GT-279.

2. G. Hamel, Y. Doz, C. Prahalad, "Collaborate with your competitors," *Harvard Business Review*, Vol.67, No.1, pp.133-139, 1991.

3. Thomas Kuhn, *The Structure of Scientific Thinking*, University of Chicago Press, 1962.

4. P. Roussel, K.N. Saad, and T. Erikson, *Third Generation R&D*, Harvard Business School Press ,1991.

5. A. Thompson and A. Strickland, *Strategy Formulation and Implementation*, Irwin Press, 1992.

6. "What is JDAPS?," JDAPS Newsletter, September, 1994.

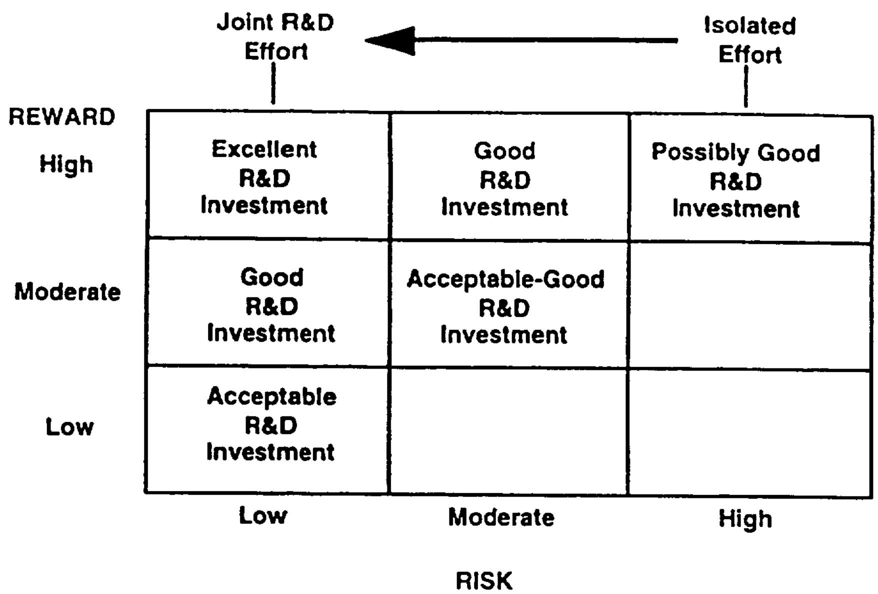

Figure 1. Effect of teaming on the project Risk-Reward Relationship

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (*Leave blank*)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	July 1995	Technical Memorandum

4. TITLE AND SUBTITLE

A System Simulation Development Project: Leveraging Resources Through Partnerships

5. FUNDING NUMBERS

WU-505-62-10

6. AUTHOR(S)

Colin K. Drummond, A. Karl Owen, and Milt W. Davis

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

NASA Lewis Research Center
Cleveland, Ohio 44135-3191
and
Vehicle Propulsion Directorate
U.S. Army Research Laboratory
Cleveland, Ohio 44135-3191

8. PERFORMING ORGANIZATION REPORT NUMBER

E-9718

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

National Aeronautics and Space Administration
Washington, D.C. 20546-0001
and
U.S. Army Research Laboratory
Adelphi, Maryland 20783-1145

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

NASA TM-106962
ARL-TR-793

11. SUPPLEMENTARY NOTES

Prepared for the Aerospace Atlantic Conference sponsored by the Society of Automotive Engineers, Dayton, Ohio, May 23, 1995. Colin K. Drummond, NASA Lewis Research Center; A. Karl Owen, Vehicle Propulsion Directorate, U.S. Army Research Laboratory, NASA Lewis Research Center; and Milt W. Davis, Sverdrup Technology, Inc., AEDC Group, 1099 Avenue C, Mail Stop 9013, Arnold Air Force Base, Tennessee 37389. Responsible person, Colin K. Drummond, organization code 2760, (216) 433-3956.

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Unclassified - Unlimited
Subject Category 07

This publication is available from the NASA Center for Aerospace Information, (301) 621-0390.

12b. DISTRIBUTION CODE

13. ABSTRACT ***(Maximum 200 words)***

Partnerships between government agencies are an intellectually attractive method of conducting scientific research; the goal is to establish mutually beneficial participant roles for technology exchange that ultimately pays-off in a stronger R&D program for each partner. Anticipated and current aerospace research budgetary pressures through the 90's provide additional impetus for Government research agencies to candidly assess their R&D for those simulation activities no longer unique enough to warrant "going it alone," or for those elements where partnerships or teams can offset development costs. This paper describes a specific inter-agency system simulation activity that leverages the development cost of mutually beneficial R&D. While the direct positive influence of partnerships on complex technology development is our main thesis, we also address on-going teaming issues and hope to impart to the reader the immense indirect (sometimes immeasurable) benefits that meaningful interagency partnerships can produce.

14. SUBJECT TERMS

Systems; Simulation; Teaming; Interdisciplinary

15. NUMBER OF PAGES

8

16. PRICE CODE

A02

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102