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GAO

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Washington, D.C. 20548

Accounting and Information
Management Division

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September 16, 1994

The Honorable Bob Carr
Chairman
The Honorable Frank Wolf
Ranking Minority Member
Subcommittee on Transportation
and Related Agencies
Committee on Appropriations
House of Representatives

This letter responds to your request that we answer several questions concerning the University of Iowa's contribution to the National Advanced Driving Simulator (NADS) project. The contribution in question was certain software, known as the Iowa Core Software, that functions as part of the University's existing driving simulator. Specifically, you asked us to (1) determine whether the utility of the Iowa Core Software that the University of Iowa is providing to the project could be fairly and accurately determined prior to completion of the NADS design contracts, (2) identify technical risks associated with the government committing to using this software prior to completion of the NADS design contracts, (3) determine what the basis was for the $3.7 million estimated cost of the Core Software, whether the $3.7 million is an appropriate estimate of the software's cost, and if it is not, what a proper estimate is, and (4) determine the status of the NADS design contractors' "thorough and objective evaluation of the various Core Software modules." Because the answer to the last question is procurement sensitive, we do not address it in the report. Instead, we orally conveyed our answer to this question to your offices. A detailed explanation of our objectives, scope, and methodology is included in enclosure I.

SUMMARY

The University of Iowa's existing driving simulator and its associated software, referred to as the Iowa Driving Simulator, is operational and being used by a variety of public and private sector clients. Thus, this software, and in particular that part of the software known as the Iowa Core Software, is potentially useful to NADS. It is too early, however, for the NADS design

contractors to fairly and accurately determine how useful this software will ultimately be. To make such a determination, the design contractors need detailed information about the Core Software, information that they have not yet received. Because such detailed information has not been provided to the contractors for all components of the Core Software, we do not find the National Highway Traffic Safety Administration's assertion that most of the Core Software will be used in NADS convincing. The utility of the Core Software to NADS, and hence, its value to the NADS project, will not be known until after the design contractors receive and evaluate all Core Software components. This will not occur before the end of phase I of the design contract in February 1995.

The government has not committed to using the Core Software, and thus no risks exist with regard to a commitment. Instead, the government has required only that the competing NADS design contractors thoroughly evaluate the software's utility to NADS. This course of action is prudent because, if the software proves to be useful to NADS, then reusing it would be less risky than developing new software.

The $3.7 million estimated cost of the Core Software is reasonable and was determined using a generally accepted software cost estimation model. However, if the software is not used in developing NADS, its value to the program would be limited, and this cost estimate would become irrelevant.

BACKGROUND

NADS is intended to be a state-of-the-art driving simulator utilizing the latest high fidelity simulation technology. The National Highway Traffic Safety Administration (NHTSA) is acquiring NADS with the primary objective of supporting a national research program that it hopes will result in safety improvements in the transportation system through reduced crash rates, improved vehicle design, increased roadway efficiency, and expanded mobility for special populations such as elderly and handicapped drivers. Currently, NADS is expected to cost approximately $32 million to develop.

NADS is being acquired in two phases--phase I design competition and phase II system development. In January 1994, NHTSA began phase I by awarding competitive NADS design contracts to both TRW, Inc., Military Electronics and Avionics Division and to Contraves, Inc., Simulation and Systems Integration. Contract deliverables for phase I consist primarily of a cost proposal and preliminary system design proposals. Phase I is to be completed in late February 1995. NHTSA will evaluate the proposals and expects to select the

phase II contractor in mid-1995. Early phase II deliverables are to include detailed design documentation for a mid-1996 critical design review. System development and integration will then follow. After system testing at the University of Iowa in mid-1998, NHTSA is scheduled to accept NADS from the system development contractor and furnish it to the University as federally owned property. The University is then expected to operate and maintain NADS.

When the Department of Transportation (DOT) approved the NADS project in January 1992, it was with the stipulation that NHTSA obtain a total of $11 million in cost-sharing from non-DOT sources. In August 1992, we reported that NHTSA had been unsuccessful in obtaining required non-DOT funding.[1] We recommended that the Secretary require NHTSA to follow through with its plans for meeting the goal of obtaining one-third of NADS funding from non-DOT sources. We also recommended that, if NHTSA should fail to attain the one-third goal, the Secretary discuss alternative funding approaches with the Congress and the Office of Management and Budget. As required, NHTSA has sought cash or other contributions to offset the total NADS acquisition cost to DOT. The University of Iowa, which won the competition to house and maintain NADS when it is complete, pledged to provide $3.25 million in cash and software from the University's Iowa Driving Simulator (IDS). This software contribution initially consisted of IDS' proprietary Real Time Recursive Dynamics Software, which the National Science Foundation valued at $2 million. Thus, the initial cost-sharing commitment from the University of Iowa totaled $5.25 million.

According to NHTSA, the University of Iowa agreed to contribute a number of additional IDS programs, collectively known as the Iowa Core Software. The Iowa Core Software consists of nine components--IDS Control (ICON), Terrain Database and Query, Collision Detect, Scenario Control, On-line Data Reduction, Simulation Configuration Software, Operator Support, Integration Tools, and Data Reduction. This software, developed by the University with funding from the Department of Defense's Advanced Research Projects Agency, was to be provided to both NADS design contractors for their evaluation and potential use in NADS, with the goal of reducing NADS development costs.

The conference agreement on the fiscal year 1994 emergency supplemental appropriations stated that NADS' unobligated funds would be rescinded unless

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[1] Motor Vehicle Safety: Key Issues Confronting the National Advanced Driving Simulator (GAO/RCED-92-195, Aug. 18, 1992).

$7.75 million of the total $11 million in non-DOT contributions to NADS project costs were raised by the time of conference action on DOT's fiscal year 1995 transportation appropriations bill. Given the University's initial cost-sharing commitment of $5.25 million, this conference action meant that an additional $2.5 million in non-DOT contributions was needed to meet the interim non-DOT funding directive.

CONTRACTORS DO NOT YET HAVE INFORMATION NEEDED TO FAIRLY AND ACCURATELY DETERMINE CORE SOFTWARE UTILITY TO NADS

The utility of the Iowa Core Software to NADS has not yet been fairly and accurately determined by the contractors because all of the necessary information has not been provided to them. Moreover, the University of Iowa does not plan to provide this information prior to completion of the NADS design contracts.

Both design contractors are required to complete their preliminary designs by February 1995. In doing so, they must determine whether to use certain IDS software, including the Core Software, taking technical, cost, and schedule implications into account. NHTSA reported to both its House and Senate appropriation subcommittees in early August 1994 that because it expects most of the Iowa Core Software to be used, it believes that the University has satisfied the immediate non-DOT funding directive ($7.75 million).

According to NHTSA officials, their assertion that most of the Core Software will be used in NADS is based on several considerations. First, NHTSA believes the contractors understand the functional and operational capabilities of the Core Software because engineers from both contractors attended briefings on the software by the IDS developers, discussed the software with the developers, and observed the Core Software in operation on IDS. Second, NHTSA believes the contractors are highly motivated to use as much of the Core Software as possible because cost and risk mitigation are two of the selection criteria for choosing the phase II contractor. Finally, NHTSA received letters from the design contractors indicating that, based on a review of ICON documentation, some of the Core Software could be used in NADS.

NHTSA's basis for asserting that most of the Core Software will be used in NADS is not convincing. To make a thorough and accurate determination of the Core Software's utility to NADS, the contractors will have to analyze all source code and associated documentation, and ideally, have full access to the principals who developed the software to answer questions. Contractors have

been provided only ICON software and documentation, and nothing for the other 70 percent of the Core Software. Without having all the Core Software and its associated documentation, neither contractor can complete a thorough and accurate evaluation of the Core Software's utility to NADS. Further, the contractors did not receive the most current version of the source code for ICON, which differs significantly from the prior version in terms of execution time constraints, until mid-August 1994. This was several weeks after NHTSA reported to the appropriations subcommittees that, based on statements by the design contractors, it expected most of the Core Software to be used in NADS. Finally, because the NADS phase II contract is currently being competed, interaction between the contractors and the Core Software developers has been necessarily restricted.

Both University of Iowa and NHTSA officials told us that the remaining eight components of the Core Software will not be provided before the contractors' evaluations of the IDS software are due in late January 1995. University officials stated that additional work is needed to bring the software documentation for the remaining components up to acceptable standards. These officials also stated that without accompanying explanation from the parties who developed the Core Software, the code and documentation for the other eight components would be of little value to the contractors. Therefore, we believe that neither contractor has, as of yet, been able to fairly and accurately determine whether the Core Software should be used in NADS.

REUSING HIGH-QUALITY SOFTWARE IS GENERALLY LESS RISKY THAN NEW DEVELOPMENT

With respect to technical risks associated with committing to using the Core Software before completion of the design contracts, we found that NHTSA has not contractually required that the contractors use any of the Core Software, and thus has not yet made such a commitment. Instead, it has left this decision to each of the competing design contractors, and required only that both design contractors thoroughly evaluate the Core Software's utility to NADS. We find this course of action to be a judicious, risk-mitigating approach.

Reusing software that has proven to function effectively in an operational setting is generally a lower risk approach than developing new software. According to a number of software experts, reuse has the potential to increase productivity by reducing the time and effort needed to develop software. Reuse can also increase reliability because systems are developed using thoroughly tested and proven components. If the IDS software, which is already built and functioning, effectively meets key NADS requirements and can be easily

extended, it would be wise to use it. The fact that the University of Iowa, the IDS software developer, would also operate and maintain it as a part of NADS is an additional advantage.

$3.7 MILLION COST ESTIMATE FOR THE IOWA CORE SOFTWARE IS REASONABLE

We believe that the $3.7 million cost estimate for the Core Software is reasonable. The University of Iowa used COCOMO, a generally accepted software cost estimation model, to derive their cost estimate of $3.692 million for the Iowa Core Software. This estimation model uses a mathematical formula containing variables representing various characteristics about the software and its development environment. These variables include the number of lines of code, the type of application, and the software development environment.[2] The output of the formula is an estimate of the number of person months needed to develop the software. The person-month estimate is then multiplied by the applicable labor rates to give an estimated total cost for software development.

Given that COCOMO is generally accepted and used in the software industry as a reasonable means of cost estimating, our evaluation of the estimate focused on the input variables used in deriving this estimate. On the basis of our understanding of the Core Software, we slightly adjusted four of the input parameters to reflect a more realistic view of the software. The specific parameters we adjusted were application experience, execution time constraints, programming language experience, and use of software tools. (The values that the University of Iowa used versus those that we used, the corresponding cost estimates, and an explanation of the reasons for our changes, are included in enclosure II.)

On the basis of the adjustments we made to the COCOMO calculation, we estimate the Core Software cost to be about $3.778 million. Given the uncertainty expected in software cost estimating regardless of the tool or method used, this difference is not significant. In fact, simply using a different cost estimating technique could produce a much wider variance in estimates than our adjustments to COCOMO produced, as other Core Software cost

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[2] COCOMO has 15 software development environment input variables that fall into four groups--product attributes, computer attributes, personnel attributes, and project attributes. Under the product attributes group, for example, the input variables are required software reliability, database size, and product complexity.

estimates produced by the University illustrate.[3] It should be noted, however, that although the $3.7 million cost estimate for the complete set of Core Software is reasonable, the University has only provided the contractors with the ICON component. The University of Iowa estimated ICON's cost to be about $1.77 million. Using COCOMO, we estimated the cost of this component to be about $1.72 million. Again, we do not consider the difference to be significant. Instead, the significant issue is whether or not the software is ultimately used in developing NADS. If it is not, the cost of either ICON or the Core Software is irrelevant.

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We discussed a draft of this report with the NHTSA program manager for NADS and have included comments provided where appropriate. As agreed with your offices, unless you publicly announce the contents of this letter earlier, we plan no further distribution until 7 days from the date of this letter. We will then send copies to interested congressional committees, the Secretary of the Department of Transportation, and the Administrator of the National Highway Traffic Safety Administration. Copies will also be made available to others upon request.

Please call Randolph C. Hite, Assistant Director, Accounting and Information Management Division, at (202) 512-6256, if you or your staff have any questions concerning this letter.

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and Communications
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[3] The University of Iowa also estimated the Core Software's cost using three other approaches: approximating actual costs, totalling actual non-University funding received, and using another cost estimating model. These three approaches produced cost estimates of $6.28 million, $2.57 million, and $4.125 million, respectively.

Objectives, Scope, and Methodology

The Chairman and Ranking Minority Member, Subcommittee on Transportation and Related Agencies, House Committee on Appropriations asked us to answer several questions concerning the University of Iowa's contribution to the NADS project. The contribution in question was certain software, known as the Iowa Core Software, that functions as part of the University's existing driving simulator. Specifically, you asked us to (1) determine whether the utility of the Iowa Core Software that the University of Iowa is providing to the project could be fairly and accurately determined prior to completion of the NADS design contracts, (2) identify technical risks associated with the government committing to using this software prior to NADS design contracts' completion, (3) determine what the basis was for the $3.7 million estimated cost of the Core Software, whether the $3.7 million is an appropriate estimate of the software's cost, and if it is not, what a proper estimate is, and (4) determine the status of the NADS design contractors' "thorough and objective evaluation of the various Core Software modules." We discussed our answer to the fourth question with the requesters' offices because it is procurement sensitive. This report addresses the remaining three questions.

To accomplish our objectives, we interviewed University of Iowa officials about their existing driving simulator and characteristics of its software. We also reviewed key documentation, including source code listings and design documentation, and observed and operated the University's simulator. In addition, we interviewed NHTSA and University officials and reviewed supporting documentation concerning (1) the components of the Iowa Core Software provided to the design contractors for evaluation, (2) the basis for NHTSA and University of Iowa positions on the utility and dollar value of the Core Software to NADS, and (3) the technical risks associated with NADS development and Core Software reuse.

To assess the cost estimate for the software, we obtained the data variables used in running the COCOMO cost estimating model that generated the $3.7 million value, as well as the results of this model. We evaluated these input variables based on our understanding of the Core Software's functionality, size, and development environment. On the basis of this evaluation, we adjusted several variables and then ran the model again.

To determine the scope, approach, and status of the design contractors' assessments of the core software's utility and value to NADS as well as the type and nature of other planned assessments, we interviewed officials representing the two contractors and obtained written responses to supplement our oral discussions. In addition, we discussed with these officials their views on the risks associated with developing NADS in general and using the core software in particular.

We performed our work primarily at NHTSA headquarters in Washington, D.C.; the University of Iowa in Iowa City, Iowa; TRW Avionics and Surveillance Group in Carson, California; and Contraves, Inc., Simulation and Systems Integration, in Tampa, Florida. We conducted our work in August and September 1994, in accordance with generally accepted government auditing standards.

Enclosure II

GAO Changes to COCOMO Variables and Reasons for Doing So

After analyzing the data variables the University of Iowa used in deriving its cost estimate for the Core Software, we modified four of the input variables based on our understanding of the software. The four variables were applications experience, execution time constraints, programming language experience, and use of software tools. After these adjustments were made, our cost estimate totalled $3.778 million, including $1.719 million for ICON. In contrast, the University's estimate was $3.695 million, with $1.773 for ICON. Table II.1 provides the respective inputs that the University of Iowa used versus those that we used and the corresponding cost estimates.

Enclosure II

Table II.1: Adjustments to Four COCOMO Software Development Environment Variables and Cost Estimates (dollars in millions)

Iowa Core Software Component	Iowa Variable Inputs		Iowa Cost Estimate	GAO Variable Inputs		GAO Cost Estimate
ICON	Appl exp[a] Exec time[b] Prog lang exp[c] Use of tools[d]	1.0 1.66 1.0 1.0	$1.773	Appl exp Exec time Prog lang ex Use of tools	0.91 1.50 0.95 1.24	$1.719
Terrain Database and Query	Appl exp Prog lang exp Use of tools	1.0 1.0 1.0	$0.358	Appl exp Prog lang exp Use of tools	0.91 0.95 1.24	$0.383
Collision Detect	Appl exp Prog lang exp Use of tools	1.0 1.0 1.0	$0.119	Appl exp Prog lang exp Use of tools	0.91 0.95 1.24	$0.128
Scenario Control	Appl exp Prog lang exp Use of tools	1.0 1.0 1.0	$0.724	Appl exp Prog lang exp Use of tools	0.91 0.95 1.24	$0.776
On-line Data Reduction	Appl exp Prog lang exp Use of tools	1.0 1.0 1.0	$0.358	Appl exp Prog lang exp Use of tools	0.91 0.95 1.24	$0.383
Simulation Configuration	Appl exp Prog lang exp Use of tools	1.0 1.0 1.0	$0.027	Appl exp Prog lang exp Use of tools	0.91 0.95 1.24	$0.029
Operator Support	Appl exp Prog lang exp Use of tools	1.0 1.0 1.0	$0.094	Appl exp Prog lang exp Use of tools	0.91 0.95 1.24	$0.100
Integration Tools	Appl exp Prog lang exp Use of tools	1.0 1.0 1.0	$0.166	Appl exp Prog lang exp Use of tools	0.91 0.95 1.24	$0.178
Data Reduction	Appl exp Prog lang exp Use of tools	1.0 1.0 1.0	$0.076	Appl exp Prog lang exp Use of tools	0.91 0.95 1.24	$0.082
Total			$3.695[e]			$3.778

[a] Applications experience
[b] Execution time constraints
[c] Programming language experience
[d] Use of software tools
[e] The difference between the $3.692 million estimated cost reported for the Core Software reported by the University of Iowa and this estimated cost is due to rounding.

Our reasons for adjusting the four input variables, as indicated in the table, are as follows:

-- For applications experience, the University of Iowa selected the value 1.0 for all nine components of the Core Software, which represents average experience in developing driving simulator software. On the basis of our understanding of the IDS developers' backgrounds, experience, and credentials, we believe that they possess better than average experience. Therefore, we changed the value to 0.91, which is the value in COCOMO representing the next higher level of experience in developing driving simulator software.

-- For execution time constraints, the University of Iowa selected the value 1.66 for the ICON component, which indicates that ICON has extremely stringent real-time requirements. That is, it must complete critical functions in a precisely specified, short time period. Because the University of Iowa is now using parallel processing for ICON, meaning that processors execute functions concurrently rather than sequentially and the software has been restructured to do so, we believe that the execution time constraints are now somewhat lower. In our opinion, the execution time constraints variable should be slightly lower to reflect this change. Therefore, we reduced the value slightly to 1.5, which is approximately halfway between the extremely stringent value and the next lower value in the model.

-- For programming language experience, the University of Iowa selected the value 1.0 for all nine components of the Core Software. This represents average experience with Fortran and C, the programming languages used for the Core Software. Because the Core Software developers demonstrated considerable experience in Fortran and C and most have advanced degrees in computer science, we changed the variable to 0.95. This indicates a high level of programming language experience, and is the next higher increment in the model for this variable.

-- For the use of software tools (e.g., requirements analysis tools, CASE or Computer Aided Software Engineering tools, automated configuration management tools), the University of Iowa selected the value 1.0 for all nine components of the Core Software. This indicates average use of software tools in developing the Core Software. Because University officials told us they did not use software tools at all because of resource constraints, we changed the value to 1.24. This represents the lowest value available in the model for this variable.

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