



May 29, 2014

Congressional Committees

Defense Acquisitions: Assessment of Institute for Defense Analyses' C-130 Avionics Modernization Program Analysis

The Air Force's C-130 Avionics Modernization Program (AMP), which entered development in 2001, was to standardize and upgrade the cockpit and avionics for various configurations of the C-130 fleet. The C-130, a four-engine turboprop aircraft also known as "Hercules" that is used primarily for military transport, was originally designed in the 1950s. The AMP upgrades were intended to ensure that the C-130 can satisfy the navigation and safety requirements it needs to operate globally while at the same time reducing crew size by one. The program would also have replaced many systems for which manufacturers no longer exist—a situation referred to as diminishing manufacturing sources.

In 2007, the program experienced a critical breach of a statutory cost threshold,¹ and in February 2012, the Department of Defense (DOD) proposed cancelling the C-130 AMP. The National Defense Authorization Act for Fiscal Year 2013 (NDAA) stated that the Secretary of the Air Force may not cancel the program until 90 days after the Secretary provided the Congressional defense committees a cost benefit analysis conducted by the Institute for Defense Analyses (IDA). The NDAA required the Secretary to seek an agreement with IDA to conduct an independent study of the costs and benefits of upgrading and modernizing the legacy C-130H airlift fleet via AMP compared to the costs and benefits of a reduced-scope program.² IDA began its work in March 2013 and produced the required study in September 2013, followed by a detailed annex in December 2013.³ The National Defense Authorization Act for Fiscal Year 2014 mandated that we review IDA's analysis.⁴ This report describes IDA's study and provides our assessment.

¹ DOD is required to notify Congress whenever a major defense acquisition program's unit cost experiences cost growth that exceeds certain thresholds. This is commonly referred to as a Nunn-McCurdy breach. Critical breaches occur when the program acquisition unit cost or procurement unit cost increases by at least 25 percent over the current baseline estimate or at least 50 percent over the original. When a program experiences a Nunn-McCurdy breach of the critical cost growth threshold, DOD is required to take a number of steps including reassessing the program and submitting a certification to Congress in order to continue the program. 10 U.S.C. §§ 2433 and 2433a.

² Pub. L. No. 112-239, § 143.

³ Institute for Defense Analyses, *C-130 Avionics Modernization Analysis*, (Alexandria, VA: Sept. 2013); Institute for Defense Analyses, *C-130 Avionics Modernization Analysis: Annex*, (Alexandria, VA: Dec. 2013).

⁴ Pub. L. No. 113-66, § 133 (2013). The NDAA for Fiscal Year 2014 also prohibited the Air Force from using any fiscal year 2014 appropriations to cancel or modify the C-130 aircraft.

To conduct this work, we obtained IDA's September 2013 study of the C-130 modernization alternatives and associated December 2013 Annex and reviewed the data and assumptions that IDA used to reach its conclusions and recommendations. GAO focused its assessment on IDA's cost estimates and did not assess the operational effectiveness portion of IDA's study as estimated costs were the major discriminating factor in IDA's conclusions. We compared how IDA's estimates were developed to the cost-estimating best practices outlined in the *GAO Cost Estimating and Assessment Guide*.⁵ Specifically, we analyzed the extent to which IDA's cost estimates met the characteristics of high-quality cost estimates. We also discussed the study results with relevant DOD officials. In addition, we reviewed IDA's C-130 AMP annex report to determine the methodologies used to support its findings. More detail on our methodology in applying the cost estimating best practices identified in the *GAO Cost Estimating Guide* can be found in enclosures II and III.

We conducted this performance audit from February 2014 through May 2014 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform our audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Results in Brief

IDA's study is comprised of two key components: (1) its estimate of the costs of AMP and two reduced scope alternatives referred to as Options A and B, which offer fewer avionics upgrades than AMP and, unlike AMP, would both require a navigator in the cockpit; and (2) its assessment of the operational effectiveness—that is, benefits—of AMP and each alternative. IDA estimated that that AMP's costs for research, development, test and evaluation (RDT&E), procurement, and operation and support (O&S) over a 25-year period would total \$2.137 billion—significantly higher than the estimated \$1.531 billion for Option A and \$530 million for Option B. Regarding benefits, IDA found that the lower-cost options offered nearly as much capability as AMP, and the study concluded that the Air Force should not pursue the C-130 AMP program as currently defined.

We found that IDA's cost analysis generally followed best practices for high-quality cost estimates, which are critical to the success of any program. We analyzed the cost estimating methodology IDA used in its study compared to best practices and found that IDA's study substantially met two of the characteristics expected of high-quality cost estimates—that they be comprehensive and credible—and partially met the remaining two characteristics—being well-documented and accurate.

Background

When the C-130 AMP entered development in 2001, it was intended for 20 variants of the C-130 for a total of 519 aircraft. In June 2007, following the program's critical Nunn-McCurdy breach, DOD conducted a five-month review. Subsequently, in accordance with 10 U.S.C.

⁵ GAO, *GAO Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Capital Program Costs*, [GAO-09-3SP](#), (Washington, D.C.: March 2009).

§ 2433, the Under Secretary of Defense for Acquisition, Technology and Logistics certified the C-130 AMP program to Congress, but for a reduced number of 222 aircraft.

The C-130 AMP entered production in 2010, and five aircraft were produced before production was halted. Figure 1 shows the cockpit of a C-130 with AMP.

Figure 1: Cockpit of a C-130 with AMP.



Source: C-130 AMP Program Office.

In the President's Budget for Fiscal Year 2013, DOD did not propose any funding for the C-130 AMP, which would have effectively cancelled the program in favor of a minimum Communication, Navigation, Surveillance/Air Traffic Management (CNS/ATM) solution for the legacy C-130 combat delivery fleet. According to DOD, CNS/ATM would address diminishing manufacturing source issues and complete fleet modifications to meet required navigation performance mandated by 2020. Congress did not authorize any modifications to the program, but rather required IDA's cost-benefit study of the issue.

IDA Study Examined Lower-Cost Options to the C-130 AMP

IDA's cost-benefit analysis of C-130 AMP and alternative options is comprised of two key components: its estimate of the costs of AMP and the alternatives, and its assessment of the operational effectiveness—that is, benefits—of AMP and each of the alternatives. In addition to AMP, IDA examined reduced-scope alternatives it referred to as Options A and B. It reported that AMP was the most sophisticated of the three alternatives and Option B the least. IDA's study noted that they differ in many details. For example, the alternatives differ with respect to level of area navigation and required navigation performance, potentially imposing future

restrictions on airfield access for Options A and B and aircraft routing for Option B. IDA also noted that the most significant difference is the removal of the navigator from the cockpit allowed by the degree of automation, a head-up display and advanced flight assistance equipment by the AMP alternative.⁶ Both Options A and B would have fewer avionics upgrades than AMP and would require the navigator. Unlike Option B, Option A would replace older technology gauges with multi-function displays, as would AMP. In addition, unlike AMP and IDA's Option A, Option B would not replace the current self-contained navigation system (SCNS) with a more modern SCNS capable of higher location and planning precision. IDA concluded that the lower-cost options to C-130 AMP had nearly as much capability and that the Air Force should not pursue the C-130 AMP program as currently defined.

To provide the cost portion of the cost-benefit analysis, IDA developed 25-year cost estimates for the alternatives and assessed their operational implications. IDA developed estimates for RDT&E, procurement, and O&S for the alternatives and combined those estimates to determine overall 25-year costs for each alternative. IDA assumed a fleet of 192 C-130Hs for all options, the number of aircraft defined in the Air Force Capability Development Document; appropriately excluded the approximately \$1.7 billion previously spent on the AMP program; and estimated the costs in constant fiscal year 2013 dollars. The results of IDA's analysis of the costs of AMP and Options A and B are presented in table 1.

Table 1: IDA Cost Estimates for Three C-130 Modernization Alternatives

	C-130 AMP	Option A	Option B
Cost Estimates (constant fiscal year 2013 dollars in millions)			
RDT&E	\$104	\$437	\$140
Procurement	3,060	1,320	480
O&S Savings ^a	-1,027	-226	-90
Totals	2,137	1,531	530

Source: GAO presentation of IDA results

^aThese estimates represent solely the avionics-related O&S costs and savings to be incurred as a result of implementing each of the alternatives. A negative amount depicts a net savings for that option.

IDA's estimates showed that that the AMP's costs for RDT&E, procurement, and O&S over a 25-year period were significantly higher than the alternative options it considered. Specifically, the analysis shows while Options A and B have higher development costs and lower O&S savings (due primarily to the fact that they do not enable the reduction of one crew member), these costs are more than offset by lower procurement costs.

Regarding overall effectiveness, IDA found the AMP's operational effectiveness advantage over Options A and B to be marginal. Specifically, the study found Option A to be at least as operationally effective as AMP since both AMP and Option A address the diminishing manufacturing sources problem. (See enclosure I for further details on IDA's analyses and results.)

IDA's Cost Estimating Generally Followed Best Practices

Given that IDA reported finding Option A at least as operationally effective as AMP, and that estimated costs were the apparent discriminating factor in IDA's recommendation that the Air Force not pursue AMP, we limited our assessment of IDA's cost estimating quality to AMP and

⁶ These capabilities are similar to those found in the C-130J, which also operates without a navigator.

Option A. We found that IDA’s cost analysis either substantially or partially met each of the four characteristics expected of high quality cost estimates. Such estimates are critical to the success of any program as they provide the basis for informed investment decision making, realistic budget formulation and program resourcing, meaningful progress measurement, proactive course correction when warranted, and accountability for results. These characteristics are described briefly below in table 2. A more detailed description of each characteristic of high-quality cost estimates and our complete assessment can be found in enclosure II.

Specifically, we analyzed the cost estimating practices used by IDA in its analysis of the C-130 AMP and alternative options against best practices for high-quality cost estimates. As table 2 shows, we found that the cost estimates in IDA’s study substantially met two of the characteristics expected of high-quality cost estimates—comprehensiveness and credibility—and partially meet the remaining two characteristics—being well-documented and accurate.

Table 2: Evaluation of IDA’s Cost Estimates

Characteristics of high-quality cost estimates	Our evaluation ^a
1. Comprehensive (estimate is complete and accounts for all possible costs)	Substantially Met
2. Well documented (detail and quality of the information used)	Partially Met
3. Accurate (should be unbiased and neither overly conservative or optimistic)	Partially Met
4. Credible (to include sensitivity analysis, risk and uncertainty analysis)	Substantially Met

Source: GAO assessment.

^a For the purposes of our analysis, we determined that a characteristic was “met” if IDA provided complete data that satisfies the entire criterion; “substantially met” if IDA provided data that satisfies a large portion of the criterion; “partially met” if IDA provided evidence that satisfies about half of the criterion; “minimally met” if IDA provided evidence that satisfies a small portion of the criterion; and “not met” if IDA provided no data that satisfies any of the criterion.

More specifically we found the following:

- Comprehensiveness:** We found the estimates to be substantially comprehensive because the estimates appeared to include the pertinent life cycle costs and the estimates’ cost element structure was at an sufficient level of detail considering the purpose of the study was a cost benefit analysis comparison of alternatives. However, we also found that few of the typical technical baseline elements were described in the study and that ground rules and assumptions were incomplete. Specifically, the study itself did not identify inflation indices or their source, although IDA subsequently identified that they used the OSD Comptroller’s Green Book for indices.
- Documentation:** We found the estimates partially met best practices for this characteristic. The study documentation described the estimating methodology used to derive each cost element, but did not describe in detail the calculations performed to arrive at the estimate. Additionally, the documentation described step-by-step how the estimate was developed, but it did not contain sufficiently detailed data to allow a cost analyst unfamiliar with the program to replicate the estimate. Furthermore, the documentation does not contain the source data used to develop the estimates.
- Accuracy:** We found the estimates partially met best practices for this characteristic. The estimates were based on actual costs from the C-130 AMP and other programs, program office estimates for C-130 AMP and other similar programs, cost estimating relationships, and factors, but because the historical source data were not included, we

could not assess the reliability and relevance of the data. Additionally, while the study team performed uncertainty analysis and displayed the point estimates and low and high ranges of the estimate, they did not show the confidence levels of the point estimates to allow us to determine if the estimates were unbiased.

- **Credibility:** We found the estimates substantially met best practices for this characteristic. The study included a risk and uncertainty analysis and displayed the results in the difference between the net present value of AMP and Option A. However, the documentation did not contain cumulative probability distributions, known as “S curves,” of the alternative estimates. Further, the study sensitivity analysis was limited to examination of the most significant contributors to AMP cost variance.

Life cycle cost analyses may be sensitive to underlying assumptions, such as, the time period covered by an analysis. In this case, IDA was tasked with and developed costs for a 25-year period. Over that period, it estimated that the estimate for Option A was nearly \$600 million less than for AMP. Comparatively, in the last year of its study, IDA estimated AMP annual savings that were \$47 million greater than for Option A. Hence, had the time period been less than 25 years, the difference between the AMP and Option A estimates could have been greater; had the time period been longer than 25 years, the difference could have been less. Other assumptions can similarly influence results. For example, IDA noted in its conclusions that factors outside of the scope of its study—including retirement schedules for C-130s and the acquisition of new C-130Js—should inform decisions determining the specific upgrade program chosen.

We are not making recommendations in this report.

Agency Comments and Our Evaluation

DOD and IDA provided comments on a draft of this report, which are reprinted in enclosures IV and V, respectively. In its comments, DOD referred to our work as validating IDA’s analysis. We note that we analyzed the cost estimating methodology IDA used in its study compared to best practices for producing reliable and valid cost estimates. However, we did not produce separate estimates nor did we evaluate IDA’s recommendations. DOD also commented that it took into consideration the data sources that supported IDA’s conclusions when reviewing IDA’s recommendations.

In addition, IDA commented that it agreed with our assessment that its cost analysis generally followed best practices for high quality estimates. Specifically, IDA agreed with our assessment that its cost analysis was comprehensive and credible, but believed they warranted a higher rating of “met”, rather than “substantially met” for these two characteristics. IDA also noted that it strongly believes our assessments of its study against the remaining two characteristics—being well-documented and accurate—should have been higher. As noted in our report, we assessed IDA’s cost estimating as having partially met the criteria for being well documented because it did not, in our opinion, contain sufficiently detailed data to allow a cost analyst unfamiliar with the program to replicate the estimate. Similarly, we assessed IDA’s estimate as having only partially met the best practice of accuracy because the historical source data were not included, and we could not, therefore, assess the reliability and relevance of the data. Our assessment was governed by the information contained in the report itself, which was limited in these two areas. That does not necessarily mean that the information did not exist elsewhere. IDA also commented that we did not find any evidence that its cost estimates were not accurate and that nothing in our assessment undermines its findings and recommendations.

We are sending copies of this report to interested congressional committees; the Secretary of Defense; the Under Secretary of Defense for Acquisition, Technology, and Logistics; and the Secretary of the Air Force. This report also is available at no charge on GAO's website at <http://www.gao.gov>.

Should you or your staff have any questions on the matters covered in this report, please contact me at (202) 512-4841 or sullivanm@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. Key contributors to this report were Bruce H. Thomas, Assistant Director; Marvin Bonner, Analyst-in-Charge; John Beauchamp; Susan Ditto; Karen Richey; Brian Bothwell; Marie Ahearn; and Kenneth E. Patton.

A handwritten signature in black ink, appearing to read 'Michael J. Sullivan', with a long horizontal flourish extending to the right.

Michael J. Sullivan
Director, Acquisition and Sourcing Management

Enclosures – 5

List of Committees

The Honorable Carl Levin
Chairman
The Honorable James Inhofe
Ranking Member
Committee on Armed Services
United States Senate

The Honorable Richard J. Durbin
Chairman
The Honorable Thad Cochran
Ranking Member
Subcommittee on Defense
Committee on Appropriations
United States Senate

The Honorable Howard P. "Buck" McKeon
Chairman
The Honorable Adam Smith
Ranking Member
Committee on Armed Services
House of Representatives

The Honorable Rodney Frelinghuysen
Chairman
The Honorable Pete Visclosky
Ranking Member
Subcommittee on Defense
Committee on Appropriations
House of Representatives

Enclosure I: IDA’s Cost Estimating and Operational Effectiveness Methodology and Results

RDT&E Cost Estimates

In developing estimated RDT&E costs associated with AMP and each of the options, IDA reported that it included nonrecurring design costs as well as the cost of building the test article and conducting associated testing. Utilizing data from the last C-130 AMP Selected Acquisition Report, the C-130J Avionics upgrade, and the KC-10 AMP, IDA estimated that the remaining development costs for AMP to be about \$104 million. To estimate the development costs for Options A and B, IDA utilized data from the C-130 AMP program, removing costs associated with reduced content (eliminated requirements and fewer variants and conversions) and sunk costs. IDA then accounted for the reduced content of Options A and B, determining the subset of equipment and associated cost necessary for the functionality of Options A and B, including government costs, as it did with AMP. Table 3 summarizes IDA’s RDT&E cost estimates for C-130 AMP and the alternatives considered.

Table 3: IDA’s C-130 AMP and Options RDT&E Cost Estimates

	C-130 AMP	Option A	Option B
Cost Estimates (constant fiscal year 2013 dollars in millions)			
IDA’s estimates	\$104	\$437	\$140

Source: GAO presentation of IDA results

As a cross-check on its RDT&E cost estimates for Options A and B, IDA examined additional data. They collected data from the C-130J avionics upgrade and reduced its content to derive a comparison cost estimate. IDA also developed comparison estimates based on the C-5 AMP development program (deemed similar to Option A) and the KC-10 AMP development program (deemed similar to Option B). In addition, IDA reported that it examined Air Force Cost Analysis Agency (AFCAA) estimates for the two successor programs the Air Force had proposed for C-130 AMP—sometimes called the “Optimize” and the “Minimize” CNS/ATM programs. Table 4 provides IDA’s Option A and Option B RDT&E cost estimate and the associated cross-check estimates.

Table 4: IDA’s Cost and Cross-check Estimates for RDT&E for Options A and B

	Option A	Option B
Cost Estimates (constant fiscal year 2013 dollars in millions)		
IDA cost estimate	\$437	\$140
IDA Adjusted C-130J avionics upgrade analogy cross-check	418	220
IDA C-5 AMP analogy cross-check	501	
IDA KC-10 AMP analogy cross-check		57
AFCAA “Maximize” and “Minimize” estimates cross-check	368	185

Source: GAO presentation of IDA results

As the table above shows, the IDA estimate for RDT&E costs fall between the upper and lower bounds of the other estimates.

Procurement Cost Estimates

In discussing its estimation of procurement costs, IDA noted that programs that modify existing platforms have distinctive features that result in cost elements that are unique relative to a new-start acquisition. In developing its procurement cost estimates for the C-130 AMP and the alternatives, IDA examined those elements: kits (i.e. hardware), installation, and other acquisition costs (e.g. training equipment, peculiar support equipment, depot standup, initial spares, and interim contractor support), and program support (e.g. system engineering and program management). IDA reported that it utilized acquisition schedules based on plans and estimates previously put forth by the Air Force and assumed a sole-source procurement strategy for each of the three alternatives.

IDA noted that estimating procurement costs for AMP was unique as cost data for completed production-configuration kits and installations for five aircraft were available. It estimated procurement costs for the AMP by defining price-improvement curves for the kits and installation and extrapolating previous experience forward to define fly-away cost (the sum of kits and installation costs). IDA reported that it estimated other acquisition costs using the relationships of other costs to flyaway costs suggested by historical data for C-130 and other transport aircraft modification programs. For Options A and B, IDA's estimates used "catalog" prices presented by AFCAA for off-the-shelf components that would meet Option A and B defined capabilities. IDA reported that it estimated the cost of associated hardware needed for the installation of those off-the-shelf components (e.g. brackets, mounts, cables, etc.) and the cost of installation itself based on a combination of historical factors and other analyses. IDA also calculated average procurement unit costs for each of the alternatives. Table 5 summarizes IDA's procurement total and average unit (per aircraft) cost estimates for C-130 AMP and the alternatives considered.

Table 5: IDA's C-130 AMP and Options Procurement Cost Estimates

	C-130 AMP	Option A	Option B
Cost Estimates (constant fiscal year 2013 dollars in millions)			
Total estimated procurement costs	\$3,060	\$1,320	\$480
Average estimated unit procurement cost	16.4	7.0	2.5

Source: GAO presentation of IDA results

IDA calculated the average procurement unit costs to enable comparison with estimates it developed based on information from other sources, thereby providing a cross-check against its estimates for AMP and Option A.⁷ For example, IDA developed two cross-check estimates for AMP: one based on the 2010 Selected Acquisition Report produced for the C-130 AMP program; the other based on a C-130 AMP System Program Office "should cost" estimate.⁸ To make these estimates comparable, IDA adjusted the unit costs from them to account for differences in their associated quantities with the number of AMP aircraft used in calculating its estimate and adjusted them to constant fiscal year 2013 dollars. Table 6 provides IDA's AMP procurement cost and associated cross-check estimates.

⁷ The IDA study did not provide procurement cross-check estimate calculations for Option B or explain why it did not.

⁸ In accordance with direction provided in Interim DOD Instruction 5000.2, "Operation of the Defense Acquisition System," and memorandums issued by the Under Secretary of Defense for Acquisition, Technology, and Logistics, each program is to conduct a "should-cost" analysis which includes justifying each cost under the program's control with the aim of reducing negotiated prices for contracts and obtaining other efficiencies in program execution.

Table 6: IDA’s Cost and Cross-check Estimates for Procurement of AMP

	C-130 AMP
Cost Estimates (constant fiscal year 2013 dollars in millions)	
IDA estimated average unit procurement cost	\$16.4
IDA cross-check estimate based on C-130 AMP Final SAR	19.5
IDA cross-check estimate based on adjusted “should cost”	14.3

Source: GAO presentation of IDA results

As can be seen, the IDA estimate for AMP procurement costs falls between the upper and lower bounds of the other estimates.

O&S Cost Estimates

IDA estimated O&S costs for the three alternatives—O&S for 192 aircraft (including aircraft previously completed) over a 25 year period—in constant fiscal year 2013 dollars and also calculated a net present value for each. IDA reported that it included only the incremental O&S costs associated with each alternative, which for all three modernization alternatives amounted to savings from the current C-130 fleet. Elements of O&S costs included personnel, indirect costs, training, fuel, depot-level reparable, diminishing manufacturing sources, consumables, sustaining engineering, program management, support equipment, and software.

IDA’s study indicates that the largest driver of cost savings in its O&S estimate for AMP relates to the elimination of the navigator position from the C-130 cockpit—savings from personnel costs as well as training. To calculate these savings, IDA reported that it adjusted information from a 2010 AMP manpower estimate report as the basis for manpower reductions and applied current salary, training costs and turnover rate information from the Air Force. It assumed no navigator-related savings for Options A and B. Another large driver of AMP cost savings relative to the other options was related to fuel consumption. IDA estimated the incremental O&S costs for fuel by factoring weight considerations for the avionic systems added or removed by each alternative along with costs relating to potential noncompliance with relevant future requirements. IDA noted that while AMP allows unrestricted global operations by meeting required navigational performance and area navigation, aircraft that do not meet those requirements—such as Options A and B—can have restrictions on maximum altitude and landings, which can reduce flying efficiency. To account for this, IDA studied historical C-130H flying and estimated the potential cost associated with not meeting future CNS/ATM requirements. In other O&S cost aspects, IDA estimated Options A and B to be less costly than the AMP. Table 7 provides IDA’s total calculated 25-year life cycle O&S costs (actually savings) for each of the alternatives.

Table 7: IDA’s C-130 AMP and Options O&S Savings Estimates

	C-130 AMP	Option A	Option B
Cost Estimates (constant fiscal year 2013 dollars in millions)			
IDA’s total 25-year O&S estimates	\$-1,027	\$-226	\$-90

Source: GAO presentation of IDA results

Total Estimated Costs

Combining its RDT&E, procurement, and O&S cost estimates from the options, IDA calculated total costs for each of the options in fiscal year 2013 constant dollars. In addition, it discounted those amounts to compute net present values for each of the options. Table 8 provides IDA's calculated total costs and net present values for the options.

Table 8: IDA's 25-year Total Cost (RDT&E, Procurement, and O&S) Estimates for C-130 AMP and Options

	C-130 AMP	Option A	Option B
IDA's 25-year total estimates (constant fiscal year 2013 dollars in billions)	\$2.12	\$1.53	\$.53
IDA's 25-year net present value estimates (in billions of discounted dollars)	2.11	1.46	.51

Source: GAO presentation of IDA results

IDA Took An Additional Step to Address Estimation Uncertainty

To deal with the cost estimating uncertainty, IDA performed cost-risk analysis developing a cost-risk model and utilizing Monte Carlo simulation. For all but two of the variables in its model, IDA utilized triangular distributions defined by a most likely value—its point estimates—and lower and upper limits. For example, the RDT&E upper and lower limits were based on the range of RDT&E costs experienced on similar programs. For cost risk relating to the elimination of a navigator position from AMP, based on discussions with Air Force and U.S. Coast Guard Personnel, IDA considered the case where some tactical missions (e.g. airdrop) require a navigator or sensor operator even with AMP aircraft. To account for this risk, using analytical judgment, IDA defined a discrete distribution. Lastly, IDA accounted for variations in flying hours by utilizing a normal distribution centered on the C-130H planned flying program. IDA's analysis accounted for correlation among inputs. For example, IDA's model included positive correlation between procurement and depot-level costs as both depend on the cost of materials.

IDA ran one hundred thousand simulations, finding that in 98 percent of the simulations AMP's net present value cost was greater than Option A. IDA also performed sensitivity analysis to identify facts that have the most effect on the AMP estimates, finding that AMP procurement cost was the most significant contributor to cost estimating variance, accounting of 72 percent of the observed variance. The second largest contributor was AMP depot-level repairable cost, which accounted for 13 percent.

IDA's Analysis of Operational Effectiveness

IDA defined effectiveness as the ability of a modernized C-130 fleet to enable C-130 operations—consisting of combat delivery, non-combat cargo and passenger movement, and the necessary functions (e.g. training) to support the first two. IDA noted that given that aircraft availability is integrally tied to all aspects of operations, it should be included as a component of effectiveness. Overall, IDA found the AMP's operational effectiveness advantage over Options A and B to be marginal. It stated that it found Option A to be at least as operationally effective as AMP since both AMP and Option A address diminishing manufacturing sources. Additionally, it noted that training and scheduling inefficiencies have largely been solved outside of avionics modernization and crew work loads are not an issue with Option A as it retains the navigator position.

In assessing the aircraft availability of the AMP and alternatives, IDA estimated the upper bound on expected improvements to the mission capable rate as a measure of availability as the mission capable rate is an indicator of whether the C-130 fleet is ready to perform its mission

when needed.⁹ IDA examined historical mission readiness data for the C-130H fleet in determining the upper bound. It found that the best-case possible mission capable rate improvement that AMP could achieve was 1.4 percent. IDA then looked at the other extreme Option B. IDA found a best-case improvement for Option B of only 0.5 percent. IDA concluded that mission capable rate improvement is not a discriminating factor with regard to operational effectiveness.

Another area included in IDA's operational effectiveness assessment was combat delivery and passenger and cargo movement. IDA chose to include these areas as part of the effectiveness assessment because the primary mission of the C-130 is to deliver troops and cargo to the forward operating locations and drop-zones in a combat environment. Although the AMP and the reduced-scope alternatives were not intended to change combat delivery capabilities, elimination of the navigator in the AMP redistributes the workload and responsibilities of the remaining crew members during combat delivery. In evaluating the effectiveness of combat delivery of AMP and the alternatives, IDA examined whether AMP's combat delivery would be affected by replacing the navigator position. IDA found that some subject matter experts believe that removal of the navigator position would increase crew workload, especially in high-threat environments. IDA reported that Operations Iraqi Freedom and Enduring Freedom, with the C-130J and C-17 aircraft, which also eliminate the navigator position, indicates that some percentage of airlift missions require augmentation with a third pilot to mitigate crew workload. In summary, IDA noted that if additional crew members are needed for AMP, then AMP will cost more than it estimated in calculating AMP O&S costs as it gave AMP full credit for removal of the navigator in determining its base AMP O&S costs.

In evaluating non-combat cargo and passenger movement, IDA sought to determine if differences in required area navigation and navigation performance for AMP and the alternative options might impose restrictions on aircraft routing and airfield access, thereby affecting operational effectiveness. To determine the effectiveness of the modernization alternatives in this respect, IDA used two methodologies—assessing the effect of limited required area navigation and navigation performance capabilities on airfield approaches and assessing the impact to flying high-altitude routes. IDA found that AMP provides the most operational flexibility if the aviation community is converted to a predominately precision navigation-based system that completely replaces the current ground-based system. There are currently no definitive FAA plans to do so. IDA also found that the AMP alternatives could experience delays at large airfields because of their limited navigation approach capability—potentially affecting up to 33 percent of C-130H sorties if certain larger airfields are required to adopt the newer technology. In assessing the effects to flying high altitude routes, IDA concluded that access to higher altitudes afforded by the AMP and Option A navigation capability result in modest fuel savings and increased payload capacity at extreme flying ranges and payloads, but may not be operationally significant for the most common routes and cargo weights.

IDA also assessed operations support—involving primarily improvements to training and scheduling—for AMP and the alternatives. IDA's objective was to determine if the different modernization options sufficiently standardized the C-130H fleet to eliminate or reduce inefficiencies associated with tailoring training to each variant of the aircraft. Standardization had been cited as a key reason for the C-130 AMP. To address this question, IDA obtained equipment lists for the C130H and sought to determine which avionics equipment varied across the C-130 fleet. IDA determined that there are eight avionics components that are the primary

⁹ Mission capable rate is a measure of an aircraft's readiness to perform its missions.

drivers for variations in C-130H training. Option A would standardize four of those differences and Option B one, while AMP would eliminate all of the avionics component differences. IDA noted that while differences in training would exist under Options A and B, the present day version of this training is no longer the concern it was a decade ago as a result of the selective retirement of aircraft that has minimized the number of C-130 variants. IDA also noted that the fewer number of C-130H variants and sub-variants facilitates mission planning and scheduling. In summary, IDA found that while neither Options A nor B completely eliminates the need for differences in training, the significantly reduced number of C-130 variants has largely solved the training problems to the point that they are no longer of operational concern.

Enclosure II: Characteristics of High-Quality and Reliable Cost Estimates and Our Detailed Assessment of IDA's Cost-Benefit Analysis

Our research has identified a number of best practices that are the basis of effective program cost estimating and should result in reliable and valid cost estimates that management can use for making informed decisions. These four characteristics of a high-quality and reliable cost estimate are that it is comprehensive, credible, well-documented, and accurate.

- **Comprehensive:** The cost estimate should include both government and contractor costs of the program over its full life cycle, from inception of the program through design, development, deployment, and operation and maintenance to retirement of the program. It should also completely define the program, reflect the current schedule, and be technically reasonable. Comprehensive cost estimates should be structured in sufficient detail to ensure that cost elements are neither omitted nor double counted. Finally, where information is limited and judgments must be made, the cost estimate should document all cost-influencing ground rules and assumptions.
- **Credible:** The cost estimate should discuss any limitations of the analysis because of uncertainty or biases surrounding data or assumptions. Major assumptions should be varied, and other outcomes recomputed to determine how sensitive they are to changes in the assumptions. Risk and uncertainty analysis should be performed to determine the level of risk associated with the estimate. Further, the estimate's cost drivers should be crosschecked, and an independent cost estimate conducted by a group outside the acquiring organization should be developed to determine whether other estimating methods produce similar results.
- **Well-documented:** A good cost estimate—while taking the form of a single number—is supported by detailed documentation that describes how it was derived and how the expected funding will be spent in order to achieve a given objective. Therefore, the documentation should capture in writing such things as the source data used, the calculations performed and their results, and the estimating methodology used to derive each element's cost. Moreover, this information should be captured in such a way that the data used to derive the estimate can be traced back to, and verified against their sources so that the estimate can be easily replicated and updated. The documentation should also discuss the technical baseline description and how the data were normalized. Finally, the documentation should include evidence that the cost estimate was reviewed and accepted by management.
- **Accurate:** The cost estimate should provide for results that are unbiased, and it should not be overly conservative or optimistic. An estimate is accurate when it is based on an assessment of most likely costs, adjusted properly for inflation, and contains few, if any, minor mistakes. Among other things, the estimate should be grounded in a historical record of cost estimating and actual experiences on other comparable programs.

Table 9 provides our detailed assessment of IDA's cost estimating compared to best practices.

Table 9: Detailed Assessment of IDA’s Cost Estimating Compared to Best Practices

Characteristic	Overall Assessment*	Best Practice	Individual Assessment
Comprehensive	Substantially Met	The cost estimate includes all life cycle costs	Substantially Met
		The cost estimate completely defines the program, reflects the current schedule, and is technically reasonable	Partially Met
		The cost estimate is product-oriented, traceable to the statement of work/objective, and at an appropriate level of detail to ensure that cost elements are neither omitted nor double-counted.	Substantially Met
		The estimate documents all cost-influencing ground rules and assumptions.	Partially Met
Well documented	Partially Met	The documentation should capture the source data used, the reliability of the data, and how the data were normalized.	Partially Met
		The documentation describes in sufficient detail the calculations performed and the estimating methodology used to derive each element’s cost.	Partially Met
		The documentation describes step by step how the estimate was developed so that a cost analyst unfamiliar with the program could understand what was done and replicate it	Partially Met
		The documentation discusses the technical baseline description and the data in the baseline is consistent with the estimate	Partially Met
		The documentation provides evidence that the cost estimate was reviewed and accepted by management.	Substantially Met
Accurate	Partially Met	The cost estimate results are unbiased, not overly conservative or optimistic and based on an assessment of most likely costs.	Partially Met
		The estimate has been adjusted properly for inflation.	Substantially Met
		The estimate contains few, if any, minor mistakes.	Substantially Met
		The cost estimate is regularly updated to reflect significant changes in the program so that it is always reflecting current status.	Not Applicable
		Variances between planned and actual costs are documented, explained, and reviewed.	Not Applicable
		The estimate is based on a historical record of cost estimating and actual experiences from other comparable programs.	Partially Met
		The estimating technique for each cost element was used appropriately.	Partially Met
Credible	Substantially Met	The cost estimate includes a sensitivity analysis that identifies a range of possible costs based on varying major assumptions, parameters, and data inputs.	Partially Met
		A risk and uncertainty analysis was conducted that quantified the imperfectly understood risks and identified the effects of changing key cost driver assumptions and factors.	Substantially Met
		Major cost elements were cross-checked to see whether results were similar.	Substantially Met
		An independent cost estimate was conducted by a group outside the acquiring organization to determine whether other estimating methods produce similar results.	Not Applicable

Source: GAO analysis of IDA’s data

* Not Met - IDA provided no evidence that satisfies any of the criterion, Minimally Met – IDA provided evidence that satisfies a small portion of the criterion, Partially Met – IDA provided evidence that satisfies about half of the criterion, Substantially Met – IDA provided evidence that satisfies a large portion of the criterion, and Met – IDA provided complete evidence that satisfies the entire criterion.

Enclosure III: Objectives, Scope, and Methodology

To conduct this work, we obtained IDA's September 2013 cost benefit analysis study of the C-130 AMP program and reviewed it to determine the data and assumptions that IDA used to reach its conclusions and recommendations. To analyze IDA's cost estimating, we relied on *GAO's Cost Estimating and Assessment Guide*. In developing this guide, our cost experts assessed measures consistently applied by cost-estimating organizations throughout the federal government and industry and considered best-practices for the development of reliable cost-estimates. We analyzed the cost estimating practices used by the IDA in its analysis of the C-130 AMP and alternative options against these best practices. For reporting, we collapsed these best practices into four general characteristics for sound cost estimating: comprehensive, well documented, accurate, and credible.

We assigned each characteristic a rating of either met, substantially met, partially met, minimally met, or not met. We determined the overall assessment rating by assigning each individual rating a number: not met = 1, minimally met = 2, partially met = 3, substantially met = 4, and met = 5. Then, we took the average of the individual assessment ratings to determine the overall rating for each of the four characteristics. The resulting average becomes the Overall Assessment as follows: not met = 1.0 to 1.4, minimally met = 1.5 to 2.4, partially met = 2.5 to 3.4, substantially met = 3.5 to 4.4, and met = 4.5 to 5.0. A cost estimate is considered reliable if the overall assessment ratings for each of the four characteristics are substantially or fully met. If any of the characteristics are not met, minimally met, or partially met, then the cost estimate does not fully reflect the characteristics of a high-quality estimate and cannot be considered reliable. Because the cost estimates were developed for a cost-benefit analysis and not for a program office estimate, we did not assess two areas within the "accurate" characteristic—regular updating of cost estimates and tracking cost variances—and one area within the credible characteristic—independent cost estimates.

Further, we interviewed agency officials from IDA, the Air Force Cost Analysis Agency, the Assistant Secretary of the Air Force Acquisition Office, and the Director of the Office of the Secretary of Defense's Cost Assessment and Program Evaluation office to discuss the IDA study results. In addition, we reviewed IDA's C-130 AMP annex report to determine the methodologies used to support findings in the September 2013 report.

Given that IDA reported finding Option A nearly (if not as) operationally effective as AMP, and that costs were the apparent driving factor in IDA's recommendation that the Air Force not pursue AMP, we limited our assessment of IDA's cost estimating to AMP and Option A.

Enclosure IV: Comments from the Department of Defense



ACQUISITION

ASSISTANT SECRETARY OF DEFENSE
3015 DEFENSE PENTAGON
WASHINGTON, DC 20301-3015

16 MAY 2014

Mr. Michael J. Sullivan
Director, Acquisition and Sourcing Management
U.S. Government Accountability Office
441 G Street, N.W.
Washington, DC 20548

Dear Mr. Sullivan:

This is the Department of Defense (DoD) response to the GAO Draft Report, GAO-14-547R, 'DEFENSE ACQUISITIONS: Assessment of Institute for Defense Analyses C-130 Avionics Modernization Program (AMP) Analysis,' dated April 30, 2014 (GAO Code 121191). The Department has received the draft report and would like to include the following comments.

The Department appreciates GAO validating the Institute for Defense Analyses' (IDA) cost analysis on the C-130 Avionics Modernization Program alternatives. When reviewing IDA's recommendations, DoD took into consideration the referenced data sources that supported IDA's conclusions. As a result, the Department did not pursue the costly C-130 AMP option and pursued less costly alternatives.

Sincerely,

A handwritten signature in blue ink that reads "Katrina McFarland".

Katrina McFarland

Enclosure V: Comments from the Institute for Defense Analyses

IDA Response to GAO Assessment of IDA Paper P-5062, *C-130 Avionics Modernization Analysis*

GAO states that “IDA’s cost analysis generally followed best practices for high quality cost estimates, which are critical to the success of any program.” IDA agrees with GAO’s assessment, having completed a rigorous analysis of both cost and effectiveness for several C-130 avionics modernization alternatives.

GAO found that “IDA substantially met two of the characteristics expected of high-quality cost estimates – that they be comprehensive and credible.” While IDA believes these two assessments should have been rated “Met,” IDA agrees with GAO that its independent assessment was both comprehensive and credible.

GAO also found that IDA “partially met the remaining two characteristics – being well-documented and accurate.” IDA strongly believes these two assessments should have been rated higher, and has provided GAO detailed justification.

Regarding documentation, GAO found that “the study documentation described the estimating methodology used to derive each cost estimate”... and “the documentation described step-by-step how the estimate was developed, but it did not contain sufficiently detailed data to allow a cost analyst unfamiliar with the program to replicate the estimate.” The IDA report scrupulously identified all data sources, but did not in many cases copy the actual source data itself into the report. IDA referenced the source, but did not always repeat the actual data in the IDA report itself, especially when the data could be easily found by other analysts. IDA believes that a source reference itself is appropriate for a report of this nature.

Regarding accuracy, GAO stated that “the estimates were based on actual costs from the C-130 AMP and other programs, program office estimates for C-130 AMP and other similar programs, cost estimating relationships, and factors, but because the historical source data were not included, we could not assess the reliability and relevance of the data.” IDA strongly believes they produced accurate cost estimates using sound methodology as described in detail in their report. GAO did not in fact find any evidence that the IDA assessment was not accurate. GAO’s primary reason for its “Partially Met” rating was that they could not verify the accuracy of the analysis because all source documentation was not included in the IDA report.

The IDA independent cost-benefit assessment determined there are lower cost options of nearly as much capability as C-130 AMP. The IDA report thus recommended that the US Air Force pursue a reduced scope option, such as Options A or B and not pursue C-130 AMP. Nothing in the GAO assessment undermines these findings and recommendations.

(121191)

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