Controlling Costs — A Historical Perspective

How Can I Make Trade-offs?

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The bright gleaming car sat on the dealers' showroom floor beckoning to me. It was everything I wanted – V-8 engine, convertible, lush interior, a cup holder for my McDonald's coffee. It was almost a match! There was that nasty little problem of price. How to negotiate the dealer down from his unreasonable price of $25,500 to my affordable price of $15,000. A large leap?

The Department of Defense (DoD) has the same problem. How to make new acquisitions affordable? The latest DoD initiative to try to tackle this problem is "Cost As An Independent Variable" (CAIV). Its goal is to "Reduce the cost to acquire and operate the Department's equipment while maintaining a high level of performance for the user..." Industry is able to do this – treat cost as a critical variable where they make trade-offs. Can the Department do this? Similar DoD initiatives in the past have not proven to be successful.

Is the Past Prologue?

Twenty-five years ago DoD faced similar problems and created a cost cutting initiative – Design-to-Cost. The purpose of this article is to examine Design-to-Cost, its objectives and history, and discuss their implication for CAIV. A review of a current program, the Joint Direct Attack Munitions (JDAM) program, provides useful information on developing a practical

"The Warthog" — The A-10 Aircraft during in-flight refueling operations over the North Sea, Royal Air Force Mildenhall, United Kingdom.

F/A-18 Hornet aircraft waits to taxi forward to one of the bow-catapults on the *USS Dwight D. Eisenhower* during flight operations off the coast of Puerto Rico, June 25, 1994.

Department of Defense photos

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approach to managing CAIV. Finally, I offer my observations, including the questions and issues to be considered as your program wrestles with implementing CAIV.

Guns and butter! The old saw was that you could not have both. In the 1960s, as a nation we decided we could have peacetime prosperity, spend a significant amount of the "government's" money in building "the great society," and fight the Vietnam War.

Yet the demands of financing the battlefield made a significant dent on our ability to develop new systems. During the later part of the McNamara era, the procurement accounts were used to pay for the operations of the Vietnam War. The increasing operations and maintenance costs, coupled with the congressionally mandated budget ceiling for defense continued into the Nixon Administration. David Packard, Deputy Secretary of Defense, and John Foster, the Director of Defense Research and Engineering (DDR&E), were faced with the need to rein in costs.

Apache AH-64 Helicopter entered development in 1976 with Hughes Aircraft.

The Design-to-Cost (DTC)[1] concept is credited to Packard and Foster who were looking for an acquisition technique to control the spiraling costs of weapons systems. While there were some test programs in 1970, DTC did not become official policy until July 13, 1971, with its incorporation into DoD 5000.1. The original policy focus was on the production cost of articles. By 1973, the Department recognized the need to include life cycle cost design as part of the DTC goal. The thrust of the policy was to weight cost as an equal design parameter with schedule/technical and life cycle cost requirements.

Initially, DTC was used as a "goal" in programs, but by 1973 it was mandated for all major programs, regardless of acquisition phase. The initial policy guidance appears to have been general, with every program developing its own methods of implementing DTC. Various programs applied individual measurements and developed individual approaches to measuring and applying DTC. Some programs looked at the (1) total force structure; (2) the life cycle of a weapon system; and (3) production of system hardware.

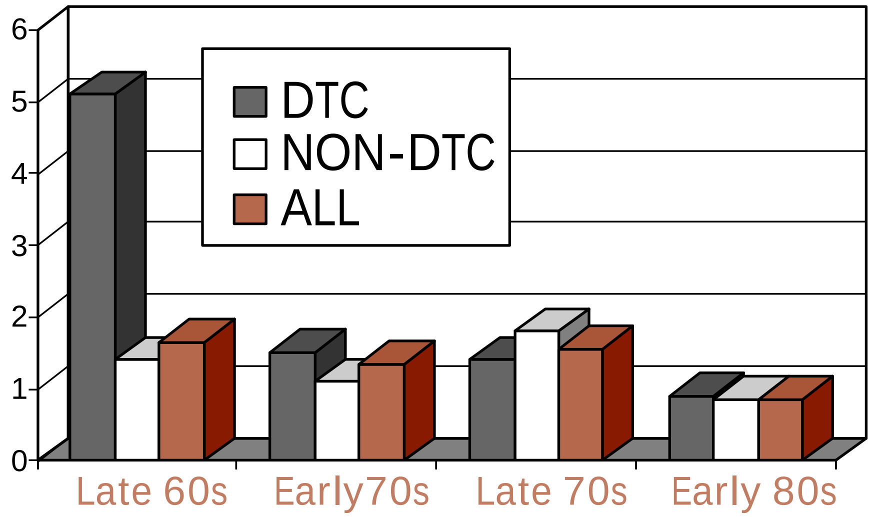
It Should Cost Less If I Have a DTC Goal, Right?

I thought the answer would be yes! Figure 1 provides surprising information. A study by the Institute for Defense Analyses (IDA)[2] found, in looking at data on 63 major systems to compare cost and schedule outcomes for DTC and non-DTC programs, that the actual overall cost growth on DTC programs was 19 percentage points greater than that of the non-DTC programs. This cost growth included the Full Scale Development and Production of the items. Unfortunately, statistical data do not always answer the question – "Why the cost growth?" To provide a flavor for the various approaches and understand the impact of DTC and its effect on the program cost growth, a 1989 IDA study looked at several programs, including the FA/18, A-10, and AH-64 programs. The following program observation should provide insight into the possible reason for this cost growth.

"The Hornet" — The F/A-18 Low-cost Fighter

The Navy's Hornet was manufactured and developed by McDonnell Douglas. After the program entered Full Scale Development (FSD) in 1976, DTC was implemented as a goal. Insta-

Figure 1. Total Program Cost Growth — DTC vs. Non-DTC



bility in quantities (2300 – 1366 – 1157 units) and changes or upgrades were complexities in measuring a "cost" for the fighter. Even as these changes occurred, the program office did not continually update and track a new DTC goal. Rather than identifying the cost of a specific aircraft, the measurement for DTC was on "the cumulative average recurring cost for 800 aircraft." The FA-18 was originally sold as a low-cost aircraft, yet the program office provided little or no guidance to the contractor on the design, performance, and cost interrelationships. There were no contractual incentives to motivate the contractor and make DTC an active effort on the program. The IDA concluded, "There appeared to be little interest in the Navy in trading off systems requirements for cost...the DTC goal was dropped or faded away in program FSD."[3]

"The Warthog" — The A-10

The 1970 FSD contract for the Air Force A-10, another low-cost fighter, was won by Fairchild Industries. The competitive "Fly Before You Buy" effort leading to FSD featured a competition between Northrop and Fairchild, with a prize of 600 aircraft for the winner. Some of the ground work for DTC was performed during this "fly-off" phase. "The selection of a high-thrust engine already developed, the extensive use of trade studies, and the use of an iteration process with the engine manufacturer to reduce engine costs,"[4] are examples of the types of activities expended in lowering the cost of the aircraft. Fairchild also placed much effort on providing a "production similar" aircraft.[5] The FSD contract was Firm Fixed Price but was designed to offer the opportunity for DTC tradeoffs since it was"...void of usual military specifications, standards, and other normal procurement requirements, [which] provided the contractor with maximum flexibility to trade performance and cost."[6] The Warthog goal, $1.5M (FY 1970), was measured by unit production flyaway costs, including both recurring and nonrecurring cost for production. There were negative penalties for failure to meet the DTC goal – contract termination. Perhaps in a precursor to Integrated Product Teams (IPT), the Company organized into design teams.

There was a feeling by both the IDA study participants and the Special Projects Office (SPO) that DTC had been an effective motivator of the contractor in controlling costs. However, Figure 2[7] shows the total program cost growth was still 10 percent higher than all eight other tactical aircraft reviewed. Would the costs have been even higher without the DTC bogey?

"The Apache" — The AH-64

Our third program to review is the Army's Apache Helicopter. It entered development in 1976 with Hughes Aircraft as the Phase 1 winner over Bell Helicopter. Unlike the FA-18, the AH-64 goal reflected continual change – 1.4M unit production cost; then revised to 1.6M unit production cost; then $1.8M unit flyaway cost; and finally $3.31M (FY 87 dollars). Both the goal and the way the program measured the goal changed. "This suggests that DTC has been used more or less like a cost-monitoring device. The DTC goal was changed to adjust to the performance requirements of the system."[8] This is probably why the DTC goal "did not serve to discipline cost growth, especially for nonrecurring tooling, engineering, and program management service costs."[9]

Traditional motivational theory suggests the use of award fees as an effective motivator of a contractor's performance. The AH-64 SPO did use an award fee to attempt to motivate Hughes to achieve the DTC goal. Unfortunately, as each initial award fee period ended, the contractor was unable to demonstrate successful performance in meeting its DTC goal and thus, received no fee. After it became obvious to Hughes that they would not be able to earn the award fees, it ceased to be an effective motivator.

What Were the Major Problems in DTC?

The Hornet, Apache, and Warthog offer insight into the implementation of DTC and a start in understanding the problems of DTC. The initial problem in the DTC implementation was that the policy was mandated on all major programs (after 1973) whether or not it made sense for the phase of the program. This creates three problems. First, after an FSD (now Engineering and Manufacturing Development Phase) contract was awarded, and in particular, after the Critical Design Review was completed, it was highly unlikely that a program office would be willing to make change. Since cost and schedule are two of the key measurement parameters of a successful program manager, the incentive is to continue with initial design.

Redesign takes time and money. Thus, DTC becomes a cost monitoring device, changeable as "new requirements" become part of the program.

Second, applying an initiative to a program (or programs) where it will not work, robs the initiative of its integrity. It becomes "just something to do" rather than a central part of the program's focus. Another researcher found that DTC was considered by many as just another initiative – "just some clause that had to be put into the contract."[10] Third, the application of DTC to already awarded contracts resulted in sole-source negotiations. In these types of situations, it is difficult to develop a realistic target.

A variety of DTC approaches was used by program offices. "They used incentives for achieving the cost goals, performance-validation plans, and price-index adjustment clauses... Considerable variations were found among programs in the requirements for production-cost tracking and reporting during the development phases. Other government DTC requirements varied widely among programs."[11] There seemed to be no central guidelines nor training on how to implement, measure, or motivate [the contractor]. Each program was on its own to invent its approach to DTC. While a "one size fits all" program would probably have failed, it might have been useful to have provided some tenets and training to those responsible for implementing the DTC requirements. Additionally, the selection of pilot programs and monitoring and promulgation of lessons learned could have provided valuable insight for future programs.

Key to making DTC work, as well as CAIV, is the willingness to make requirements trade-offs. None of the programs reviewed seemed to have a clear cut process for making this happen. The user does not appear to have been a part of the process, at least not in a formal way. In most cases, as witness the Apache, there were continual requirements changes. This makes it hard to measure and reward when your goal is always changing. Some authors felt that whoever would make the changes would make a difference as to how effective DTC would be – if you wait until the time comes to make a change, then start the process with the users, you are too late. The engineering changes must be made quickly, or as time passes changes become more costly. This approach would put the authority to make changes into the hands of the program manager. An effective Integrated Product Team (with the empowered user as part of the team), or another approach where the user and the acquisition organization agree to a speedy process for handling changes, would meet the concerns of the need for reasonably quick decisions and contract changes.

Some programs set unrealistic goals. One Army program had a Design to Unit Production Cost of $3564.00 per unit, while the contractor was estimating the cost was closer to $20-30,000 per unit. Eventually it was dropped as a contract requirement.[12]

What was the contractor's response to DTC? An IDA study concluded that most contractors did not have DTC policies or operating procedures.[13] It appears that contractor management personnel believed that their normal mode of operations would be adequate to accomplish the DTC requirements, and that the DTC process would be handled on a demand basis by project or program staff personnel. Oscar Solar, current Joint Direct Attack Munitions (JDAM) Program Director, related his experience on the Advanced Medium Range Air-to-Air Missile (AMRAAM) program's DTC efforts. "During design reviews, the engineers were going over the individual design of each board, explaining how they had allocated the technical values of each part on the board. When I asked how had they allocated the DTC goals to each part, it quickly became obvious that DTC had not penetrated into the engineering design process. To make DTC work we needed the design engineers and the engineering department to be a part of the process."[14] To make CAIV work, it is critical that the contractor's engineering personnel see this as part of their job.

In summary DTC did not succeed for a variety of reasons: the perception by many that it was just another initiative; lack of a process for making requirement trade-offs; desire for achieving the last 2 percent of performance; and lack of management attention, both contractor and government.

CAIV Can Be a Success!

The JDAM program provides a potential example of a program that foresaw

Figure 2. A-10 Schedule and Cost Outcomes vs. All Tactical Aircraft Outcomes

Growth	A-10	All Tactical Aircraft (8)
Development Cost	1.27	1.18
Development Schedule	1.08	1.03
Development Quantity	0.71	1.10
Production Cost	1.34	1.25
Production Schedule	0.98	2.12
Production Quantity	1.00	1.65
Total Program Cost	1.33	1.23

many of the problems DTC encountered and developed management strategies to make cost-effective tradeoffs an important part of the program. "We were doing CAIV before DoD coined the term," said Terry Little, former Program Director for the JDAM Program. As the program entered into the competitive Demonstration/Validation phase, it faced a significant cost problem. The program office costs estimates ranged from a high of $68K to a low of $48K. Even then, this made the system unaffordable within the Air Force budget.

Management focus on the cost of the system was critical to success of the program. Early on, the JDAM program office set aggressive, but achievable cost/price objectives. Their cost/price production objective included all recurring costs, warranty price, Engineering Change Proposals, and unamortized tooling/test equipment. In an unusual approach, they made the cost objective part of the contract systems specification. It was important to focus the need to make cost versus performance design trade in the contractor's technical community. This helped provide organizational penetration into the contractor's engineering community.

As a necessary adjunct to the organizational penetration of the contractor was the need to have "heavy" user involvement and their willingness to trade performance for cost, as necessary. The JDAM's program office and the user created "Live or Die" requirements – those that the user was unwilling to trade off. They were accuracy, aircraft compatibility, aircraft carrier suitability, captive in flight retargeting, warhead compatibility, and *low unit cost.* With the user agreement to the "Live or Die" requirements, everything else was a trade-off. The contractor was thus provided guidance on where to focus its attention and where to make its design trades.

The contractor's motivations must also match our goals. Part of the JDAM "CAIV" approach was to make selection of the two competing contractors based upon achievement of the cost/price goals. There was a requirement to have the contractors sign up to a price commitment on future contracts with both rewards and penalties for failure to live up to that promise. The contractor and government made mutually agreeable, early and challenging, long-term pricing commitment to one another. Using a "carrot and stick" approach, the government agreed that if the contractor meets its commitment to the unit price, then the government would:

- not require cost data;
- nor require negotiation;
- not ask for new technical proposals for each production lot ordered;
- not mandate subcontractor competition (goal was to encourage a long-term, collaborative relationship, thus providing stability for capital investment and encourage supplier warranties); and
- no in-plant oversight.

The contractor was also given the right to make unilateral changes to reduce cost as long as it was transparent to the user, but with government notification.

But what if the contractor does not live up to its promise? The answer – the "stick" – government business as usual: oversight, technical proposals, cost data, and potential loss of future business, since the contractor is required to deliver engineering data to allow the government the ability to compete future buys.

There were several other lessons learned from the JDAM program efforts. During the competitive Demonstration/Validation phase, the JDAM program originally included an Award fee to motivate the contractor. Their findings, similar to the Multiple Launch Rocket System, were that during the competitive phase, as they strove to achieve cost goals, the award fee was not effective; rather, competition drove the contractor's efforts.

Teaming was also a critical part to the success of the program's efforts. During the Demonstration/Validation phase of the program, two Integrated Product Teams (government and industry) each struggled with the issue of lowering the cost of the production items. This created a sense of teamwork, an understanding of the "real" Air Force issues, and a buy-in to the need to lower the cost of the system.

Often small efforts can lead to significant cost savings. The JDAM $25 Power Transistor is a good example. The original requirement was for a 2500 in-lbs. stall torque requirement. The first trade came when they were asked to ease the 2500 in-lbs. stall torque requirement to 1600 in lb. The prime agreed with the subcontractor's recommended change in requirement, and the cost dropped to $15 per transistor. The next change – could we live with a commercial part? Would it meet our environmental requirements? Answer – yes. This lowered the cost to $4.05. This may not seem like much, but saving 20.95 per transistor, times the 24 in the system and the 74,000 units to be bought, equates to a $37.2M program savings. It is the small things that add up to the big things!

The final price commitment – $14K per unit!

According to Little, "CAIV can work when everyone is an owner of the issue – that includes the users and engineers, rather than just the bean counters and managers."[15]

Observations On How to Implement CAIV

Affordability will be a key requirement of any future weapon system. This translates into a need for making cost as an independent variable with performance and schedule at the dependent variables. Design to Cost was not a success for a variety of reasons, but a primary problem was the unwillingness to make cost, performance, and schedule trade-offs. Cost as an independent variable means cost is, and must be, in the tradespace. It can be traded for requirements verification (Military Specifications and Standards), performance (that last 2 percent), and schedule (accelerating or decelerating).

How Would You Structure a Successful Cost As an Independent Variable Approach?

Start early. If your system is in the demonstration/validation phase, then CAIV provides an early opportunity, for industry and the government, to focus on a goal. Performance and design trades are made easier, and at less cost then, once the contractor has designed and tested the item.

Get your hands on the real requirements. Most discussion of requirements focus on the user requirements, but technical requirements with cost implications are also mandated by the SPO when they translate the users' requirements into a statement of work or a specification. The contractor also imposes requirements on the system by his design process. The program office must keep these issues in mind as it implements CAIV. First, a systematic process that ties the SPO and the user together, must be in place to evaluate requirement changes and provide expeditious response. The user also needs information – what is the real cost of his or her requirement? A small increase in reliability may not provide enough military usefulness when traded off for the cost of its achievement. The JDAM's "Live or Die" approach to requirements provides one example of incorporating the user into a real evaluation of his or her requirements. By being flexible about the design and ranking performance parameters, the contractor is provided trade-off guidelines.

If the relative importance of specific performance requirements can also be identified, the contractor can focus its efforts in the most fruitful areas for which the government is willing to consider changes. The second issue is SPO-issued requirements. As seen in the A-10 example, the move to performance statements of work and specifications and/or statement of objectives helps in the design trade-off process by again providing the contractor with flexibility. Finally, the contractor, through its engineering design practices, can also impose non-cost conscious requirements on the design. It is critical that part of the contractor's design engineering practices be cost consideration. I would also not restrict the analysis to just the design engineering portion of the contractor's organization. The production process and environment are just as important in attempting to achieve lower costs.

The recent PBS special, "Accidental Empires, Triumph of the Nerds," highlights DTC in action. In designing the original Apple II Computer, Steven Wocsniak achieved a "model of efficient engineering." Because of the large demand for chips, traditionalists would have known it was impossible to design a "personal computer." Not knowing it was impossible, "Woz" ended up using his own sense of design. Rather than two memory chips – one for the TV screen and one for the computer – he combined them. For the floppy disc drive controller, he needed only eight versus the traditionalist's 35 chips. This model of efficient engineering made for a sleek looking model and created the "Personal Computer." It is this type of continual technical evaluation of design, technical effectiveness, and cost tradeoffs that are necessary to meet CAIV goals. Just as in the Commercial market **Cost/Price** is the independent variable, so too in the government it must be one of the program's design parameters.

How Will You Establish a CAIV Goal?

If the acquisition is competitive, the contractor can be asked to propose, or our "goal" (hopefully based upon some reasonable estimate) could be provided. I like the JDAM approach to apply the goal to unit one. The price is then set for future buys, tied to the learning curve costs (with rewards and penalties). It is also important to allocate CAIV goals down the Work Breakdown Structure and track costs regularly for both primes and subs (60 percent of work may be with subs). Consideration should be given to having a goal for subcontractors. It is critical that Life Cycle Cost impacts always be considered as part of contractor trades. If the acquisition is sole-source, an integrated effort, government and contractor, is necessary to develop a goal that both parties can agree is reasonable and achievable.

How Will You Manage CAIV?

Government management emphasis and organizational penetration into the contractor's organization are the main keys to success of DTC and by extension to CAIV. The emphasis on CAIV must start with the source selection process. The request for proposal and the source selection criteria both must emphasize the importance of cost trade efforts. Once the contract is awarded, government management must continually follow up with concern for the contractor's efforts in implementing CAIV. As seen in the A-10 and the JDAM cases, a competitive phase provides an opportunity to successfully motivate a contractor to focus on cost. Management interest in CAIV should be part of design review, program reviews, and other government industry meetings. It should be stressed to the contractor that this needs to be a part of its engineering design process. Once a single contractor has been selected, the use of award fees provides an effective tool to motivate contractor's efforts.

Certainly, CAIV will not happen by putting it on contract. The contractor's management personnel have conflicting motivations. Not only do they want to perform on the current contract, but they are interested in winning the next contract. They also must deal with organizational and personnel issues, and a reward system that may actually conflict with successful performance (as seen by the government) on your contract. For example, companies often pay bonuses based upon increase in cash flow and increase in orders or new business. Additionally, as illustrated in the AMRAAM example, the contract DTC requirement got lost in the "contracting or finance shop" and did not "flow down" to the person designing the equipment. This is why the government must demonstrate to the contractor that CAIV is important and must be in the forefront of the contractor's management of the program. One final thought – use technology to lower cost, not increase performance – this is aimed at engineers who have for years been encouraged to rank performance over cost.

What Type Of Feedback is Needed to Accomplish Your CAIV Goals?

Will you receive monthly, quarterly reports? How will you handle feedback in the SPO? Who is the person responsible for making the process work? How will feedback be evaluated?

What is the Contractor's Approach to CAIV?

Does it have a separate design trade-off process? Are you satisfied with it? Do its designers buy into process? Does it have "redesign" built into the production process?[16] Can it make changes without SPO concurrence? What is its reward for CAIV? Will it increase or decrease profit by CAIV? Is anyone other than the "bean counters" aware of CAIV? Is CAIV a management issue at the company? What actions to be taken by contractor employees are critical to success? How much of the work is being subcontracted? What are the incentives for the subcontractors – award fees and performance penalties? What are the penalties if the contractor fails?

CAIV May Require More Up-front Money!!

How do you handle that if you don't have it? Could Value Engineering Change Proposals be used?

Remember Problems With DTC:

- Unwillingness to make trade-offs.
- Perception that government was not interested in making trade-offs.
- Contractor's motivations versus ours.
- Often used only as a cost-monitoring device.

Endnotes/References

1. It was called by a variety of names – design-to-price, cost-to-produce, and design-to-cost-to-produce.
2. Om, Neang I., Karen W. Tyson, Paul R. Palmer, and J.R. Nelson, "Acquiring Major Systems: Cost and Schedule Trends and Acquisition Initiative Effectiveness," Institute for Defense Analyses Study, Paper P-2201, 1989, p. IX-12.
3. Ibid, p. IX-5.
4. Ibid, p. IX-8.
5. Ibid, p. IX-8.
6. Ibid, p. IX-7.
7. Ibid, p. IX-8.
8. Ibid, p. E-9.
9. Ibid, p. IX-9.
10. Beeckler, C. Eugene, "The Award Fee Influence on Design to Unit Production Cost (DTUPC), U.S. Army Material Systems Analysis Activity Research Paper, March 1983, p. 33.
11. Weimer, C. David, "The Application of Design-Cost Acquisition Policies to Selected Electronics-Subsystem Development Programs," Institute For Defense Analyses Interim Report, February 1975, p. 11.
12. Beeckler, C. Eugene, "The Award Fee Influence on Design to Unit Production Cost (DTUPC), U.S. Army Material Systems Analysis Activity Research Paper, March 1983, p. 22.
13. Om, Neang I., Karen W. Tyson, Paul R. Palmer, and J.R. Nelson, "Acquiring Major Systems: Cost and Schedule Trends and Acquisition Initiative Effectiveness," Institute for Defense Analyses Study, Paper P-2201, 1989, pp. IX-13 and E-6.
14. Discussions on June 6, 1996, at the Defense Systems Management College with Oscar Solar.
15. Proceedings discussion taken from a briefing provided by Mr. Terry Little to the students of the Advanced Program Management Course, 96-1, April 25, 1996.
16. May 1996, Contract Management Article provides a valuable look at savings achieved through "redesign of the production processes and the production environment."

Bibliography

Caver, Troy V., P.E., Robert Andrews, "Design to Cost: Achieving Cost Through Product and Process Trade-offs," *Contract Management Magazine*, May 1996, pp. 18-20.

Defense Science Board, "Report of Task Force On Reducing Costs of Defense Systems Acquisition, Design-to-Cost, Commercial Practice vs Department of Defense Practice," March 15, 1973.

Hamer, Stephan A., "Problems Encountered in Implementing Design to a Cost in Major Air Force Weapon System Acquisition Programs," Air Force Institute of Technology, Thesis, October 1973 (AD-769 912).

Hotz, Robert, "Mr. McNamara's Legacy," *Aviation Week & Space Technology*, Editorial, January 22, 1968.

Klass, Philip J., "Little Change Seen in Post-Viet Spending," *Aviation Week & Space Technology*, January 22, 1968, pp. 68-69.

Linville, Capt Ray P., USAF, and 1st Lt Warren M. Rose, USAF, "Design-to-Cost: An Examination of its Use in Weapon System Acquisitions," Thesis, Air Force Institute of Technology, August 1973 (AD 769 199).

Logistics Management Institute Report, "The Contractual Implications of the Design-to-Cost Concept," March 1974.

Tyson, Karen W., Neang I. Om, D. Calving Gogerty, J. Richard Nelson, and Daniel M. Utech, "The Effects of Management Initiatives on the Costs and Schedules of Defense Acquisition Programs," Institute for Defense Analyses Study, Paper P-2722, Vol. 1, November 1992.

Weimer, C. David, "The Application of Design-Cost Acquisition Policies to Selected Electronics-Subsystem Development Programs," Institute For Defense Analyses Interim Report, February 1975.