USING ACEIT FOR TOTAL OWNERSHIP COST MODELING AND ANALYSIS

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INTRODUCTION

Cost estimators and analysts face a challenge to define program costs and cost impacts clearly, and in terms that can be used for decision making in the program. Cost estimators must, therefore, apply cost models and reporting measures that relate directly to a program and that everyone can understand. This paper presents Total Ownership Cost (TOC) as a universal measurement of life-cycle costs that can be applied to any program. The Automated Cost Estimating Integrated Tools (ACEIT) program provides cost analysts with the ideal environment for modeling TOC estimates and impacts.

WHAT IS TOTAL OWNERSHIP COST?

TOC is a single measure of expected costs for a program, expressed as a normalized fraction, such as cost per system per year, cost per operating hour, or other such "Life-Cycle Cost-per-Common-Program" factor. This single measure is very useful when evaluating cost trade-offs for the program manager, or for comparing costs across dissimilar systems. TOC only measures the economics and costs of a system. Factors such as reliability and availability alter TOC, are not reported by the TOC factor.

A complete life-cycle cost estimate treats all three phases of the life-cycle as dependent periods, based on a common schedule and product baseline. As changes occur in one phase, corresponding impacts occur and must be accounted for in other phases. This dependent relationship between phases in the analysis is critical to estimating true ownership costs.

To capture driving life-cycle costs, and to ensure all relevant trade-offs between phases can be made, TOC includes all operations, support, and sustainment (O&S) costs as a minimum baseline in the *numerator* of the "Cost-per-Common-Program" fraction. Production phase costs for a system's life-cycle can be added to O&S costs to evaluate expensive policy trade-offs, such as contractor vs. organic repairs. Research and development phase costs can be further added-in to evaluate design impacts for a system early in its life-cycle. The inclusion of all three phases gives the cost estimator a full range of costs to trade-off against schedule, performance, and other program factors when evaluating cost as an independent variable (CAIV).

The *denominator* of the fraction is the total program being evaluated: operating hours per system per year; flying hours per aircraft per year; miles driven; end items in place, but dormant; etc. This fraction gives managers the ability to evaluate dissimilar systems and compare them on an equal (or normalized) basis.

Formulation of the Ownership Cost Metric:

← Minimum → ← Optional As Needed →

$$\frac{\text{O\&S Phase Costs + (Related Production Phase Costs + R\&D Phase Costs)}}{\text{Common Program (i.e., Flying Hours, Ops Hours, Miles Driven)}}$$

Production and O&S costs are usually the drivers for TOC estimates and trade-offs. Within the O&S phase, driving ownership costs include hardware maintenance, software maintenance, and depot level sustaining engineering/ program management costs.

CALCULATING AND EVALUATING TOTAL OWNERSHIP COST

This section focuses specifically on O&S costs as they apply to TOC.

A. Three things are critical to estimating and evaluating TOC:

1. First, the cost analyst must develop a work breakdown of costs that captures the relationship between life-cycle phases, and that adequately reports cost drivers for the system being evaluated. Attachment A presents key cost elements for a lifecycle, and how these elements are related through critical variables, such as: production quantities and schedules, system performance factors (reliability, maintainability, supportability), and labor and material costs.

2. Second, costs for each element should be estimated with a flexible approach that can be tailored to meet the maturity of the system. For example, in the early stages of a program, support costs for a system can be estimated with statistical cost estimating relationships (CERs). As specific designs emerge, and especially after prototype testing, specific reliability, maintainability, and supportability factors can be used instead of the CERs. Attachment B provides some general approaches which can be applied to any system.

3. Third, historical operations, maintenance, and sustainment data from similar systems can be used to develop cost relationships and analogous system costs until more mature data is available from prototype/ production item testing.

B. There are two basic approaches to executing the methods for each cost element in a cost model:

1. Estimate the complete WBS using a general approach, characterized as:

Given specific system factors and relationships, estimate Life-Cycle costs by Phase

This forward approach (given factors, estimate costs) represents the standard approach for cost estimating employed by most models. Sensitivity analysis is used to evaluate changes in Life-Cycle costs as system factors are adjusted. This approach is used to establish a baseline cost position for a system.

2. Estimate schedule, design, and other program factors to fit within a range defined by cost caps or budget constraints. This is characterized as:

Given a budget cap or spending limit, adjust schedule, performance, or other program factors to ensure the Life-Cycle cost estimate does exceed the specified cap or limit.

This "backwards" approach (given costs, estimate factors) is an excellent approach to defining program cost, schedule, and performance relationships when cost is an independent variable (CAIV). Sensitivity analysis of the factors (or an optimization algorithm) is used to calibrate the factors to fall within a suitable range to ensure costs are not exceeded. System users, design engineers, and program management staffs can then determine if the constrained factors are achievable and if the resulting system adequately meets user requirements.

WHY IS ACEIT WELL ADAPTED FOR TOC ESTIMATING AND ANALYSIS

Current "off-the-shelf" models used to estimate O&S costs typically do not include dependent methods to also estimate the costs of the development or production phases. These earlier phases are usually entered as throughput costs into O&S models, and they are not calculated as dependent phases by the model. This means the model user (cost analyst) has no control over how R&D and Production costs impact O&S costs for a system, and the user has no way to know how operating scenario changes (during the O&S phase of the life-cycle) may impact design and production costs for a system. ACEIT allows users to develop complete life-cycle cost models that capture the relationships between phases and use them in dynamic calculations of life-cycle costs.

ACEIT is not a model, so it does not assume there is a pre-defined, rigid work breakdown structure (WBS) of costs for a system. It is a modeling environment that allows users to include all relevant costs (by life-cycle phase) in a tailored WBS for their unique system. Then they develop/tailor estimating methodologies for each WBS row, based on data available for their system. This flexible approach to building a tailored model means that every unique system can be evaluated with its own flexible, tailored approach (WBS, methodologies). This level of flexibility requires the cost analyst to know and understand the cost estimating processes for DOD or other systems, and to be skilled in developing cost models. In return, the program manager has the benefit of a flexible cost tool that can rapidly evaluate alternative approaches to estimating costs in any phase of the life-cycle.

Because ACEIT is a strong model development environment, it should be seen as a tool for the experienced cost estimator. However, once a model is developed in ACEIT, Excel can be used as a user interface to the model, and as the database manager for model inputs and reports. The ACE Executive client application (an Excel add-in), furnished with ACEIT, allows cost estimators to link detailed cost models in ACE to Excel spreadsheets, which can then be used by non-cost staff (program managers, engineers) to evaluate system costs without knowing the intricate details of the cost model. The ACE Executive also provides cost estimators, and others in a program office, with an optimization tool to execute cost models in a "backwards" mode to calibrate schedule, performance, and other program factors to fit within limits defined by a constrained budget or cost cap. This enables users to perform various Cost As an Independent Variable (CAIV) analyses.

You can download sample ACEIT sessions developed for O&S, LCC, and TOC analysis from the following web site, which was developed by the Air Force Electronic Systems Center, ESC/FMC, Hanscom AFB, MA:
HTTP://WWW.C2COST.COM/SAMPLEACEIT.HTM

Attachment C is a letter from a satisfied ACEIT user at Raytheon Service Company. It is typical of the comments we receive from life cycle cost estimators who wish to build their own tailored life cycle cost models.

ATTACHMENT A:
KEY LIFE-CYCLE COSTS AND HOW THEY ARE IMPACTED BY O&S TRADE-OFF DECISIONS

COST ELEMENT	(1) FULL CLS	SUPPORT SCENARIOS (2) WARRANTY/ KTR REPAIRS	(3) WARRANTY/ ORGANIC RPR	(4) FULL ORGANIC REPAIRS	COMMENTS
1. DLR Costs LRUs SRUs	- Ship direct to Ktr - No surcharges - Not Stock listed - Vendor spares	- Temp ship to Ktr - Then to depot - Stock listed - Organic spares	Same as scenario (2), except recoverable costs are at depot rates for repair + surcharges	- Direct to depot - Stock listed - All surcharges - Organic spares	
2. Maint Training D-Level O-Level	None R&R training only	None R&R training only	Annual Recurring R&R training only	Annual Recurring R&R training only	O-level techs are military, who only remove and replace LRUs
3. Maint Persnl D-Level O-Level	Ktr techs Enlisted military	Ktr techs Enlisted Military	Organic depot techs Enlisted military	Organic depot techs Enlisted military	Use Ktr for warranty, then depot techs
4. Modifications	Ktr responsible for engineering and all ECOs	Ktr does ECOs until after warranty, then depot handles mod designs and kit installs	Ktr does ECOs until after warranty, then depot handles mod designs and kit installs	Depot handles mod designs and all lit installs (sharing design work with users	This category is primarily the kit purchase and installation costs
5. Sustaining Engineering	Ktr responsible for all sustaining engineering, with some SPO input	Ktr responsible until after warranty, then depot and users provide	Ktr responsible until after warranty, then depot and users provide	Depot responsible for sustaining engineering, shared with users	This element is for ECO and ECP design and management
6. Initial Spares	Ktr option on range and depth to stock (must maintain Ao)	Depot determines range and depth to stock after warranty	Depot determines range and depth to stock after warranty	Depot determines range and depth to stock	Stock funded; users reimburse initial spares costs
7. Initial Support Equipment	Ktr option for what to use at their facility; service decides base level requirements	Service determines depot and base requirements (for after warranty)	Service determines depot and base requirements (for after warranty)	Service determines depot and base requirements	What to put where is a function maint concept (i.e., 2 v 3 level); items are production funded
8. Initial Data	No organic data	Organic data used to recompete the contract for repairs	Organic data used to repair items at depot	Organic data used to repair items at depot	Production funded

ATTACHMENT B:
GENERAL APPROACHES FOR ESTIMATING O&S COSTS FOR A SYSTEM

SOFTWARE OPERATIONS/SUPPORT/MAINTENANCCE (AIS Systems)

COST ELEMENT STRUCTURE	METHODOLOGY	COMMENT
Part I: OPERATIONS MAINTENANCE AND SUPPORT	*Includes all costs for an AIS from IOC (during development) through to the end of the system's life-cycle; accounts for all levels of support (unit, depot, DISA); focus on system specific labor, equipment and interfaces.*	
1. SE/PM Personnel Program Management System Engineering Central System Admin/Operations Upgrades/Replacements Hardware Software	 - Staff Authorized x Labor Rate - Engineers Auth x Labor Rate - Staff Authorized x Labor Rates - COTS Items Replaced x Replacement Price - COTS Packages Replaced x Replace Price	*Post FOC; could be "fee-for-service" such as Material Systems Group at AFMC;* - Assumes Government Civilians - Assumes Government Civilians - Could be contractors; centrally located (These are for replacement costs only.) - Could also be mod costs for non-COTS - SW mod costs are included below under SW Maintenance
2. UNIT LEVEL/SITE HARDWARE MAINTENANCE Organic Hardware Maint (Labor) Annual Operations Invest (Materials) Reparable Spares (D-Level Reps) Supplies and Consumables Spares Contractor Hardware Maintenance Other Hardware Maintenance	(The Theater Battle Management Core System is a good analogy for system HW) - Military or Civilians Auth x 65-503 Rates - Qty Removed x Cost to Repair & Replace - Items Purchased x Purchase Price - Field Reps Authorized x Contract Rates - Repair Techs Authorized x Labor Rates	*Non-DISA; system and site specific; on-site activities; costs to repair, not replace* - O-level remove and replace actions only (Includes all AFWCF recoverable costs) - Spares repaired at organic depots - Non-repairable and admin supplies - Includes labor/matrls; no AFWCF costs - I.e., comm interfaces; peripherals; admin equipment
3. CENTRAL SYSTEM SOFTWARE MAINTENANCE COTS Software Application/Mission SW Communications SW Data Center SW Other SW	 - SW Items Replaced x Replacement Price - Ktr or Gov Techs Auth x Labor Rate - Ktr or Gov Techs Auth x Labor Rate - Apportioned Share of Annual Costs - Ktr or Gov Techs Auth x Labor Rate	*Centrally managed; AFWCF funded; system, but not site, specific costs* - Replacement costs only; vendor rates - Correct/Adapt/Modify; labor & materials - System specific; could be fee for service - System portion of central facility costs - I.e., peripherals, management, etc…
4. MEGA CENTER RECOVERABLE COSTS (Optional Element if DISA not used) Operations Maintenance Materials Equipment Replacement	(Resources apportioned as %-age of total systems managed by DISA at each location) - Apportioned Labor x Rate (incl overhead) - Apportioned Labor x Rate (incl overhead) - Apportioned Materials x Price (plus fees) - System Specific + General HW (plus fees)	*DISA owned central HW; fee for service; costs apportioned by system share of total* - DISA HW ops costs (labor and overhead) - DISA HW maint cost (labor & overhead) - DISA HW support materials (AFWCF) - DISA HW/SW recurring replacements (Gen HW replace costs in center fees)
5. DATA MAINTENANCE Mission Application Data Other Data	(Military, Civilian or Contractor labor) - Data Techs Auth x Appropriate Labor Rate - Data Techs Auth x Appropriate Labor Rate	*System specific; collect/store/update; NOT a DISA function; includes interfaces* - For interfaces, databases, and storage - Part of system, but not mission specific
6. UNIT/SITE LEVEL OPERATIONS System Operations Personnel Base Operations and Support Facilities Energy Communications Links Hazardous Material Contracts	 - Military, Civilian or Ktr Auth x Labor Rate - Operators Auth x AFI 65-503 Factor - KWHrs/Hour x Cost per KWHr - Leased Lines x Lease Rate - Throughput Handling and Storage Costs - Throughput Annual Costs	*Unit funded activities; site specific; rates include all recoverable costs* - HW operators and local SW load/manage - System specific HW location(s) - System specific HW power consumption - System specific interfaces/lines - System specific HW related material - System specific; e.g. leases, labor, etc…
7. RECURRING TRAINING Unit Funded Costs AETC Funded Costs	(Military and Gov Civilian Only) - Number Trained x Annual Days x $/Day - Number trained x Annual Days x $/Day	*System specific; HW/SW ops, maint; Contr training costs incl. In labor rate overhead* - TDY: per diem and travel - Formal schools cost for instructors, facilities, materials, etc…

COST ELEMENT STRUCTURE	METHODOLOGY	COMMENT
Part II: PHASE-OUT STATUS QUO SYSTEM	*Includes all costs to maintain a system being replaced by a newer system, from IOC of the newer system until FOC of the newer system. Methods similar to O&S of a legacy or developing system, shown in Part I above.*	
1. SE/PM		*Pre- FOC of new system; could be "fee-for-service" activity in AFMC;*
Program Management	- Staff Authorized x AFI 65-503 Labor Rate	- Assumes Government Civilians
Sustaining Engineering	- Engineers Auth x AFI 65-503 Labor Rate	- Assumes Government Civilians
Materials	- Items Purchased x Prices	- Includes AFWCF recoverable costs
2. UNIT LEVEL/SITE HARDWARE MANAGEMENT		*Non-DISA; system and site specific; on-site activities; costs to repair, not replace*
Hardware Maintenance	- Gov or Ktr Techs Auth x Labor Rates	- O-level remove and replace actions only, plus spares repaired at organic depots, plus Non-repairable and admin supplies (Primary and peripheral system HW)
Disposal		
Capital Recoupment	- Items Redeemed for Credit x Credit Rate	Redemption value or recycle value
Retirement	- Items Disposed x Disposal Costs	Throw away or destroy equipment
Hazardous Disposal	- Items Disposed x Disposal Price	Component level materials
Phase-out Investment	- Items Purchased x Price	Necessary capital purchases, short term
3. CENTRAL SOFTWARE MANAGEMENT		*Centrally managed; AFWCF funded; system, but not site, specific costs*
COTS SW Replacement	- SW Items Replaced x Replacement Price	- Replacement costs only; vendor rates
Other SW Maintenance	- Ktr or Gov Techs Auth x Labor Rate	- Correct/Adapt/Modify; labor & materials
4. UNIT LEVEL/SITE OPERATIONS AND SUPPORT		*Unit funded activities; site and system specific; rates include all recoverable costs*
Unit/Site Level Ops		
Personnel	- Military, Civ or Ktr Auth x Labor Rate	- HW operators and local SW load/manage
Base Operations & Support	- Operators Auth x AFI 65-503 Factor	- System specific; Planning factor only
Recurring Training		
Unit Funded Costs	- Number Trained x Days x Cost per Day	- TDY: per diem; travel
Formal Schools Costs	- Number Trained x Days x Cost per Day	- For facility, instructors, materials, etc…
Miscellaneous Support	- Number Auth x Labor Rate	- I.e., communications, contracting, etc…
5. MEGA CENTER COSTS		*DISA owned central HW; fee for service; costs apportioned by system share of total;*
Hardware Operations	- Apportioned Labor x Rate (incl overhead)	- DISA HW ops costs (labor and overhead)
Hardware Maintenance	- Apportioned Labor x Rate (incl overhead)	- DISA HW maint cost (labor & overhead)
Maintenance Materials	- Apportioned Materials x Price (plus fees)	- DISA HW support materials (AFWCF)
Capital Equipment Replacement	- System Specific Items x Replace Costs	- DISA HW/SW recurring replacements (Short term, pending new system start)
6. CONTRACTS		*Short term contracts for support pending new system start-up*
Leases	- Throughput costs from contracts	- I.e., ADP or office equipment, facilities
Termination	- Termination costs per contract for early termination of services	- Contract termination costs at start-up

COTS HARDWARE EQUIPMENT OPERATIONS AND SUPPORT COSTS

COST ELEMENT STRUCTURE	METHODOLOGY	COMMENT
1. MISSION PERSONNEL		*(For USAF, this is military only.)*
OPERATORS	- Number Auth x AFI 65-503 Rates	- Assumes military operators
MILITARY MAINTAINERS	- Number Auth x AFI 65-503 Rates	- Remove and Replace only
OTHER MILITARY	- Number Auth x AFI 65-503 Rates	- i.e, staff, administrative
2. UNIT LEVEL CONSUMPTION		*(Unit funded & managed; includes AFWCF recoverable costs.)*
ENERGY		(Excludes batteries (DLR cost))
Commercial Source	- Ops Hours x KWH/Hr x $/KWH	- Based on commercial rates
Field Generators	- Ops Hours x Gal/Hr x $/Gal	- Cost of diesel for power
CONSUMABLE MATERIAL	- Ops Hours x Avg $/Hr (65-503)	- Consumable parts & supplies
PURCHASED SERVICES	- Contract Throughput $/Year	- Such as local PC repairs
TRAINING COSTS	- # Trnd x Trng Days x $/Tng Day (per diem, TDY and Travel)	- Mil Personnel TDY, Per Diem, and Travel
3. CONTRACTOR SUPPORT		*(Costs based on contractor rates and factors)*
HW MAINT (FIELD REPS)	- # Auth/Ops Site (based on install equip at each site) x Ktr Rates	- Base level repair techs
MATERIALS	- Removals x Replace Cost	- Post warranty parts replacement
COTS SW REPLACEMENT	- Upgrades x Manufacturers Price	- Periodic upgrades by manufactr
4. INDIRECT SUPPORT		*(Based on government assigned by site - military and civilian)*
TRAINING	- # Trnd x Trng Days x $/Tng Day (Instructors, materials, overhead)	- Formal schools; centrally funded
BASOPS	- Auth per Site x 65-503 Factor	- Gov or contr provided services
FACILITIES	- Auth per Site x 65-503 Factor	- Gov or contr provided upkeep
5. SUSTAINING SUPPORT		*(Centrally funded depot level costs; system specific)*
RECURRING HW REPLACE	- # Replaced x COTS Vendor Price	- On periodic schedule
RECURING SW MAINT	- Labor Auth x Rates (incl. O-head)	- Correct/Adapt/Modify, not replace
SE/PM	- Labor Auth x Rates (Gov't or Ktr)	- Post-Production sys management

COST OF OWNERSHIP FOR C4I SYSTEMS

COST ELEMENT STRUCTURE	METHODOLOGY ***Each of the following methods is: Sum $/FY by PE by MAJCOM in a specific FY from ABIDES, for each EEIC by Cost Element***	COMMENTS
1. MISSION PERSONNEL	(Mission Personnel and Civilian Pay EEICs)	(*Government only; direct mission support*)
MILITARY	2XX, 56202, 57101, 598, 613, 618	Operations and Maintenance
CIVILIAN	383, 386, 388, 390-399	Operations, Maintenance, Support
OTHER	592	Command, admin, support
2. OPERATIONS	(Stock Fund and Support EEICs)	(*Generally funded at unit level with stock funds*)
POL/ENERGY		(Direct system fuel, electricity ,etc..)
Aviation	601-603, 689-691, 693, 695-699	AVFUEL, Jet Fuel
Ground (not for facilities)	612, 641, 64508	AVGAS, Generator Fuel, Diesel
SPECIAL EQUIPMENT	627, 637, 639	ADP, office machines, local PC support
TAD/TDY	403-409, 434	Unit funded for training, meetings, etc..
MISSION TRANSPORT	431-433, 451, 454, 462, 463, 469	JCS directed exercises and travel
COMMUNICATION SERVICES	490-495, 497-498	Leased lines, contractor services
3. HARDWARE MAINTENANCE	(Depot level organic and contractor EEICs)	(*Component costs are stock funded at unit level; all others are depot level costs*)
CONS/REPAIR PARTS	605,609	Consumable spares, includes surcharges
DLR's	545, 644, 645, 64530	Reparable spares, includes surcharges
DEPOT MAINTENANCE	541-544, 546, 548-549, 560, 569	Engine, Airframe, Avionics overhaul
CLS/ICS	578 (CLS), 579 (ICS), 585 (Pre-1988)	Contracted repairs, base or depot level
SE/PM	583, 584, 587, 59200, 592AA-592CE, 592CG-592IH, 592LA, 592SA-592SX, 597	Post-production system management
SUP EQUIP REPLACE	628, 705, 64540	Replacement only; initial buy is not O&S
DATA	501, 502, 592CF, 594	Tech manuals, drawings, etc..
4. SOFTWARE MAINTENANCE	(Depot level organic and contractor EEICs)	(*MAJCOM reimburses depot or contractor*)
CLS/ICS	582, 592TA-592TT	Contractor provided correct/adapt/modify
ORGANIC	540	Depot provided correct/adapt/modify
5. INDIRECT SUPPORT	(Base level reimbursable costs and direct funded costs for facility support)	(*General base support; not mission specific*)
BASOPS (PERSONNEL)	511, 512, and CE 20101/2 and 39X	Personnel, supply, medical, finance, etc..
BASE MAINT & SUPPORT	120, 130, 140, 181-184, 471-474, 480, 513-515, 521-523, 527-529, 53X, 55300, 567-568 580,5920-5922, 592RX, 592QX, 592U, 592V, 593, 596XO, 600, 604, 607, 614, 618, 619, 624, 634-638, 642, 651, 683-684, 706-709, 716, 741-750	Primarily facility and civil engineering
CONTR OPERATED FACIL	570, 577, 57100, 57200, 57400	Such as ANG facility or remote comm site

ATTACHMENT C:

RAYTHEON SERVICE COMPANY LETTER

Marc Barden
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August 14, 1997

Thomas J. Kielpinski
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Dear Tom,

It's been nearly a year since I made my final delivery of SOCET, (Special Operations Cost Estimating Tool). SOCET was programmed as a session in ACEIT for the United States Special Operations Command (USSOCOM). As you may recall, I contacted you some six months before that with a requirement to perform a model search/evaluation to find or develop a Life Cycle Cost model to satisfy the USSOCOM's unique requirements.

USSOCOM was adamant that the model they were to adopt be: flexible, easy to use, able to handle multiple cost categories and evolutionary acquisitions, as well as supportable. They needed a model to which, as users, they could add cost elements and change cost methodologies.

After evaluating several models, we presented them with our best recommendation, ACEIT, and they agreed. Ironically, they first envisioned their solution to be an existing model or one developed specifically for them; it turned out to be both. ACEIT provides a user with the confidence of a comprehensive, proven tool, as well as the ability to build a cost model specific to one's needs, quickly and efficiently. With help from Tecolote's very competent, development, training, and support staff in both the Massachusetts and California offices, we built the unique USSOCOM ACEIT session, SOCET.

Delivery of SOCET brought written accolades from Raytheon, E-Systems, and the USSOCOM. USSOCOM's Gary L. Smith, Deputy for Acquisition and Acquisition Executive, wrote: "SOCET enhances the life cycle cost estimating capabilities of USSOCOM program and project officers and will help improve the command's management resources. As a result of this superb effort, SOFSA's capabilities to plan proper sustainment support of SOF has been tremendously enhanced."

Since that time I have had the opportunity to work with the Windows version of ACEIT and have found it to be a valuable enhancement to the product. Thank you, Tom, for a fine product you as developers, and we as users, can be proud of.

Marc Barden
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