The International Space Station Management and Cost Evaluations Task Force

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Introduction

The NASA-led International Space Station (ISS) is a technological marvel and a great feat of international cooperation. The ISS is an Earth-orbiting laboratory drawing upon the scientific and technological expertise of 16 nations: the United States, Canada, Japan, Russia, Brazil, and the 11 member nations of the European Space Agency (ESA). The ISS is a gateway to new space frontiers, a hallmark to United States space leadership, a unique laboratory, and a virtual space classroom. The ISS also is an out-of-control project, one that needs an immediate managerial overhaul to assure its productivity and retain its promise of being a world-class orbiting laboratory. The project is a victim of inadequate cost-accounting measures, a skyrocketing price tag, and an increasingly suspect research agenda given cost overruns and shrinking crew size. All these issues help frame the program as one steeped in controversy rather than as a cosmic gateway to the universe.

ISS Cost Growth

Revelations at the start of 2001 pointed to a $4.8 billion growth in NASA's part of the program. That raised the cost to complete the ISS to a projected $30.1 billion. The escalating number is one that NASA, Congress, and other budget-watchers fear will grow. Furthermore, it was estimated that the outpost would cost on the order of $1.5 billion a year to operate. These revelations prompted then-NASA Administrator Daniel Goldin to gather an independent task force to help get on top of the issues. "We've been working to select a team of outstanding innovators in the fields of science, engineering, finance and business to advise NASA and the Administration how to maximize the scientific returns on the station, while living within the guidelines of the President's budget," said Administrator Goldin. "The financial management of the International Space Station needs an overhaul."[1]

[1] Brown, D. & Jacobs, B. (2001, July 11). "NASA ADMINISTRATOR ANNOUNCES DISTINGUISHED TEAM TO REVIEW INTERNATIONAL SPACE STATION PROGRAM", NASA Press Release: 01-152.

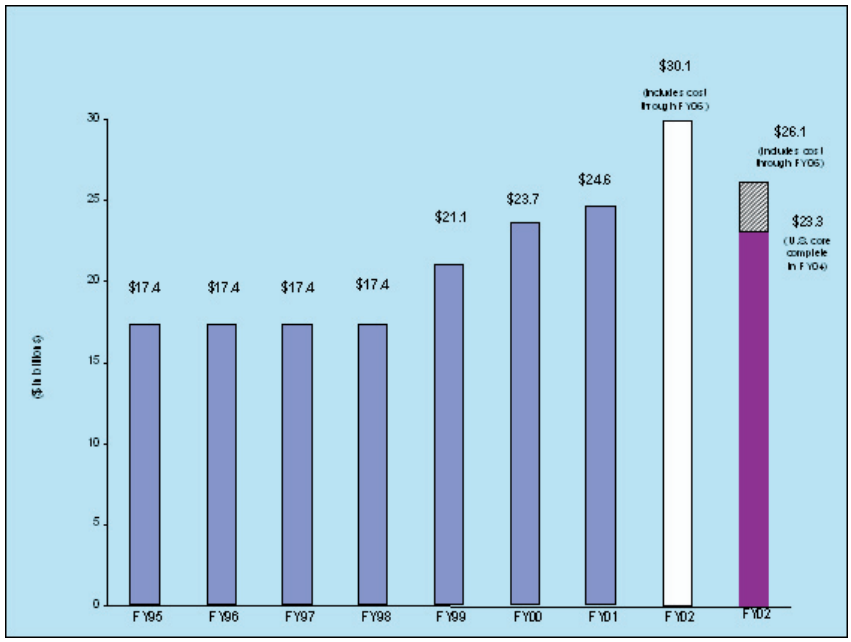

Figure 1: ISS Estimated NASA Completion Costs by Year of Estimate. The first FY02 column represents NASA's estimate of the full scope Assembly Complete. The second FY02 column represents the NASA/OMB negotiated budget for the reduced scope U.S. Core Complete configuration.[2]

ISS Management and Cost Evaluation Task Force

In July 2001, Mr. Goldin asked the author to serve as a member of the ISS Management and Cost Evaluation (IMCE) Task Force[7] and Mr. DeMarco agreed. On August 20, the other members of the austere group and Mr. DeMarco, including Nobel Prize winners, as well as other military and civilian experts from scientific, high-tech, financial, and managerial circles began grappling with a myriad of thorny and head-spinning issues. The report was due November 1, 2001.

"Our NASA people need help," Goldin proclaimed to open the first meeting. "We have not been able to accurately predict how much this program is going to cost." Goldin said. While noting that the ISS team is comprised of hardworking and good people, he said that they are working with deficiencies in the management system. "The object is not to come in as a bunch of gun slingers and criticize. The object is to help these folks figure out how to get a much better cost estimating system…how to do a much better job…and more efficiently manage costs,"

[2] Task Force to the NASA Advisory Council, (2001, November 1). "Report" The International Space Station (ISS) Management and Cost Evaluation (IMCE).

Goldin said. “They need your help to see things differently,” he said. Admittedly, Goldin said that the answers are going to be painful and difficult for many to accept. “But in life we have to live with priorities,”[3] he said.

IMCE Task Force Terms of Reference

The IMCE Task Force was chartered to perform an independent external review and assessment of cost and budget on the ISS program. The final report was to focus specifically on the following items[2]

- Assess the quality of the ISS cost estimates for the approved ISS program, including identification of high-risk budget areas and potential risk mitigation strategies.

- To ensure that the program can remain within its available budget, assess program assumptions and requirements -- specifically those that led to significant cost growth relative to FY 2001 budget estimates -- and identify options for small growth and/or budget savings and efficiencies that offset any additional spending recommended by the Task Force and approximately $500 million in unfunded cost growth.

- Review the management reforms in the ISS Program Management Action Plan -- particularly cost estimating and reporting issues, early warning of potential growth, and managing program reserves -- and make recommendations for additional and/or refined management reforms. Integrate results from the Financial Management Task Force.

- Identify opportunities for improving the capability to meet priority research program needs within the planned ISS budget and International Partner contributions.

Briefings

During the next two days, a series of NASA and ISS program executives briefed the Task Force on the technology and travails of the space station. All the presenters were extremely competent and knew the subject matter well. However, after the flood of information and a series of questions, five key program management issues became apparent:

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[3] The International Space Station, (ISS) Management and Cost Evaluation (IMCE). (2001, August 20). Meeting Minutes.

[4] Lytle, T, (2001, August 21). “NASA tries to cut costs, not science”, Orlando Sentinel. http://www.orlandosentinel.com/news/custom/space/orl-station082101.story

1. The project is managed by good people dedicated to safely delivering on the promise of a world-class laboratory

2. The project was initially underestimated.

3. A $2.1B budget cap imposed by Congress helped to create an "institutional mentality" versus one of "cost and project management".

4. Changes, complications, and delays to overcome technical challenges and to satisfy the large number of international stakeholders caused project completion costs to skyrocket, but the full magnitude of completion costs were not routinely evaluated or reported.

5. Total Ownership Cost was never a design criterion. Program management did not manage costs to "cost to complete" targets – they strictly focused on managing progress within a 5 year budget window.

In all, disregard of proven cost management practices was evident. Task force chair, Thomas Young, said the ISS program is being run using methods from the Dark Ages of program management. In this day and time we are enormously better than that, said Young.[4]

The Task Force met six more times during the two and one-half month assignment, alternating between NASA headquarters and Johnson Space Center. The group interviewed scores of ISS program professionals, technical experts, international partners, and management personnel. The Task Force reviewed the basis of the program budget projections, and performed independent studies. After the intensive investigation, discussion and debate, details on the five key issues were clearer.

1. The project is managed by good people dedicated to safely delivering on the promise of a world-class laboratory.

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[5] PRICE Systems, L.L.C. 17000 Commerce Parkway – Suite A, Mt. Laurel, NJ 08054, http://www.pricesystems.com, PRICE H and PRICE S are parametric cost estimating and analysis models available for commercial licensing. PRICE H is used to estimate costs, resources, and schedules for hardware projects such as electronic, electro-mechanical, and structural assemblies. It can be used to estimate hardware projects of any scale, from the smallest individual component to the complex hardware assemblies of a complete aircraft, a ship or a space station. PRICE S is used to estimate costs and schedules of software development projects. It is designed to handle all types of software from business systems and communications to command and control, avionics, and space systems. PRICE S has been applied to virtually any size project, from the individual software component level to extremely complex software systems, such as those in mission-critical vehicles. PRICE S can be used to estimate selected portions of a software project, or to comprehensively estimate the entire project, including all development, modification, and life-cycle costs. It also provides sizing applications that make it easier to determine the size of the project to be estimated.

Each ISS manager interviewed proved to be smart, talented and dedicated to his or her job. However, it was apparent that two traits pervaded the team that contributed to the overrun issues:

- Contagious over-optimism that things would always go right
- An acceptance of the need to work "within the system" rather than make changes that would assure an affordable program

2. The project was initially underestimated.

The initial ISS program estimate in 1994 was $17.4 billion. The author performed a top-level parametric estimate using PRICE H and PRICE S [5] on the ISS program based on information readily available at the time of program inception. The PRICE H model uses the Manufacturing Complexity (MCPLX or MX) parameter as a surrogate to describe the fundamental cost per size (weight in this case) cost estimating relationship (CER). Higher values of MCPLX represent a steeper curve with weight and lower values represent economies of scale. Studies have shown a high correlation between time and MCPLX for various equipment groups (Figure 2).

The correlation is most often a line with a positive slope indicating increasing cost per pound with time. To capture the "NASA-way of doing business" a calibration based on previous programs like the Space Shuttle (Figure 3) was carried out. The estimate results were $60 billion for the total program with the U.S. portion at $30.6 billion (Figure 4).

It should have been obvious in 1994 that this was not a $17.4 billion program. The basis of the 1994 estimate was not presented to the Task Force. However, it is clear that NASA analysts were over-optimistic. Analysts involved in the original estimate were questioned on the assumptions and revealed, "some heroic assumptions were made at that time", and "…during that period the program had to fight to stay alive".[3]

One of the heroic assumptions was software size. Initial estimates of source lines of code (SLOC) increased by a factor of eight from 500,000 to 4,200,000 during the program.

The underestimate set the stage for the ISS cost management problems. ISS management was under-funded to meet difficult program milestones and the ensuing balancing act exacerbated the problems. There were endless reviews, funding caps, schedule stretch-out, and an increase of stakeholders to keep the program alive – all adding to cost growth.

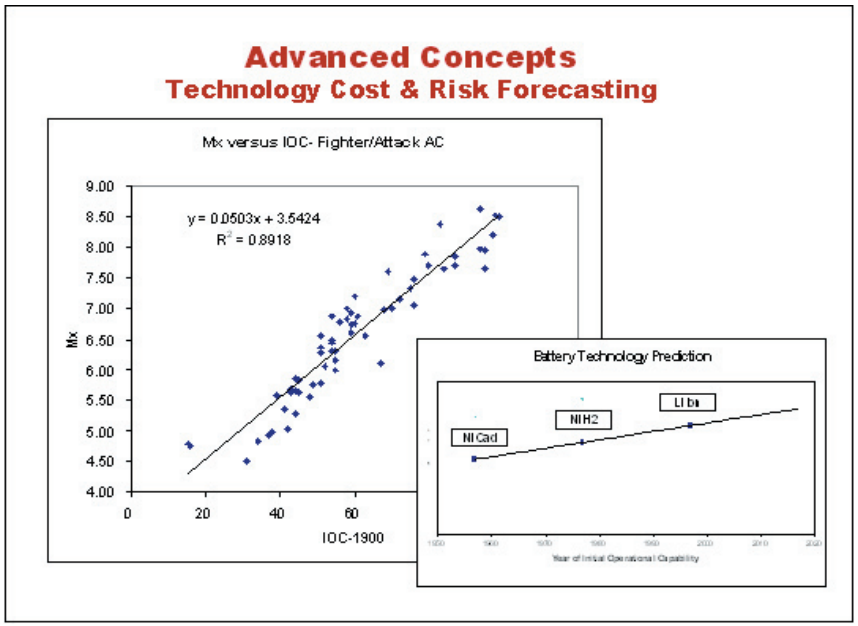


Figure 2: Studies have shown a high correlation between time and the PRICE H parameter Manufacturing Complexity (MCPLX/MX) for various equipment groups. The correlation is most often a line with a positive slope indicating increasing cost per pound with time.

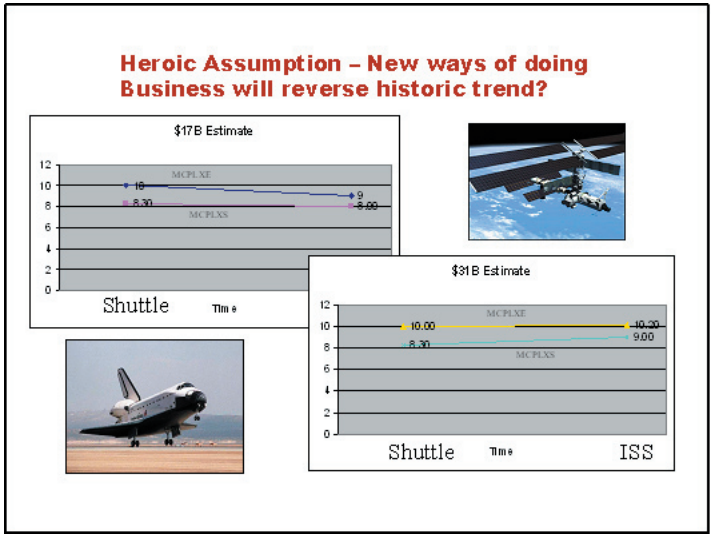
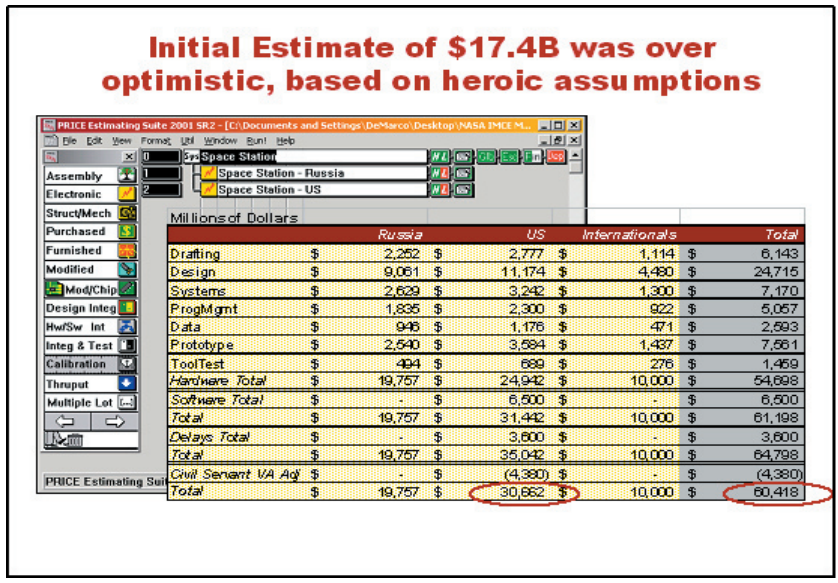


Figure 3: The initial estimate for the ISS correlates to MCPLX values lower than that of the NASA Space Shuttle. The lower MCPLX is counter to a preponderance of evidence and indicates "new ways of doing business" and heroic assumptions. Historic trends indicate that MCPLXs should be in the range of 9.0 to 10.5.



	Russia	US	Internationals	Total
Drafting	$ 2,252	$ 2,777	$ 1,114	$ 6,143
Design	$ 9,061	$ 11,174	$ 4,480	$ 24,715
Systems	$ 2,629	$ 3,242	$ 1,300	$ 7,170
ProgMgmt	$ 1,835	$ 2,300	$ 922	$ 5,057
Data	$ 946	$ 1,176	$ 471	$ 2,593
Prototype	$ 2,540	$ 3,584	$ 1,437	$ 7,561
ToolTest	$ 494	$ 689	$ 276	$ 1,459
Hardware Total	$ 19,757	$ 24,942	$ 10,000	$ 54,698
Software Total	$ -	$ 6,500	$ -	$ 6,500
Total	$ 19,757	$ 31,442	$ 10,000	$ 61,198
Delays Total	$ -	$ 3,600	$ -	$ 3,600
Total	$ 19,757	$ 35,042	$ 10,000	$ 64,798
Civil Servant VA Adj	$ -	$ (4,380)	$ -	$ (4,380)
Total	$ 19,757	$ 30,662	$ 10,000	$ 60,418

Figure 4: A top-level estimate performed with PRICE H and PRICE S using the MCPLXs expected from historic trends is much closer to the ISS actual costs.

3. A $2.1B budget cap imposed by Congress helped to create an "institutional mentality" versus one of "cost and project management".

The program was managed to level spending within the cap, flattening the most efficient resource management profile to meet scheduled deliverables. Therefore, the cap stretched the program out beyond the most efficient schedule. The PRICE models estimate a baseline cost correlated to a typical schedule also estimated by the model. The models then look at the actual schedule milestones and adjust estimated costs by a schedule-effect CER. PRICE H uses the CER depicted in Figure 5. Schedule stretch-out, as in the case of the ISS, causes inefficiencies that result in cost growth. Both PRICE H and PRICE S produce reports that show costs for the optimal schedule versus the actual schedule. As highlighted in Figure 4, the models in PRICE H and PRICE S show that delays caused by the spending cap cost the program an estimated $3.6 billion.

4. Changes, complications, and delays to overcome technical challenges and to satisfy the large number of international stakeholders caused project completion costs to sky-rocket, but the full magnitude of completion costs were not routinely evaluated or reported.

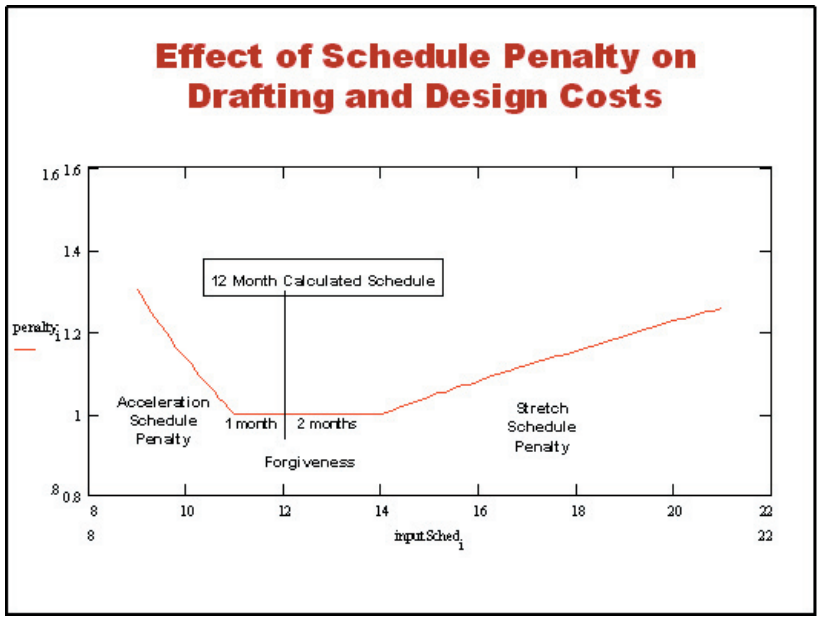


Figure 5: The PRICE models estimate a baseline cost correlated to a typical schedule also estimated by the model. The models then look at the actual schedule milestones and increase the baseline costs by a multiple based on a schedule CER. Schedule stretch-out, as in the case of the ISS, causes inefficiencies that result in cost growth.

Escalating program costs were obvious to ISS management but they were never adequately quantified. NASA's EVMS system showed the program was behind schedule, but detailed "estimates to complete" were not performed. Routine independent reviews were often postponed or canceled. Ignoring the compilation of estimates-to-complete caused a large backlog of uncosted changes to buildup during the program. It was not until the winter of 2000 that ISS management fully evaluated program completion causes. Their estimate was $4.8 billion more than the previously reported completion costs. The news was shocking and led to the IMCE task force appointment.

5. Total Ownership Cost was never a design criterion. Program management did not manage costs to "cost to complete" targets – they strictly focused on managing progress within a 5 year budget window.

The annual spending cap created an institutional budgeting culture versus a project management culture. There was no cost management other than annual spending controls. The effects were:

- A baseline estimate synchronized with the change traffic was not maintained
- Estimates-to-complete were not performed
- A cost management team performing cost analysis did not exist
- Independent cost estimates were not performed
- Estimates were not based on cost drivers. Only staffing profiles and delivery milestones were used

IMCE Recommendations

The majority of the IMCE task force concluded that the ISS program could regain credibility with major changes. The resulting recommendations included changes in management processes, organization, and cost reductions within the program and from other programs in the Human Space Flight budget. However, the report cautioned that the NASA Human Space Flight "way of doing business" will be difficult to change in time to prevent further cost growth.

NASA management was encouraged to accept the need to invest in attracting and retaining a sufficient number of cost analysts and most importantly, to listen to them. Too often, the message delivered by cost analysts is unpopular and subsequently stifled. As Pete Aldridge, the Pentagon acquisition chief, recently told members of the House Armed Services Committee panel on research and development, "We have to be realistic in how we cost programs rather than being too optimistic. And, there should be some 'reserve' funds in program accounts to deal with the programmatic uncertainties that crop up in development. If this is not done, funding is often robbed from other program accounts and all programs get sick".

Other specific recommendations made by the Task Force include: [2]

- Establish the ISS Program Office separate from, but residing at JSC, reporting to a new Associate Administrator (AA) for the ISS.
- Consolidate prime and non-prime contracts into a minimum number of resulting contracts all reporting to the program office.
- Develop a life cycle technical baseline and manage the ISS Program to total cost and schedule as well as fiscal year budgets.

- Consider revising the ISS crew rotation period to 6 months and reducing the Space Shuttle flight rate accordingly. The result would be a delay in U.S. Core complete assembly sequence by up to 2 months. Target cost savings: $668M.

- Continue to examine the Strategic Resources Review (SRR) and Institutional cost reductions. Target cost savings: $350M-$450M.

- Develop a credible program road map starting with core complete and leading to an end state that achieves expanded research potential. include gate decisions based on demonstrated ability to execute the program.

- Identify funding to maintain critical activities for potential enhancement options.

- Establish research priorities. The Task Force is unanimous in that the highest research priority should be solving problems associated with long-duration human space flight, including the engineering required for human support mechanisms.

- Provide the Centrifuge Accommodation Module (CAM) and centrifuge as mandatory to accomplish top priority biological research. Availability as late as FY08 is unacceptable.

- Establish a research plan consistent with the priorities, including a prudent level of reserves, and compliant with the approved budget.

- Provide additional crew time for scientific research through the use of extended duration shuttle missions, and overlap of Soyuz missions.

- Create a Deputy Program Manager for Science position in ISS Program Office. Assign a science community representative with dual responsibility to the Program and OBPR.

Action Plan

Today, NASA is working to implement the reforms recommended by the IMCE task force and to get the ISS program healthy. A management action plan has been compiled and put to work, implementing several cost management reforms. A cost analysis team is performing a detailed cost estimate of the program to be used as a new baseline. It will be at least two years before it will be known if the management reforms are sufficiently earnest and adequate to prevent further cost overruns.

Conclusion

The ISS cost overruns were caused by an over-optimistic initial cost estimate and inattention to total ownership cost management. It seems unjust that intense scrutiny and bad press on the program's cost growth mar the ISS team's tremendous accomplishments. However, in today's political climate, cost is an important design criterion along with performance. And no project is a complete success when it misses cost expectations so badly. The IMCE task force was a valuable learning experience for both its members and ISS management. ISS cost management reforms will hopefully mitigate the bad press, allowing the team to receive the recognition they deserve for their accomplishments.

[6] Webb, D. (2000, November 16). Optimization of Performance, Cost, and Schedule: Technology Infusion Using PRICE-H, PRICE Systems Users Symposium.

[7] International Space Station Management And Cost Evaluation Task Force Members

Leadership
A. Thomas Young, Chairman, North Potomac, MD
RADM. Thomas Betterton, USN (Retired), Vice Chairman, Warrenton, VA

Science Group Members
Michael DeBakey, Baylor College of Medicine, Houston TX
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Robert Grady, The Carlyle Group, San Francisco, CA
ADM. Paul Reason, USN (Retired), Metro Machine Corporation, Norfolk, VA
Roger Tetrault, Punta Gorda, FL

BIOGRAPHY

Anthony A. DeMarco

Mr. DeMarco is the President and Managing Member of PRICE Systems L.L.C., a privately held company in Mt. Laurel, New Jersey. PRICE is the world leader in Parametric Planning, Estimating, and Budgeting tools and services with clients in the North America, South America, Europe, and the Pacific Rim. PRICE introduced the first commercially available Hardware and Software Cost Estimating Models in 1975 and attained its industry leading position through dedication to speed, quality and customer satisfaction.

Mr. DeMarco received a Bachelors degree in Mathematics from St. Joseph's University in Philadelphia, Pennsylvania, and a Masters degree in Computer Science from the New Jersey Institute of Technology in Newark, NJ.

Since joining PRICE Systems in 1981, Mr. DeMarco's accomplishments have included the development of the PRICE electronics cost model (PRICE M), major enhancements to the PRICE hardware model (PRICE H), and the personal computer program XPERT/H. As PRICE Product Development Manager for several years, Mr. DeMarco led a team of operations researchers, logisticians and computer scientists in the development of parametric models and tools to serve the cost estimating and analysis community. During his tenure as the leader of PRICE Systems, PRICE migrated its tools to desktop and client/server computing platforms and has introduced several new services including professional services, tailored on-site training, PRICE Enterprise and the PRICE Knowledge Manager.

Mr. DeMarco is a recognized expert and frequent speaker on predictive parametric modeling and has published many papers on the subject. In 1997, Mr. DeMarco received the highest honor bestowed by the International Society of Parametric Analysts (ISPA), the Freiman Award. In 2001, NASA Administrator Daniel S. Goldin appointed Mr. DeMarco to serve on the International Space Station Management and Cost Evaluation Task Force (IMCE) to help NASA address cost growth on the program by assessing the quality of the ISS cost estimates as well as program assumptions and requirements, and by identifying high-risk budget areas and potential risk mitigation strategies.

In 1998, Mr. DeMarco led the management buyout of the PRICE Systems business unit from the Lockheed Martin Corporation to form PRICE Systems, L.L.C. PRICE is now an independent employee-owned business dedicated to helping enterprises sustain profitable growth through faster, better planning, estimating and budgeting.

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