An Evaluation on the Use of Ultra Low-Flow Toilets In Four Developing Countries as a Means to Contribute to Water Resource Sustainability

Saeed D. Foroudastan. Ph.D., Associate Professor
Monette Rebecca, Graduate Assistant

Engineering Technology and Industrial Studies Department
Middle Tennessee State University

Abstract

This paper is an investigation into the use of water-saving toilets by developing countries to clarify whether their application can help promote water resource sustainability. To begin this evaluation, theoretical data collection is made of toilet water-use prior to and after the hypothetical installation of these conserving toilets to determine quantitative statistics between each chosen country in the analysis of water conserved. By determining each country's theoretical percent of water usage savings and comparing these results between the various countries, an evaluation as to the affect these ultra low-flow toilets (ULF) have on water conservation is made. Secondly, an evaluation from this data is made on the impact each country had on water usage and therefore the percentage of savings it contributed towards water conservation. Lastly, a comparison between each country was theoretically presented to infer individually and collectively the contribution possible towards global water resource sustainability.

Australia was chosen to be in this evaluation because it is a country experiencing severe drought conditions and one which could benefit profoundly due to its' inherent environment. The United States was chosen because of their enormous water usage and ensuing, diminishing supply. The remaining countries, Canada and the United Kingdom, were chosen randomly of data available between the remaining developed countries with a high percentage of domestic water usage.

The research that supports ULF toilets as a feasible means to conserve water and therefore have more water available for delivery is supported by studies, yet there is still controversy over the efficient design of these toilets and the 1992 U.S. Energy and Conservation Act mandated for ULF toilets to be installed.[1] This paper addresses the validity of this opposition as well as evaluates the contribution toilets could make towards water resource sustainability, especially when the engineering design is adequate. The purpose of this paper is to confirm a need for engineering education and industry to address this issue jointly and how their involvement could contribute towards global water resource sustainability and world peace.

Copyright © 2003, American Society for Engineering Education"

Introduction

There were two main reasons that spawned this investigation into the use of ULF toilets as a means to conserve water use. The first was the observations made on a recent visit to the driest continent in the world, Australia. Australia was and still is experiencing unprecedented drought conditions which are causing winter bush fires, water shortage and water use restrictions. The second point that inspired this evaluation was the combination of common remarks made by those at home that these ULF toilets are inefficient and the ensuing opposition in Congress in 1999 to repeal the mandate set up by the 1992 Energy and Conservation Act for these toilets to be installed in new construction.[2] The contradictory impressions about water resource sustainability between those I spoke to in Australia and in the United States was alarming. It was also my observation during my visit in Australia, that the toilet designs were more efficient than the ULF toilets in the U.S. while still using considerable less water per flush. These observations and facts spawned this investigation to clarify the discrepancy of ULF toilet's effective design as a contribution towards water conservation

Water resource sustainability is a current environmental issue around the globe due to increasing demands by the growing global population.[3] It is a known fact that only 1% of the water on the globe is suitable for human consumption, with the remaining being 97% sea water and 2% glacial. It is also important to note that of the 1% of suitable freshwater; approximately only 10% of that is accessible to the human population because of its remote location. This amount is dwindling even more because of the increasing percent of polluted water being returned to our resources. So important is the issue of global water sustainability that the United Nations General Assembly declared March 22 to be "World Day for Water" in 1992, which has now been renamed "World Water Day."[4] Also captured in a U.S. News and World Report article were statements by the U.S. Environmental Protection Agency's administrator saying, water quantity and quality "is the biggest environmental issue that we face, and the U.S. Central Intelligence Agency "predicts by 2015 drinking-water access could be a major source of world conflict."[5] Ironically, this precious and limited resource is under-valued and under-priced and is why the UNEP and other governmental officials are discussing the revaluing of this resource as a means to reduce its abuse and overuse in an effort to promote water conservation and sustainability.[6]

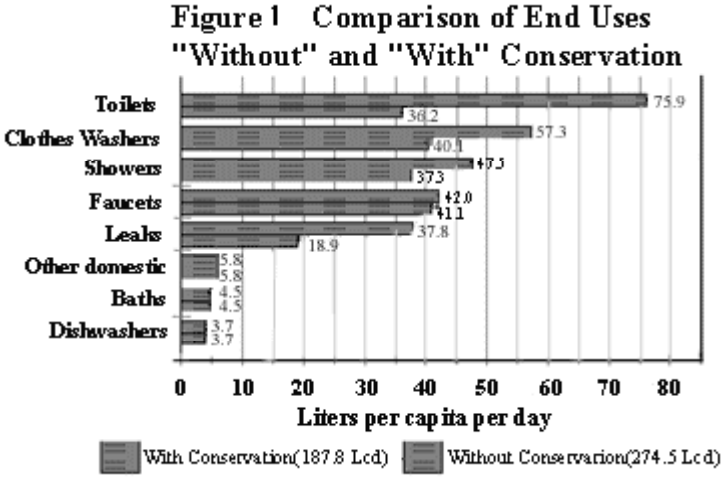
ULF toilets as a tool to conserving domestic water resource withdrawals

The effective use of low-flow bathroom fixtures as a means to conserve water use and contribute to the sustainability of global water resources reached the conference table of the "Proceedings of the International Symposium on Efficient Water Use in Urban Areas in 1999."[7] Yet during that same year, there were still public and congressional debate in the U.S. as to the efficiency and legitimacy of the 1992 Energy Policy and Conservation Act calling for the installation of these fixtures as a means of water conservation, as previously mentioned. The Competitive Enterprise Institute stated in a 1999 press release, " since the law took effect in 1994 millions of Americans, whether buying a new or replacing an existing toilet, have had to deal with these new water-stingy models that do not work as well as their predecessors, yet cost more."[8] These claims, ULF toilets requires two or more flushes to do the same work as one flush for the traditional toilets, was a common complaint among those forced to install these toilets because of this mandate. It is

Copyright © 2003, American Society for Engineering Education"

suggested in the following editorial that the engineering of these toilets fell short compared to the European manufacturer designs and accounts for the dissatisfaction by American consumers. As stated by the Oregon State University in an editorial called "Don't Dispose of Low-Flow," "a simple redesign, rather than increased water flow, could alleviate the concerns of the staunchest low-flow critic," and that "water saving capacity is not the issue; the problem is one of efficacy."[9]

One report presented at the Proceedings of the International Symposium was the "Residential End Uses of Water and Demand Management Opportunities" by John Olaf Nelson and addresses the efficacy of ULF toilets.[10] In Mr. Nelson presentation he reported the findings conducted by the American Water Works Association (AWWA) Research Foundation in 1996, named The North American Residential End Uses of Water Study (REUWS). In this study, which involved twelve cities of the U.S., it was found the ULF toilets conserved over 50% of the water used by the non-conserving toilets (Figure 1).



Determining annual withdrawal of water for domestic use in four nations

The percentage of annual domestic withdrawals for flushing toilets varies in developed countries, and of the four countries chosen for this evaluation range between 19 and 33 percent. It is the proposal of this evaluation; by determining the conservation of water by ULF toilet flushing the capability of saving significant portions of domestic water use would provide more water for delivery. "Water saved is exactly the same as water supplied," according to The Master Plumbers' and Mechanical Services Association of Australia.[11]

To begin the compiling of necessary data for this evaluation research from the Environmental Data Tables of the World Resources Institute (WRI) was obtained.[12] The global "Freshwater Resources and Withdrawals" (FW.1) information from WRI was reported in the year 2000-2001 for the year 1995 and is outdated, but could hypothetically be deducted to be higher than indicated due to population growth. The population totals from the 2000 Census is also included for an illustration of the difference in population size as a comparative perspective to water usage.[13] Domestic water withdrawals amounts for each country in this evaluation were retrieved from the Food and Agricultural Organization (FAO) for 1988.[14] The extrapolation, the percent

Copyright © 2003, American Society for Engineering Education"

of annual global domestic withdrawal, for this evaluation were compiled by calculations using both the FAO and the WRI totals and shown in the following (Table 1). These totals are hypothetically low estimates since the percents were calculated using totals from different years. In other words, a low estimation of savings is made in this evaluation because the percent of annual global withdrawals would have been considerably more because in 1988 domestic withdrawals were less than the withdrawals of 1995, due to considerable population increases.

Table 1
Annual Withdrawal of Water for Domestic Use

	2000 Population (Millions)	1995 Withdrawals (km3/ yr)	Percent of Annual Global Withdrawals	1988 Domestic Withdrawal (km3/ yr)	Percent of Annual Global Domestic Withdrawal
USA	282	470	13%	61	18%
Canada	31	45	1.20%	8.1	2.40%
Australia	19	15	0.40%	9.5	2.80%
UK	59.5	9	0.24%	2.36	0.70%

In the "Freshwater Resources and Withdrawals" (FW.1) information reported by the WRI these global totals were designated as: "Average Annual Internal Renewable Water Resources" reported as 42,665 km^3, the global "Annual Withdrawals" reported as 3,760 km^3, and the global "Sectoral Domestic Withdrawal" which is just 9% of the "Annual Withdrawal," amounting to 338.4 km^3. Totals were rounded up for simplicity. It is apparent that the U.S. has a much larger percent of withdrawal annually then any other country in this study and it is a known fact that the U.S. is the largest user of water in the world per capita. It was reported by the World Water Council that Americans use twice the amount of water per person than Europeans.[15]

Illustration of calculation using the U.S. as an example: $(470km^3/3760\ km^3) \times 100 = 13\%$
$(61km^3/338.4\ km^3) \times 100 = 18\%$

Determining the annual water use for the conserving and non-conserving toilets

Obtaining the percentage of domestic water use for toilets was also gathered from various authorities and indicated in Table 2. For the United States it was reported by the AWWA that toilet usage is 27.7% of household withdrawals.[16] For the toilet usage in Canada, *Canada's Liquid Assets*, "A Wretched Excess?" reported the percentage of household withdrawals were 30%.[17] The "Watermark" organization findings of 33% for household usage provided the United Kingdom percent of toilet use.[18] For Australia it was much more difficult to pin down a precise percent because I found a range between 18%-40%, depending on which state was reporting. I chose 19%, which was reported for Melbourne by the Plumbing Industry Commission, because it is where a substantial portion of Australia's population lives.[19] The amount of water usage for

Copyright © 2003, American Society for Engineering Education"

each toilet flush was also obtained from the same resources, respectively, and then converted into liters for consistency, as shown in (Table 2).

Table 2
Annual Water Use for Toilets

	Percent of Annual Domestic Withdrawl for Toilets	Water Use for Toilets (km^3/ yr)	Water use per flush non-conserving (liters)	ULF Toilet Water Use 75% participation (km^3/ yr)
USA	27.70%	14	13.25	8.33
Canada	30.00%	2.4	15.22	1.32
Australia	19.00%	1.9	10.75	1.27
United Kingdom	33.00%	0.8	8.52	0.63

Using the percents of water use for toilets and the annual domestic withdrawals, the total annual water withdrawal for toilets are computed, which an example of is provided below. Although there have been varying degrees of installation of these conserving toilets in these nations to date, the data used in the computation was in 1988 and assumed not to be very widespread. It wasn't until 1992 that the Energy and Conservation Act mandated installation of the 3.5-gallon toilets in new construction in the U.S. and not until 1993 in Australia. This information was not retrieved for Canada or the United Kingdom at all.
U.S. example: $.2270 \times 61km^3 = 14km^3$

The final computation, "ULF Toilet Water Use", is the most assuming extrapolation made in this report. Since there are numerous types of conserving toilets and the amount of water used per flush, one particular toilet had to be chosen for this evaluation. The U.S. ULF toilet that uses 1.6 gallons per flush was the chosen conserving toilet for this comparison and then converted into liters; 6.06 liters per flush. This amount was used as the ULF toilet amount for each nation to find the ratio of difference as a percent between conserving and non-conserving toilets.
U.S. example: [6.06L/ 13.25L] x 100 = 46%
The results were as follows:

United States	46%
Canada	40%
Australia	56%
United Kingdom	71%

The United Kingdom would have the lowest amount of water conservation using the ULF toilet, because their older toilets were found to use the least amount of water between all the four nations. The next assumption made was only 75% of the population would participate and be computed as "ULF Toilet Water Use" totals in each nation, primarily because 100% participation of the population seemed too simplistic. Nevertheless, the indication of these conserving toilets is still apparent. An example of one country's computation is as follows:

Copyright © 2003, American Society for Engineering Education"

United States (75%) x (14 km^3/yr) = 10.5 km^3/yr
(46%) x (10.5 km^3/yr) = 4.83 km^3/yr (ULF water use)
14 km^3/yr - 10.5 km^3/yr = 3.5 km^3/yr
3.5 km^3/yr + 4.83 km^3/yr = **8.33 km^3/yr**

Evaluating the affect of ULF toilets on water conservation

Table 3 is the final extrapolation of data for this evaluation. It is computed to determine quantitatively the amount of water hypothetically saved by ULF toilets toward water conservation nationally and globally. The "Amount of Water Saved" by ULF toilets is a simple subtraction between "Toilet Water Use" and "ULF Toilet Water Use" in (Table 2). The percent of "Domestic Withdrawal Conserved" was determined by computing a ratio of "Water Saved" over the "Domestic Withdrawal," from (Table 1). The percent of "Global Domestic Water Resources Saved" was similarly determined, but figure 338.4 km^3/yr"for the annual withdrawals of global "Domestic Sectoral Withdrawal", replaced the national reporting for "1988 Domestic Withdrawal." The final computed amount, the hypothetical total water conserved by ULF toilets by these four countries, was found to be **7.6 km^3/year**. This was calculated by simply adding together each nation's withdrawals.

Table 3
Evaluation of Water Saved by ULF Toilets

	ULF Toilet Water Use (km3/ yr)	Amount of Water Saved (km3/ yr)	Percent of Domestic Withdrawal Conserved	Percent of Global Domestic Water Resources Saved (Annual Withdrawals)
USA	8.33	5.7	9.30%	1.70%
Canada	1.32	1.1	13.60%	0.33%
Australia	1.27	0.6	6.30%	0.20%
UK	0.63	0.2	8.50%	0.06%
Total	**11.55**	**7.6**		**2.30%**

What does 7.6 km^3/year represent in water supplied?

To begin, this amount of water could provide United Kingdom's domestic supply need for three years, or almost an entire year of Canada's annual domestic withdrawal. This evaluation was only done for four of the developing countries in the world, totaling only 15% of the total annual global withdrawals, but if all of the developed countries would have been included in this comparative evaluation, the percent of water conserved would hypothetically be much greater. According to the WRI Freshwater Resources and Withdrawals report of 2000-2001, Europe's total percentage of the annual global domestic withdrawals is 14%, almost doubling the percent of

Copyright © 2003, American Society for Engineering Education"

withdrawal used in this evaluation. Looking at this from another perspective, the countries in this evaluation represent less than 24% of the "Annual Global Domestic Withdrawal," and could hypothetically be seen to at least quadruple, if global participation was possible.

As stated earlier in this report, the AWWA Research Foundation in 1996 conducted a study on conserving toilets and found them to reduce water use for toilets by 50%. From this authoritative research one could surmise that the amount of water conserved by these four nations could increase to 9.6 km^3/year; an increase of 26% over this report's evaluation. This evaluation found hypothetically that the use of ULF toilets is an effective tool in providing more water available for supply and one could surmise that expanded use of conserving household fixtures could curtail water usage even further.

The importance of evaluating toilet water usage

It was reported in the year 2000 by Gar Smith of the Earth Island Journal, and "according to *EcoForum,* the magazine of the Nairobi-based UN Environmental Program, standard flush toilets use 2,000 tons of fresh water to flush each ton of human waste."[20] Not only is this a massive imbalance in the productive use of water, at the rate of population growth, the global water resources cannot maintain such an imbalance. Not only is this an inefficient use of water but also a needless amount of energy spent at wastewater treatment plants.

The World Water Council (WWC) announced we are in a "water crisis" and as the population grows so does the demand for more water.[21] According to the U.S. Department of Energy, the water withdrawals in the U.S. have gone from 21 billion gallons per day in 1960 to 40.2 billion gallons a day in 1995.[22] The United States is the largest water user in the world and even though there was the mandate of the 1992 Energy and Conservation Act for the installation of conserving toilets in new construction, yet many in the U.S. still feel the use of these conserving toilets are inefficient. Actually, enough complaints were made "to warrant an action for repeal of certain parts of the 1992 Act" in 1999.[23] This evaluation and other supporting findings presented here suggests there needs to be more federal incentives for conserving toilet replacement programs, not repeals of those in place. If the U.S. federal government would also contribute to this effort more replacement of water wasting toilets could occur and a considerable increased amount of water conserved. In addition to water conserving national policies, a public education awareness program needs to be addressed in the U.S. to effectively involve their citizens towards water conservation and the effectiveness of ULF toilets. It was my observation after visiting Australia and hearing people's concern about water shortage there and then comparing their awareness to those in the U.S., it became distinctively apparent that U.S. citizens take water for granted to a much higher degree. Finally but not least, attention given to engineering education towards improved designs of ULF toilets, would have positive and long lasting environmental importance and political clout, that could alleviate the growing concern of a water crisis for generations to come. Informing engineering students of these toilet design shortcomings and the discussion with the industry for improved designs would help solve the political and economical debate, as well as contribute to global water resource sustainability.

Conclusion

Copyright © 2003, American Society for Engineering Education"

On my visit to Australia it was first assumed that the dual-flush toilets in place there were an abuse of water usage because of the powerful flush that was provided. After investigation and confirmation from the research of this study, it was discovered it was the design of these toilets that provided the powerful flush not the amount of water used for each flush. This confirms that the design of toilets is very pertinent and important to their effectiveness and consumer satisfaction.

The United States uses more water per capita than any other country in this study and it is a known fact they are the largest user of water in the world. As a global leader, therefore, the U.S. has the greatest potential of conserving water in the world. Of the four nations in this evaluation, Canada has the ability to save the largest percent of their water use by installing conserving toilets, followed by the U.S., U.K. and then Australia. This same order of conservation falls true for the amount of water saved as a "Percent of Domestic Withdrawal Conserved." From a global perspective, the U.S. has the largest contribution to make towards global water resource sustainability, followed by Canada, Australia and U.K. respectively. The amount of global water conserved by this evaluation could hypothesize as being considerably larger for the following reasons. The annual global withdrawals used in this study were from a later period than the annual withdrawals used for each nation. So theoretically, if the global amount could have been used for the same year and been obtained for this study, the percentage of conservation would have been considerably higher; assuming the withdrawals in 1988 were less than 1995. If the AWWA Research Foundation's study in 1996 is founded, a 26% increase over this evaluation report could also be assumed. It can also be deducted from this evaluation and from the AWWA Research Foundation study, that ULF toilets and conserving toilets are an effective method of conserving water and therefore are able to provide more water for delivery.

"The world has no more fresh water than it did 2000 years ago when the population was less than three percent of its present size."[24] It is through the hydrologic cycle that our water resources are replenished but because of the over demand of water resources, ground and surface water tables are falling because we are using the resource faster than nature can replenish them. The importance of this reduction in annual withdrawals from surface water resources is that it will delay the demand for supply, leaving the amount water conserved in its original location. This delay of domestic withdrawal allows more time for the hydrologic cycle to replenish resources. In other words, the amount of water conserved is equal to an amount of water not withdrawn from resources, which means that the water used for domestic purposes does not have to recycle through the hydrologic cycle and can be stored for delivery later. Curtailing water use per person directly corresponds to decreasing the amount required per capita and delays the panic amongst the population of an ensuing water shortage. On a global perspective, the sharing of water resources are more likely to occur when there is less of a panic amongst the population that there is a water shortage crisis.

It is the position of this evaluation to pose to the ASEE the important contribution of engineering education, and their alignment with the industries that manufacturer these ULF toilets, towards water resource sustainability. The purpose of this paper is to illustrate that engineering design of ULF toilets can have an essential role towards affecting global water resource sustainability. The

Copyright © 2003, American Society for Engineering Education"

education of engineering students on the magnitude of water conservation could spark designs for innovative, efficient and economically feasible water conserving toilets, for instance, which could be far-reaching and beneficial for decades to come.

Bibliography

1. *Legal Information Institute*. 1992 U.S. Energy and Conservation Act, Title 42, Chapter 77, Section 6201, U.S. Code Collection. http://www4.law.cornell.edu/uscode/42/6201.html (15 March 2203).
2. *Ephinsights*. "U.S. Congress wants to 'flush' federal regulations for low-flush toilets." http://www.ul.com/eph/insights/ephiv3n3/flush.html (12 November 2002).
3. *The World Water Council,* "The Use of Water Today." http://www.worldwatercouncil.org/Vision/Documents/Chapter2.pdf.
4. *United Nations General Assembly,* "World Day for Water," A/Res/47/193, (December 22, 1992). http://www.unesco.org/water/water_celebrations/ (12 November 2002).
5. Laavelle, Marianne and Kurlantzick, Joshua. "Water Crisis." *U.S. News and World Report* 12 August 2002: Vol. 133 No. 6.
6. Toepfer, Klaus, Executive Director, UNEP. "World Water Day" speech, march 22, 2002. http://www.unep.org/Documents/Default,asp?DocumentD=243&ArticleD=3031.html (12 November 2002).
7. *United Nations Environmental Programme Division of Technology, Industry, and Economics,* "Proceedings of the International Symposium on Efficient Water Use in Urban Areas. www.unep.or.jp/ietd/Publications/ReportSeries (12 November 2002).
8. *Competitive Enterprise Institute staff,* "Flushing Federal Regulations Down the (Low-Flow) Toilet," (July 27, 1999). www.cei.org/gencon/003,02636.cfm (13 March 2003).
9. *Oregon State University editorial,* "Don't dispose of low-flow," (May 7, 2002). www.lexis-nexis.com (September 18, 2002).
10. *United Nations Environmental Programme Division of Technology, Industry, and Economics,* "Proceedings of the International Symposium on Efficient Water Use in Urban Areas, REUWS. www.unep.or.jp/ietc/Publications/ReportSeries?IETCREP9/4.paper_F/4-F-nelsl.asp. (12 November 2002)
11. *The Master Plumbers' and Mechanical Services Association of Australia,* "Water Smart Guidelines." www.ausmasterplumbers.com.au/consumer/watersmart.asp (13 November 2002).
12. *World Resources Institute*, Environmental Data Base, Freshwater Resources and Withdrawals (FR-1). www.wri.org/wri/wr-00-01/pdf/fwin (14 November 2002).
13. *2000 Census*, International Data Bases. www.census.gov (14 November 2002).
14. *Food and Agriculture Organization of the United Nations*, AQUASTAT-FAO's Information System on Water and Agriculture. www.fao.org (14 November 2002).
15. *The World Water Council,* "The Use of Water Today." http://www.worldwatercouncil.org/Vision/Documents/Chapter2.pdf (12 November

Copyright © 2003, American Society for Engineering Education"

2002).
16. *American Water Works Association*, Stats on Tap. www.awwa.org (14 November 2002).
17. *Canada's Liquid Assets*, "A Wretched Excess?" www.canadiangeographic.ca/Magazine/MJ00?Water/water_use.asp (14 November 2002).
18. *Water UK*, "Water Facts. www.water.org.uk/index.php?cat=2-35 (14 November 2002).
19. *Plumbing Industry Commission*, Victoria government Australia. www.pic.vic.gov.au/pdf_file/5.%20water%20conservation.pdf (15 November 2002).
20. Smith, Gar. *Earth Island Journal,* "Water Wars, Water Cures", spring 2000. http://yeoldeconsciousnessshoppe.com/art8.html (15 November 2002).
21. *The World Water Council,* "The Use of Water Today." http://www.worldwatercouncil.org/Vision/Documents/Chapter2.pdf. (20 November 2002).
22. *Department of Energy* (DOE), "U.S. Water Use by Source and End-use Sector, 1900-1995. http://ceq.eh.doe.gov/nepa/reports/statistics/tab6x3.html (12 November 2002).
23. *Ephinsights*. "U.S. Congress wants to 'flush' federal regulations for low-flush toilets." http://www.ul.com/eph/insights/ephiv3n3/flush.html (12 November 2002).
24. Smith, Gar. *Earth Island Journal,* "Water Wars, Water Cures", spring 2000. http://yeoldeconsciousnessshoppe.com/art8.html (15 November 2002).

DR. SAEED FOROUDASTAN

Saeed Foroudastan is an Associate Professor in the Engineering Technology and Industrial Studies Department. He received his B.S. in Civil Engineering (1980), his M.S. in Civil Engineering (1982), and his Ph.D. in Mechanical Engineering (1987) from Tennessee Technological University. Professor Foroudastan's employment vitae includes: Graduate Instructor for Tennessee Technological University (1983-86), Instructor of Mechanical Engineering for Tennessee Technological University (1987-88), Assistant Professor of mechanical Engineering for Tennessee Technological University, Senior Engineer, Advanced Development Department, Textron Aerostructures (1990), and Middle Tennessee State University. Professor Foroudastan is involved with several professional organizations and honor societies, and has many publications to his name. He also holds U.S. and European patents.

Copyright © 2003, American Society for Engineering Education"