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April 14, 2017  
Sherm Sweeney  
ASHRAE Region VI Regional Historian

Dear Mr. Sweeney,

I am enclosing the La Crosse Area Chapter's 35th entry for the Gold Ribbon and Lou Flagg award. The La Crosse Area Chapter, 115, is pleased to present the history of Trane's TRACE™ Load and Energy Modeling Software.

The HVAC design and analysis computer program, dubbed as Trane Air Conditioning Economics (TRACE™), revolutionized the way design engineers evaluated loads and energy consumption for various building types and systems. Conceived in 1971, the program offered combined analysis of energy consumption and life cycle costs with simple and easy to understand inputs. The first version of TRACE required paper manuals to be mailed to Trane headquarters in La Crosse, Wisconsin, where the mainframe computer ran the simulation using punched cards. The entire process of mailing in the inputs and waiting for the outputs could take a couple of weeks. As computer technology advanced in the 1970s, users could utilize their personal computers (PCs) instead of paper manuals to enter the program's inputs and then electronically transfer the inputs to La Crosse, Wisconsin. Eventually, in the late 1980s, users were able run TRACE simulations on their own PCs. Today, TRACE is going through another major transformation by utilizing a 3D visual interface and the Department of Energy's EnergyPlus calculation engine.

I would like to thank all the people who helped me with researching and writing this history article. In particular, I would like to acknowledge Eric Sturm, Mick Schwedler, Jim Richason, Eugene "Smitty" Smithart, Sue Bouffleur, Art Hallstrom, and Larry Scheier. Their input has been invaluable in forming this history submission.

Respectfully Submitted,



John L. Sustar  
Historian  
La Crosse Area Chapter

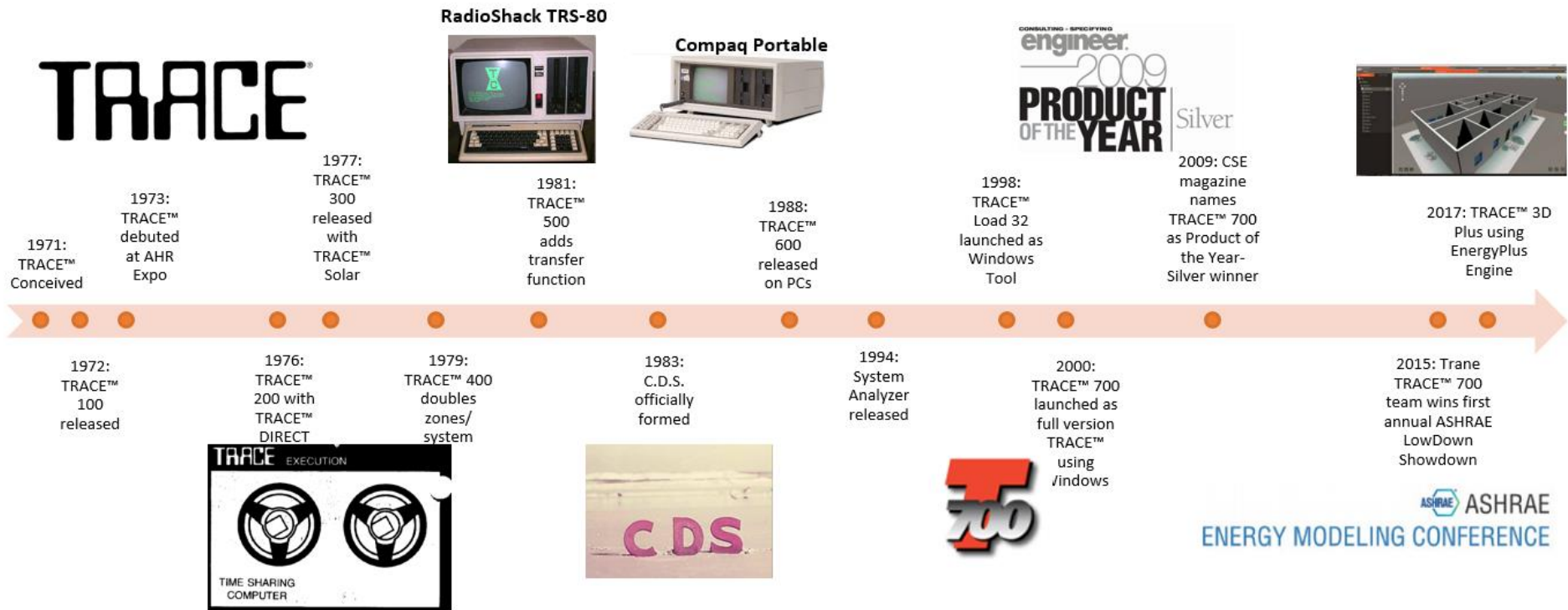


Figure 1: Beginning in 1971, TRACE offered combined analysis of energy consumption and life cycle costs with simple and easy to understand inputs. The first version of TRACE required paper manuals to be mailed to Trane headquarters in La Crosse, Wisconsin. Today, TRACE is going through another major transformation with the upcoming release using EnergyPlus.

## **ASHRAE History of a System: History of Trane's TRACE™ Software**

The 2013 ASHRAE Handbook of Fundamentals contains six chapters under the heading "Load and Energy Calculations." The chapters include detailed information on aspects directly affecting building loads, load calculations and energy modeling. Chapter 19, titled, "Energy Estimating and Modeling Methods," is authored by Technical Committee (TC) 4.7, Energy Calculations. The chapter introduction states, "Energy requirements of HVAC systems directly affect a buildings operating cost and indirectly affect the environment." Due to these affects, energy analysis tools and programs have been developed by a number of public- and private-sector entities. This article examines the historical development of a private sector program: Trane Air Conditioning Economics (TRACE™).

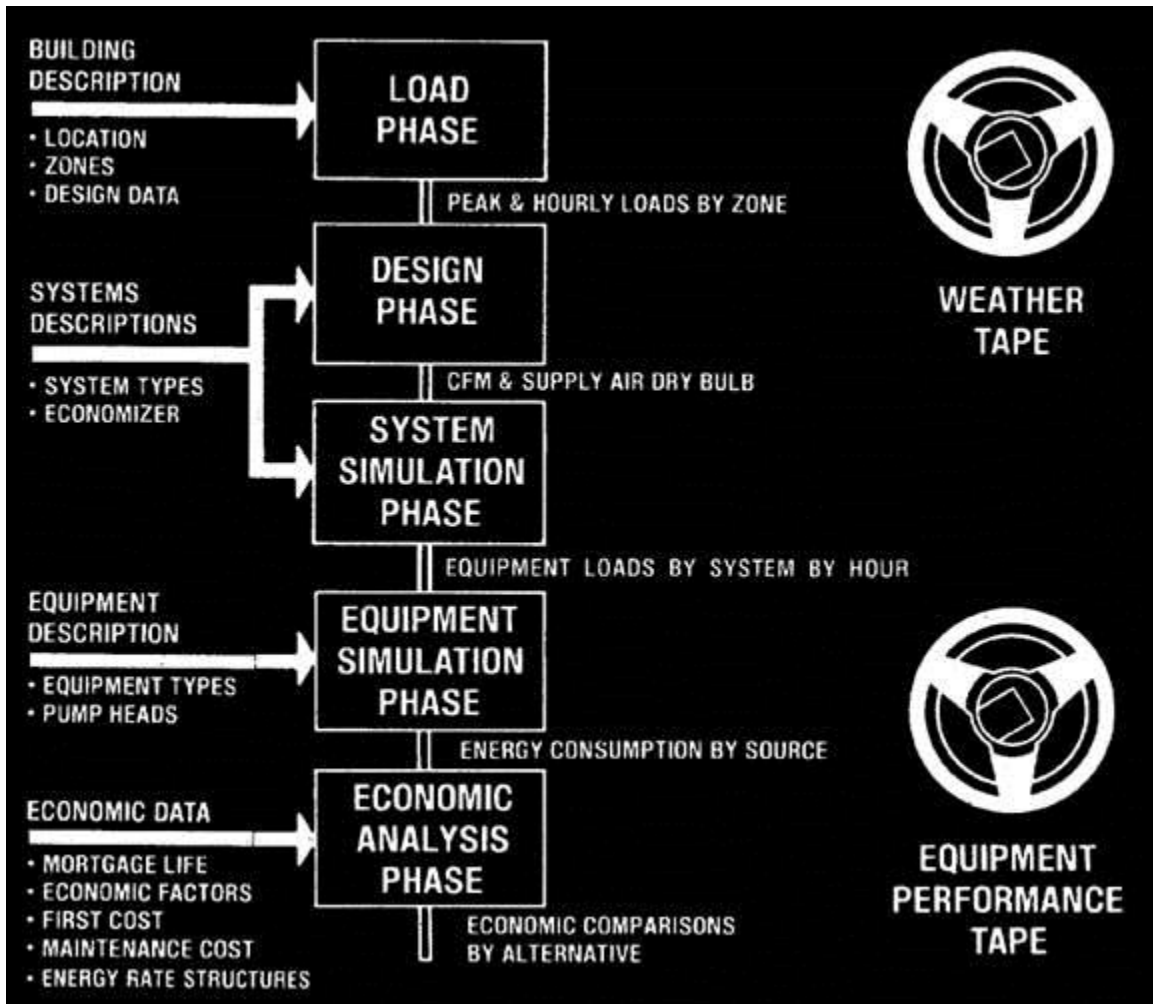
In 1971, Dennis Bridges, manager of marketing at Trane<sup>1</sup>, and Neil Patterson, manager of applications engineering, conceptualized TRACE. To help with the implementation, the team pulled in Dick Grant, an engineer familiar with both computer programming and HVAC design. The first release was based on the "Post Office Program." The "Post Office Program" was created in 1971 when the U.S. Postal Services developed a computer program to analyze energy use in post offices.<sup>2</sup> In fact, according to Larry Scheier, lead software developer, there are still algorithms used in today's version of TRACE that use "PO" in the variable naming convention.

Since the beginning, TRACE incorporated five major phases to calculate its outputs. The names of these phases are load, design, system simulation, equipment simulation, and economic analysis (Figure 2).The load phase of the program calculates the peak loads, including weather-dependent loads, for each zone. The calculated loads are passed to the design phase to determine design supply air temperatures and supply airflows based on the peak loads. The system simulation phase calculates hourly equipment loads based on the system type and weather data. The system loads are then passed to the equipment simulation phase to calculate hourly energy consumption. The purpose of the equipment phase is to convert hourly loads into site and source energy consumption broken down by fuel type. Lastly, in the economic analysis phase, TRACE determines lifecycle costs using the site energy consumption, entered utility rates and installed costs.

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<sup>1</sup> Unless otherwise noted, all people referenced in this article were employees of Trane

<sup>2</sup> "Early History And Future Prospects of Building System Simulation", Tamami Kusuda. Retrieved April 11, 2017. [http://www.ibpsa.org/%5Cproceedings%5CBS1999%5CBS99\\_P-01.pdf](http://www.ibpsa.org/%5Cproceedings%5CBS1999%5CBS99_P-01.pdf)

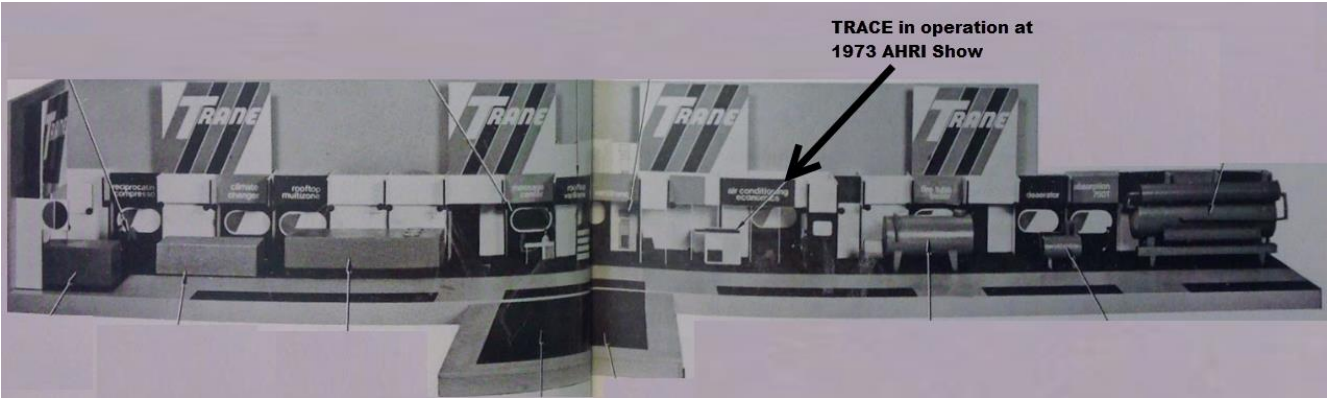


**Figure 2. 1973 depiction of TRACE. Note the term “Weather Tape.” The weather was loaded on large, reel-to-reel magnetic “tape.”**

The program was officially introduced to the market as TRACE 100 in late 1972. In its initial release, users filled in their building inputs using a paper manual. The user mailed these manuals to Trane’s headquarters La Crosse, Wisconsin, where the manuals were reviewed. Punch card stacks were created based on the user inputs by a staff of keypunchers in the IT department. It could take weeks to receive the results of one input.

The computer program was first demonstrated as a product at the Twenty Second International Air Conditioning, Heating and Refrigeration Exposition on January 29th, 1973 in Chicago, Illinois. At the exposition, TRACE was prominently placed in the center of the Trane booth, where a key punch machine and data transmission terminal were available for actual input and output of building analysis data (Figure 4). During the show, booth visitors could physically create punched cards. The data was transmitted directly to the Computer Center in La Crosse, Wisconsin to run the

simulation. After seven minutes of calculation and transmission time, the reported outputs returned to the booth in Chicago, where the customers could evaluate the output.



**Figure 3. TRACE in operation at the 1973 Exposition**



**Figure 4. Bud Simpson (Trane) discusses TRACE with customers at 1973 Exposition**

A typical simulation consisted of a base model plus three alternative models. In the early days, applications engineers Art Hallstrom, Don Eppelheimer, Jim Miles and Bill Landman, were actively developing and running the simulations. “Once the group in La Crosse received the input book, the simulation of the model with four runs was at least a 24-hour process”, stated Hallstrom. The mainframe computer, which read the punched cards, would run the simulations overnight. The output reports were then reviewed on the next day. In between several phone calls with customers, the building model datasets were corrected numerous times. The engineers at Trane had to hand-correct any key punch errors manually using keyboard terminals before running datasets again through the mainframe. After a completed simulation, the results were sent to the Trane sales offices, where account managers provided and analyzed the outputs with their customers.

The price per run in the beginning was \$1200—equivalent to \$5,500 in 2017 dollars—so it was critical that the inputs were accurate. To run the simulations, weather was obtained from the National Oceanic and Atmospheric Administration (NOAA) and the U.S. Air Force on magnetic reel-to-reel tape drives, which had to be loaded onto the mainframe before each run was executed.

An Oil Embargo oil embargo led to skyrocketing energy costs in 1973<sup>3</sup>, and building owners became more aware of their utility bills. More emphasis was placed on design engineers to devise ways to conserve energy. As a result, TRACE became more widely utilized as customers understood the power of energy simulation.

In 1976, TRACE 200 was launched, and allowed users to input their building and systems data directly into their office terminal computers and transmit the data electronically to a mainframe computer. The electronic transmission service— coined TRACE DIRECT—used nationwide computer time sharing networks run by Boeing, McDonnell Douglas and General Electric. The results of the TRACE runs were then mailed back to the user via US Postal Service. On rush orders, Scheier recalls frantically driving to the La Crosse airport to airmail the results to customers. TRACE 200 also added a feature allowing users to override building loads in order to match peak loads. This facilitated better evaluations of energy conservation measures in existing buildings. Two day training seminars were offered to teach users proper model inputs using their computer terminals.

In 1977, TRACE 300 integrated TRACE Solar into the program. TRACE Solar utilized algorithms based on TRNSYS (Transient System Simulation Tool). In TRACE Solar, users could model active solar domestic water and space heating systems within their building models. The U.S. Air Force chose to

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<sup>3</sup> Responding to Crisis". University of Wisconsin. April 26, 2010. Retrieved April 11, 2017  
<http://nelson.wisc.edu/che/events/place-based-workshops/2010/project/energy-perspectives/crisis.php>

use these features for its energy audit and retrofit program in the late 1970s. The audit and retrofit program resulted in a 25% reduction in energy consumption.

Launched two years later, TRACE 400 doubled the number of zones from 30 to 60 and systems from 4 to 8 per alternative (Figure 5). It also allowed for dead band thermostats, wall tilts, skylights, new system types, equipment sequencing, and heat recovery. In addition, the program introduced the ability to simulate thermal mass to properly estimate early morning loads when the building transitioned from unoccupied to occupied mode.

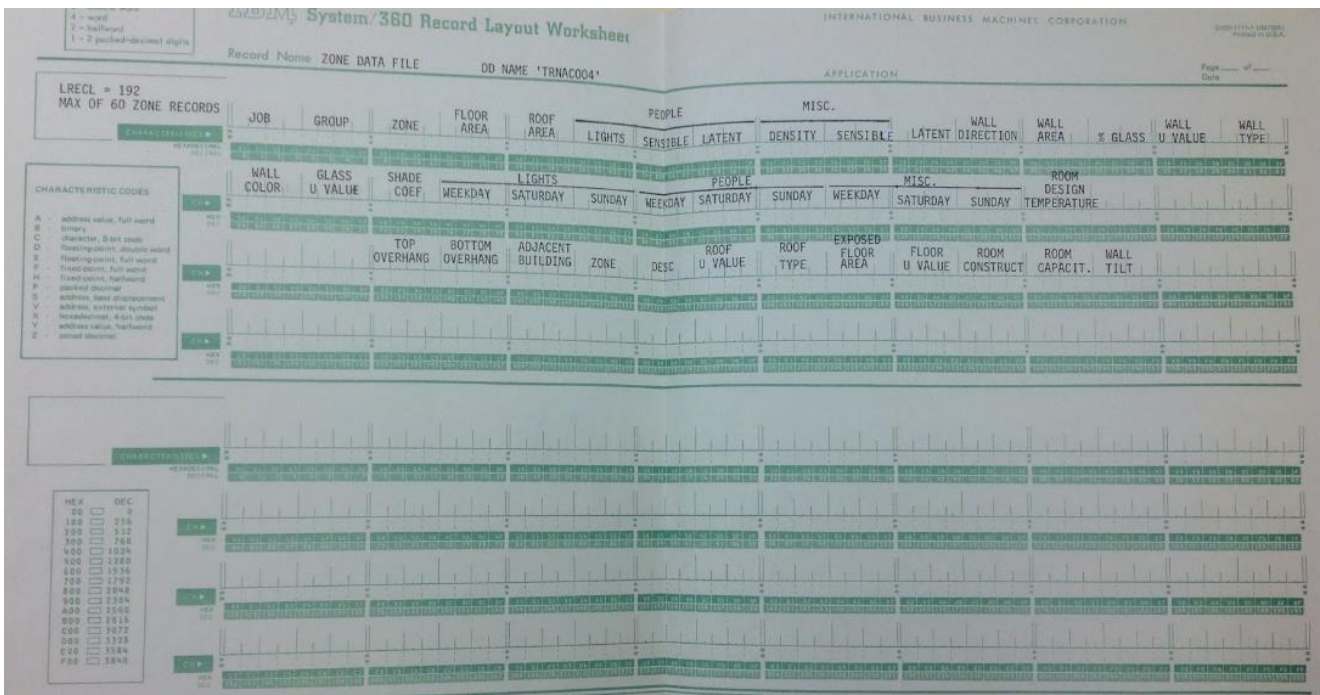


Figure 5. TRACE 400 input manual

TRACE 500, debuted in 1981, included an optional transfer functions for load calculation and also included vertical fin shading. Transfer functions allowed users to model more construction types, such as concrete walls with insulation on either the inside or the outside of the building. This version also introduced improved temperature drift calculations, additional system types, such as the water-source heat pumps, improved infiltration algorithms, and time-of-day utility rates.

Eventually, the Load Design portion of TRACE was stripped down so it could be run standalone on a user's PC. The first PCs had very little memory and ran very slow compared to today's simulations. The first personal computer the development groups used was the Radio Shack TRS-80, purchased in 1979 for \$3500—approximately \$11,000 in 2017 dollars. The TRS-80 was available with either 32 or 64 kilobytes (kB) of RAM and included 500 kB of data storage on an eight-inch floppy drive.

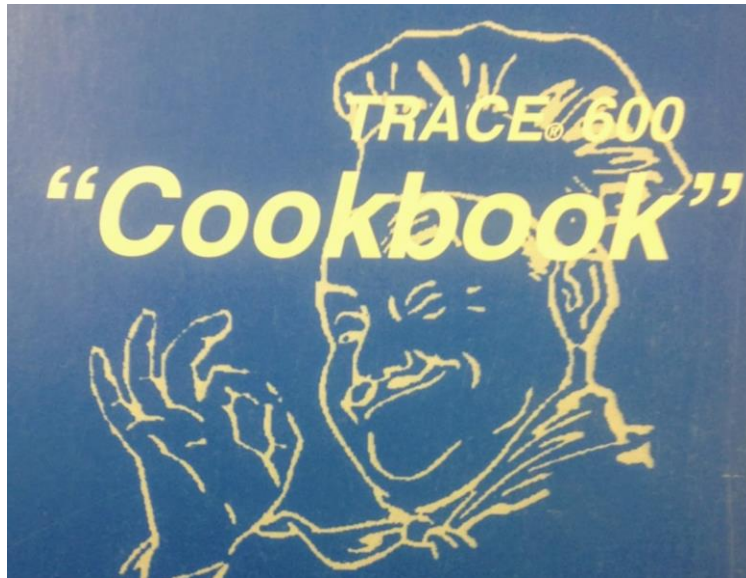
In 1983, the Customer Direct Services (C.D.S.) department at Trane was officially formed to support, train customer and develop TRACE and other design and analysis software programs. The department's support structure offered three levels of customer support:

- Basic Package: TRACE Load Design program with a 150-zone limit that ran on the user's standalone PC
- Intermediate Package: Offered local dial-up usage of the TRACE Load Design program with a 700-zone limit and 20 simulations per year of the simplified energy analysis program called TRACE-II.
- Full Package: Direct Access to 10 full TRACE runs per year and 40 runs per year of the TRACE Economics Life Cycle Costing program.

That same year, Eugene "Smitty" Smithart, manager of C.D.S. in the 1980s, had the idea to rent a panel truck, fill it with PCs, and deploy people to travel to company locations to train customers primarily on how use personal computers. There were three types of computers on the panel truck: Apple IIe, Radio Shack TRS-80, and the Compaq Portable. "During a typical training week, someone from the group would fly out to an office on Monday, train in the office or a local hotel on Tuesday and half of Wednesday, pack the truck with computers, drive to next office in a different city, conduct another training session on Thursday and half of Friday, and then fly home on Friday", said Mick Schwedler, applications engineer. The sales offices were responsible for driving the truck to the next training location.

By the late 1980s, PCs had become powerful and widespread enough to run simulations on customer's desks. In March 1988, TRACE Ultra was launched as the first desktop version of the software running on Microsoft's MS-DOS. TRACE Ultra only lasted 6 months, due to programming bugs, before it was rebranded as TRACE 600. Additionally, TRACE Ultra was renamed to TRACE 600 because there was name confusion with other software the company had developed. During the time, Sue Bouffleur, who worked in C.D.S., had to reformat new versions of the program and mail them out to customers on a daily basis because of the bug fixes.





**Figure 6. TRACE 600 “Cookbook” manual provides recipes for modeling systems and control strategies**

Following that inauspicious beginning, in 1992, TRACE was used to settle a lawsuit. The owners of One Beacon Street, an office building in downtown Boston, were disputing steam usage with their utility company, Boston Edison Company. The lawsuit used TRACE modeling as evidence to determine the damages to the owner. Boston Edison Company tried to exclude the modeling evidence. However the evidence was included because the judge found that the program data and equations were accurate and complete due to its widespread acceptance by HVAC professionals.<sup>4</sup>

In 1994, the company announced release of a new Microsoft Windows-based software using the TRACE calculation engine. Known as System Analyzer, the program was used for load, energy and economic calculations, but its inputs were simplified to reduce the amount of data entry for quick modeling.

In 1995, the information superhighway led to the creation of an internet email alias to help support customers. Any questions, comments, or feedback on programs, along with input files could be sent to this email address for support. Also, TRACE Load Express was launched. This Windows-based tool calculated peak load and detailed psychrometric outputs for small and medium-sized commercial buildings.

In 1998, TRACE Load 32 was announced as the first windows version of the full load program. Two years later, the full version of TRACE on Windows, called TRACE 700 was released, and included

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<sup>4</sup> “COMMERCIAL UNION INSURANCE COMPANY & others vs. BOSTON EDISON COMPANY”. April 27, 1992. Retrieved April 11, 2017. <http://masscases.com/cases/sjc/412/412mass545.html>

load, energy and economics. During that time, between Load 32 and TRACE 700, users were forced to perform load calculations in Windows and Energy/Economics calculations using TRACE 600 on the MS-DOS platform. This was obviously not convenient for program users.

Up until the mid-2000s, TRACE had always been primarily used for load calculations, so much of the development was load-driven. In the mid-2000s, users started to utilize full energy and economic calculations much more often. Both ASHRAE Standard 90.1 and LEED™ green building certifications were drivers that led to more performance-path compliance energy modeling.

In the late 2000s, TRACE and System Analyzer were prominently recognized by Consulting-Specifying Engineer (CSE) magazine. The magazine named TRACE 700 version 6.2 a Product of the Year - Silver winner in the "Software: Design, modeling, analysis" category in 2009.

In 2015 and 2016, TRACE customers participated in the ASHRAE LowDown Showdown modeling challenge sponsored by the Department of Energy (DOE) and the National Renewable Energy Laboratory (NREL) at the ASHRAE Energy Modeling Conference. The challenge showcased the work of several teams competing to model a net-zero building using criteria set forth in the contest requirements. A number of other public- and private-domain energy analysis programs, including eQuest, HAP, and EnergyPlus, were also utilized in the competition.

As energy modeling moves into the future, a new program, called TRACE 3D Plus, has been announced. The calculation engine is transitioning away from almost 50 years of internally developed coding. The new version utilizes the Department of Energy's EnergyPlus calculation engine. In addition, the user interface has been updated to allow for drag and drop components and 2D or 3D visual model validation.

For almost fifty years, energy analysis and simulation tools have evolved as computing, graphic and communication technologies changed. However, the goal has always been to help building owners and designers reduce energy use and cost in buildings and the resulting impact on the environment.



(Left to Right) Jim Miles, Rick Nelson, Jack Stokes, Jim Omernick, Sandy Luepke, Jim Richason, Marian Seitz, Pete Dawson, Nancy Clayton, Bob Stegman, Mick Schwedler, Bob Shuman



(Left to Right) Jim Richason, John Knudson, Dennis Stanke, Mick Schwedler, Dana Pongratz, Brenda Bradley, Ron Mussman, Dick Vance, Dave Guckelberger, Bill Landman, Pat Carlson



(Left to Right) Scott Guthrie, Eugene Smithart, Betty Nierengarten, Pete Dawson, Mick Schwedler, Brian Kammers, Jim Miles, Jim Richason, Neil Patterson, Dave Willets, Jim Hoch, Sue Bannon, Ted Kennan, Larry Scheier (1983).



(Left to Right) Nancy Smith, Wayne Wright, Sal Sorrentino, Joe Monfre, Jay Althof, John Lake, Jim Richason, Carol Paisley, Don Eppelheimer, Ed Watson, John Walton, Sue Bouffleur, John Knudson, Mick Schwedler, Dave Guckelberger, Dean Henderson (1990)



(Left to Right) Michael Lee, Nancy Smith, Clair Jacobson, Vance Tang, Sal Sorrentino



Dave Guckelberger



(Left to Right) Carlos Oropeza, Matt Biesterveld, Justin Wieman, Tony Bruno, Nissa Ali, Christian Tabor, Katie O' Rourke, Wes Drye, Rene Kingsbury, Pete Kramer, Mike Filler, Kevin Walters (2002)



(Left to Right) Sue Bouffleur, Clair Jacobson, Wendy Brown, Ken Scanlon, Deb Bratberg, Sue Ganshaw, Jim Richason, Rob Davidson, Andrew Youra, Sharon Honeck, Marie Busack, Nancy Smith (2002)



(Left to Right) Chris Hsieh, Delia Estrada, Deb Bratberg, Jim Richason, Susanna Hanson, Sue Bouffleur, Clair Jacobson, Wendy Brown, Celene Xi, Adam Wellman, Eric Sturm, Scott Hintz, Jeanne Harshaw, Mark Trochinski, Matt Biesterveld, Dave Guckelburger, Jeremy Arms, Mike Patterson, Bob Fassbender, Marie Busack (2008)



(Left to Right) Sue Bouffleur Nagappan Chidambaram, Chris Hsieh, Jim Spielbauer, Nick Cavitt, Jeremy Arms, Mayra Reyes, Mark Trochinski, Caitlin Bohnert, Matt Biesterveld, Jim Richason, Mick Sharma, Haley Goslinga, Ted Eschenbaum, Kit Fransen, Deb Bratberg, Sarah Hilden, Kris Knickrehm, Shawn O'Brien, Marie Busack (2016)