PWA- David Chanin: MACCS2 Support Forum & The Development of MACCS2: Lessons Learned

MACCS2 Support Forum

August 23, 2006

RE: MACCS2 Economic Costs

Filed under: MACCS2 Questions — DonCatanzaro @ 9:24 pm

I had a question about the Economic Parameters within MACCS2 and I think some of it was answered by your post "Economic Costs Without [sic] Basis" but other questions were not.

If I understand correctly, MACCS2 counts/accounts for four types of economic costs 1) food/lodging for the displaced persons (short-term); 2) decontamination costs for property; 3) losses due to temporarily interdicted property; and 4) losses from permanent interdicted property.

Costs 3, 4, and 5 are all tied to a physical place on the earth and the buildings and such associated with them (ie [sic] physical property). This is pretty much items that a real-estate agent and auctioner [sic] could sell for or to you. If I understand correctly how these costs are calculated, I wonder if we are missing some important sectors of our economy.

For the last 30 years, the US economy has moved towards a service industry where a significant proportion (I have no idea how much) is not tied to the physical land in the same way as it was in the past. In most states, tourism is the number one economic engine, not manufacturing as in yesteryear. Over the last 10 years the US economy has moved towards an information economy where economic activity is being produced in a much more distributed fashion over the internet.

So the crux of my question is "How do these aspects of the economy get accounted for in MACCS2?" I don't think we could assume it is accounted for in the value of the land (V) because V is calculated using Reproducible Tangible Wealth (ie [sic] government and private capital (equipment/structures) and durable goods), value of land (suburban, value of farm household possessions etc).

Any ideas? [sic]

3 Comments

1. Hello, Don. I have spent much time thinking of a way to "jigger the inputs" so that the cost model of MACCS2 could be used in a sensible way. As the person who coded it into MACCS and then refined it for MACCS2, and also the person who wrote SAND96-0957, I think what you are attempting is impossible. The economic cost model in MACCS2 was included (at request of sponsors) only for historical reasons to allow comparison of its cost estimates to those of previous studies. It is my firm belief that the MACCS2 cost model is so seriously flawed that even with reevaluation and modification of all its input parameters, its cost results should not be used unless for replicating prior studies.

   With my colleague Walt Murfin, I was tasked by a nuclear weapon safety group to develop a methodology for estimating the costs associated with a hypothetical weapons accident with release of plutonium to the environment from HE explosion or fire. That report represents three years of work and it includes a bibliography of the 300+ sources used in the research. There are links to that report, SAND96-0957, at http://chaninconsulting.com , and a ZIP file with the report in WordPerfect format together with spreadsheets is downloadable. Our cost model was adopted by Sieglinde Neuhauser for the RADTRAN code. The cost model of SAND96-0957 is used by NASA for NEPA (and maybe other) studies of space missions involving the launch of radioactive materials such as found in RTGs. Most of the data we used for the effectiveness of decontamination was based on data found for fission products, as clear from its Appendix D. The laws that would come into play for site remediation in the event of a reactor accident are the same as for a weapons accident. My advice is to use MACCS2 (or other consequence code) to estimate the areas requiring cleanup and apply the cost figures of SAND96-0957. When I was involved with the MACCS2 project (from 1991-1996, and also later in 2000-2001) the NRC had no interest in implementing the cost model of SAND96-0957 into MACCS2. I could have done it without a lot of work, but they weren't interested.

   According to http://www.multinationalmonitor.org/hyper/issues/1986/05/welch.html , the first U.S. public cost estimate for a "worst case" accident at a nuclear power plant was the $7 billion presented in the 1957 AEC report WASH-740. I have no idea how that number was calculated. It is possible, however, that the MACCS2 cost model dates back to 1957. Even in 1975 (as shown in SAND96-0957) the WASH-1400 cost numbers were underestimated to a significant degree. The underestimation is much more significant today. All of this should be clear from reading SAND96-0957.

   I do know that the economic cost model of MACCS2 is essentially identical to the cost model of the 1975 Reactor Safety Study (RSS), aka [sic] "Rasmussen

Report," published by the NRC in October 1975 as WASH-1400. Under the direction of Prof. Norman Rasmussen (MIT) and AEC/NRC staff (NRC came into being in January 1975), the consequence modeling was performed by Sandia Laboratories, which used the CoMO computer code for the calculations (never released to the public because virtually all model parameters were hard-wired for the RSS). The consequence model in its entirety is probably best described in RSS Appendix 6 ("Consequence Modeling"), the individual authors of which were uncredited [sic] and the basis for the model was not made clear.

Additional information can be found in the 1982 "Sandia Siting Study" (NUREG/CR-2239) where its peak cost estimates made the headline of the Washington Post as a result of what was thought to be high costs for accidents postulated to result in high contamination levels at remote cities as a result of rain occurring [sic] when the plume reached the city (largely due to a "non-physical" artifact of the CRAC/CRAC2 rain model not found in MACCS/MACCS2). The public alarm from those newspaper stories led to Congressional hearings held by Rep. Edward Markey of Massachusetts.

The only other significant source of information on the cost model was the Ph.D. dissertation (possibly a Masters thesis) of Richard P. Burke from MIT, who had Norm Rasmussen as an adviser, with the topic being off-site costs of reactor accidents.

Sandia National Laboratories (SNL) later used virtually the same economic cost model in the successor codes: CRAC, CRAC2, MACCS, and MACCS2. There are many aspects of their cost model(s) that don't make sense. Even in 1975, the WASH-1400 assumption that a DF of 20 could be achieved in urban areas with a decontamination cost that was 10% of the property's value was based on a civil defense report from the 1960s where radioactive fallout from a nuclear weapon could be cleaned up by sweeping with brooms–and there was no cost assessed for disposal of the swept-up radioactive waste. Although we removed that DF=20-for-10%-of-property-value in the MACCS/MACCS2 Sample Problem data, the model itself is hopelessly flawed for reasons very clear from SAND96-0957.

That opinion of mine was shared in 1977 by the Lewis Committee [sic], which independently reviewed the RSS for the NRC under the auspices of the American Physical Society. The Lewis report did not elaborate on the matter, but it did say, essentially, that the RSS economic cost model lacked a firm basis, though their exact wording escapes me.

Despite the known shortcomings of the cost model, when the GAO requested technical assistance from SNL circa 1986 to help Congress update the indemnity limits of Price-Anderson, an interim version 1.5.x of the MACCS code (prior to MACCS v. 1.5.11, publicly released in 1990 to accompany NUREG-1150) was used by SNL for the cost calculations requested by the GAO. See http://en.wikipedia.org/wiki/Price-Anderson_Nuclear_Industries_Indemnity_Act .

The GAO published a report largely based on that SNL analysis. The cost estimates from GAO were used by Congress to increase the Price-Anderson commercial power reactor indemnity limit from the previous baseline of $560 million to $6.5 billion in 1987 (periodically adjusted for inflation).

As the person who implemented the CoMo/CRAC/CRAC2 cost model into the publicly released MACCS and MACCS2 codes, there were quite a few things that never made sense to me, but SNL was directed by the NRC to continue using the prior approach. When MACCS2 was originally developed under DOE sponsorship from what is now the NNSA, the estimation of economic costs was not deemed important enough to change the cost model, since the primary application of MACCS2 for DOE safety analyses was the estimation of 95th quantile [sic] site-boundary doses for comparison to the 25-rem Evaluation Guideline of DOE-STD-3009, and, (for historical reasons and for NEPA studies) the 50-mile collective dose incurred during the "emergency phase," which was typically one week in duration. It was rare for DOE safety analyses to even use the CHRONC module to estimate long-term doses, with even less interest in estimating economic costs, since there were no DOE requirements for such analyses.

Anyway. [sic] Good Luck to you. Sorry for the rant and lack of substantive assistance in what appears to be an impossible dream. Hopefully, this information will be of some help to you in understanding the magnitude of your task. If you publish anything based on the cost estimates of MACCS2, I'd appreciate a copy. I'd also be happy to talk to you on the phone, as I see that you tried calling me.

In using Google to form a reply, this interesting paper came up:
http://economics.gmu.edu/candidates/kymn_paper.pdf#search=%22ACRS%20review%20WASH-1400%22

Cheers!

Comment by David Chanin — August 26, 2006 @ 12:26 am

MACCS2 Support Forum

January 23, 2007

MACCS2 Economic Parameters

Filed under: MACCS2 Questions — DonCatanzaro @ 10:01 am

I had a question about the Economic Parameters within MACCS2 and I think some of it was answered by your post "Economic Costs Without [sic] Basis" but other questions were not.

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Any ideas ? [sic]

1 Comment

1. Speaking as the sole individual who was reponsible [sic] for writing the FORTRAN in question, which was done many years prior to my original work in SAND96-0957, I think it's foolish to think that any useful cost etimates [sic] can be obtained with the cost model built into MACCS2.

   If there were any possible way to use the cost model of MACCS2 to even roughly approximate the cost modeling of SAND96-0957, I would have worked hard to find a way to do it. In my opinion, it's simply impossible.

   When the NNSA wants to look at the cost-benefits of various operational alternatives involving nuclear weapons, I would hope that they continue to use the cost models of SAND96-0957 developed for the Surety Assessment Department at SNL for use in assessing the consequences of accidents involving nuclear weapons. That project took three years of hard work and the end product is a much larger contribution to "nuclear safety" than the MACCS and MACCS2 codes (which have been applied to assess the safety of at least 300 nuclear facilities worldwide).

   When NASA performs NEPA studies related to the launch of RTGs into space and they want to estimate the cleanup costs that would be associated with catastrophic [sic] failure on launch and the dispersal of plutonium, I know for a fact that their EISs and EAs use SAND96-0957.

   Back more than 15 years ago when the NRC published NUREG-1150, the NRC decided to depart from WASH-1400 in not publishing the economic cost numbers that came out of the predecessor MACCS code. That is right. NUREG-1150 did not include any estimates of the economic costs associated with the accident risks studied for the five reference plants.

   As made clear in SAND96-0957 (page 2-9), the cost estimates of WASH-1400 are without a technical basis. That lack of basis was pointed out soon after 1975 with the report of the Lewis Commission review of it, which was totally dismissive of the cost estimates in WASH-1400. Things only got worse with time. It calls to mind cliches [sic] such as "The elephant in the room," and "The Emperor's New Clothes." If they stick their heads in the sand all together, maybe nobody will notice that all their work to estimate doses and notional cancers from their LNT cnacer [sic] estimates represent the "true" consequences of concern. The economic costs of severe accidents at 3-GWt commercial reactors sited near large urban areas are not evaluated because their costs would be so staggering that they would be the largest expenditure ever faced by this country in its entire history. An event that made New York City uninhabitable due to down-river

transport of large releases from Indian Point would be on a par with the Civil War in its disruptive effects on our nation.

It's not even worth discussing further. The economic cost numbers produced by MACCS2 have absolutely no basis. It is unfortunate that Congress raised the Price-Anderson indemnity limit (from the former $560 million) for NRC-licensed commercial reactors and DOE facilities to an inflation-adjusted $6.5 billion (1988 dollars) based on calculations done by SNL in 1986-1987 as documented in the GAO reports cited on p. 2-8 (ibid.). Those calculations were done without my involvement. They were simply a continuation of the misleading information on reactor risks that has been foisted on the world since "(white-) WASH-1400."

If you want to discuss economic costs, I'd be glad to discuss SAND96-0957, but the "cost model" of MACCS2 is not worth anyone's time. My sincere advice is to not waste anyone's time (and money) in trying to make any sense of it. If you can make any sense of it, you're much smarter than I am. My hat goes off to you!

If you have a genuine interest in the economic consequences of radiological releases, my advice to you (as the first author of SAND96-0957 and collector of 300+ sources listed in its Bibliography) is to just please forget about the "cost model" of MACCS2.

In conclusion, since the "litigative action model" (pun intended) of the CHRONC model has no basis in reality either, if you want to estimate cancers and collective dose for a long-term exposure period, set the dose limit to its maximum to "turn off" the nonsensical mitigative [sic] action models. If you do that, you could calculate cancers using a LNT model, which is probably bounding, and LNT still has some (dwindling) support in the health physics community the last time I checked.

David

Comment by David Chanin — January 24, 2007 @ 1:15 am

[written for:] Energy Facilities Contractor Operating Group Safety Analysis Working Group,
Annual Workshop, April 29–May 5, 2005, Santa Fe, NM

The Development of MACCS2: Lessons Learned

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Introduction

Soon after the 1996 public release of MACCS2 version 1.12,[1] there was significant controversy concerning its appropriateness for use in DOE authorization basis analyses.[2] This was triggered by the discovery of the "source-term looping" coding error found by [Chris Steele of] the DOE Los Alamos Area Office.[3] [4] That discovery led to exhaustive independent investigation into the quality assurance (QA) pedigree of MACCS2 and other DOE computer codes by the Defense Nuclear Facilities Safety Board (DNFSB) which was documented in their report TECH-25.[5]

The QA status of MACCS2 and other codes used by DOE entities for authorization basis studies led to a comprehensive effort[6] by the DOE to create the "Toolbox" of computer codes suitable for authorization basis analyses when used in accordance with supplied guidance.[7] In light of the fact that MACCS2 was never intended or advertised as appropriate for use in authorization basis analyses, its selection for the DOE Toolbox was a significant departure from the intent of the code developers.

Now, when we will soon be seeing a new version of the code incorporating major enhancements, it is timely to address widespread questions about the code's QA shortcomings. The lessons to be learned from this experience are explored.

[1] D.I. Chanin, M.L. Young, *Code Manual for MACCS2: User's Guide*, SAND97-0594, NUREG/CR-6613, Sandia National Laboratories, Albuquerque, NM (1997 *and* 1998).

[2] *Preparation Guide for U.S. Department of Energy Non-reactor Nuclear Facility Safety Reports*, Appendix A, "Evaluation Guideline," DOE-STD-3009-94, Department of Energy, Washington, DC (2000).

[3] C. Steele, personal communication to D. Chanin, DOE Los Alamos Area Office, Los Alamos, NM (1997).

[4] J. J. Gregory, May 26, 1998 memo to MACCS2 users: "MACCS2 Software Package, Software Defect Notification," Log Number M2V1-12A, Sandia National Laboratories, Albuquerque, NM (1998).

[5] *Quality Assurance for Safety-Related Software at Department of Energy Defense Nuclear Facilities*, TECH-25, Defense Nuclear Facilities Safety Board, Washington, DC (2000).

[6] *Software Quality Assurance Criteria for Safety Analysis Codes,* Department of Energy, Washington, DC (2003).

[7] *MACCS2 Computer Code Application Guidance for Documented Safety Analysis*, DOE-EH-4.2.1.4-MACCS2-Code Guidance, Department of Energy, Washington, DC (2004).

Within the DOE and its contractors, MACCS2 is probably the most widely-used radiation dose-calculation computer code *despite* the QA problems identified by the DNFSB. MACCS2 was one of the two dose-calculation codes selected for the DOE Toolbox of computer codes as appropriate for use in assessing the authorization basis of nuclear facilities, provided that a program be initiated to improve upon its QA status.[8]

Discussion

Two dose codes were chosen for the DOE Toolbox: GENII[9] and MACCS2. The difference in QA standards used during the development of the two codes is made clear in quotations taken from their respective code manuals given below.

MACCS2 was developed in an evolutionary fashion from a series of computer codes created by Sandia National Laboratories (SNL) under the sponsorship of the U.S. Nuclear Regulatory Commission (NRC). The predecessor computer codes (COMO, CRAC, CRAC2, and MACCS[10]), all of which were developed to assess commercial nuclear power plant accident risks, were developed by SNL for the NRC over a period of roughly fifteen years beginning with WASH-1400[11] (using the COMO code) and culminating with NUREG-1150[12] (using the MACCS code).

The numerous studies performed by SNL with these codes were performed for the Research Branch of NRC. The *probabilistic risk assessment* (PRA) results of these codes were never used by the NRC for licensing decisions or to support the authorization basis of nuclear facilities. The predecessor accident analysis codes from SNL were seen by the NRC as research tools *not* subject to the stringent QA requirements of the deterministic *authorization basis* analyses in Safety Analysis Reports (SARs) reviewed and approved by the NRC's Licensing Branch.

For that reason, MACCS (and its successor MACCS2) were not held to the strict 18-point QA requirements of NQA-1,[13] as is required for SARs, which the DOE now terms Documented Safety Analyses (DSAs). Rather, both MACCS and MACCS2 were developed following the much less rigorous QA guidelines of ANSI/ANS 10.4. [14]

[8] D.Y. Chung, K.R. O'Kula, P.R. McClure, *Selection of Computer Codes for U.S. Department of Energy Safety Analysis Applications*, National Nuclear Security Administration, Germantown, MD (2002).

[9] B.L. Napier, *et al.*, GENII – The Hanford Environmental Radiation Dosimetry Software System, PNL-6584, Vols. 1–3. Pacific Northwest Laboratory, Richland, WA (1988).

[10] D.I. Chanin, *et al.*, *MELCOR Accident Consequence Code System (MACCS): User's Guide*, NUREG/CR-4691, SAND86-1562, Vol. 1, Sandia National Laboratories, Albuquerque, NM (1990).

[11] Nuclear Regulatory Commission, *Reactor Safety Study*, WASH-1400, Washington, DC (1975).

[12] Nuclear Regulatory Commission, *Severe Accident Risks: An Assessment for Five Nuclear Power Plants*, NUREG-1150, Washington, DC (1991).

[13] American Society for Mechanical Engineering, *Quality Assurance Program Requirements for Nuclear Facilities,* NQA-1, Fairfield, NJ (1994).

[14] American National Standards Institute and American Nuclear Society, *Guidelines for the Verification and Validation of Scientific and Engineering Codes for the Nuclear Industry*, ANSI/ANS 10.4, La Grange Park, IL (1987).

GENII explicitly claims to conform to NQA-1 and be appropriate for authorization basis:

> *The GENII package of codes was developed under a QA plan based on the American National Standards Institute (ANSI) standard NQA-1 as implemented in the PNNL Quality Assurance Manual PNL-MA-70. All steps of the code development have been documented and tested, and hand calculations have verified the code's implementation of major transport and exposure pathways for a subset of the radionuclide library.*

MACCS2 makes no such claim. On p. 1-7 of the MACCS2 User's Guide, there is a strong warning for analysts who *choose* to use it for such purposes:

> *When MACCS2 is used for authorization basis studies, it is very important to carefully review the code's phenomenological models and input parameter values to ensure that they conform to applicable guidance and are appropriate for the accident scenario being modeled. The identification of deficiencies in these areas could bring into question the safety basis of the facility. If errors are later found in authorization basis calculations, an Unreviewed Safety Question (USQ) could be raised, and continued operation of the facility would then require a demonstration that the facility's safety basis was adequate.*

One of our tasks from DOE was to support the MACCS and MACCS2 user communities, with the clear majority of both groups engaged in DOE projects. Consequently, because the two codes had mostly identical coding, DOE funds were used to support MACCS users as well as the beta-test group for MACCS2. Feedback and error reports from both user groups resulted in the identification and correction of many coding errors which had been inherited from MACCS, a code which was never updated after the public release of MACCS version 1.5.11.1 by NRC.

Error reports and defect investigation reports which followed a review and approval process, along with detailed configuration management and code testing information, they were all maintained in paper files through 1997. All of those QA files were unfortunately lost when the author relocated after over a year of separation from the project. SNL had never requested them.

Why did MACCS2 become so widely used for authorization basis safety analysis by DOE entities? In fact, this type of usage began with its predecessor, MACCS. SNL never encouraged it and always warned analysts that they alone were responsible for the results generated. We also went so far as to scrupulously avoid using the common "default value" in referring to the code's provided "Sample Problem" input data files. "Sample data"and "example usage" were the terms used to remind the analyst that they, and they alone, were responsible for reviewing MACCS and MACCS2 input data and resultant code outputs to ensure appropriateness for their application.

In fact, one analysis led to another, with approval of one study by a DOE office constituting the basis for approval of another. In the case of its predecessor MACCS, where the code manuals made no mention of authorization basis, safety analysis using MACCS was sometimes performed by individuals who never had direct contact with the code developers at SNL. There were numerous occasions when we only first learned of such usages from literature searches performed *after* the DOE publication of their finalized authorization basis documents, and the subject facility or operation had begun operation or had already taken place.

This pattern probably began with analyses of the K-reactor at Savannah River Site (SRS) dating from the mid-1980s. At the time, K-reactor was the nation's only tritium production facility, but it was later shut down for safety reasons. The K-reactor studies of SRS were deemed to require the modeling flexibility afforded by MACCS, which had the perceived high pedigree of being an NRC-sponsored product that was specifically developed to analyze the consequences of reactor accidents. The use of *MACCS* for such an important DOE facility added to its credence.

In that era of safety analysis prior to the Tiger Teams and the widespread large-facility shutdowns of the late 1980s, there was no detailed guidance for safety analysis available from DOE Headquarters. Before the issuance of DOE-STD-3009-94, analysts at a site which lacked site-specific formal guidance often utilized guidance documents prepared for *other* DOE sites such as the 1986 LANL report by J.C. Elder.[15] It was a time before the standardization of safety analysis that now comes to all from DOE Headquarters, fostered by [DOE/EH and] EFCOG.

There was also a conflict of interest. SNL was receiving funding from DOE to develop MACCS2, and (as done from the earliest days of MACCS), the code developer often assisted DOE analysts who were using the code for authorization basis as well as NEPA studies (where the chosen ANSI/ANS 10.4 would be an applicable QA standard). While consistently warning those engaged in safety analysis to be cautious and verify all results, we were averse to doing things that would jeopardize our continued funding. We also did not want to limit our user community by saying that safety analysis with MACCS2 (and MACCS) was inappropriate. To do so could have jeopardized the MACCS2 project. Those were some of the pressures we faced.

Conclusion

The reasons for writing this paper are both historical and personal. In 1992, I was the one who proposed the MACCS2 project to DOE and then obtained DOE sponsorship for the effort, which made use of beta testers from across the DOE Complex. Without the contributions and behind-the-scenes support of the beta-test group, MACCS2 might not have been completed. The beta-testers named in the code's documentation were co-developers, with one organization contributing the entire COMIDA[16] food model at its own expense. They all deserve thanks.

At the time the project began, by far the largest body of MACCS users was engaged in work for DOE. DOE was then working diligently to standardize safety analysis, with our only detailed guidance from DOE Headquarters in draft and subject to frequent revision.

To further the standardization process, there was a widespread perception that DOE required the improvements of MACCS2 in order to have a true general-purpose radiological assessment code, in contrast to the *strictly reactor* focus of MACCS. For non-reactor nuclear facilities, MACCS was obsolete because of its limited capabilities.

[15] J.C. Elder, *et al.*, *A Guide to Radiological Accident Considerations for the Siting and Design of DOE Non-reactor Nuclear Facilities*, LA-10294-MS, Los Alamos National Laboratory, Los Alamos, New Mexico (1986).

[16] M.L. Abbott, A.S. Rood, *COMIDA: A Radionuclide Food-Chain Model for Acute Fallout Deposition*, EGG-GEO-10367, Idaho National Engineering Laboratory, Idaho Falls, ID (1993).

The expansion of code capabilities was seen as enhancing the standardization process because many sites developed their own site-specific accident analysis codes and methods, with no easy way for DOE Headquarters to compare results from one site's authorization basis dose calculations to those from other sites.

Unfortunately, aside from the generally applicable QA requirements of DOE Order 5700.6c,[17] there was no explicit statement of QA requirements in our project tasking and funding directives. We believed that by following ANSI/ANS 10.4 that we were compliant with the DOE Order.

However, despite its reactor-focused limitations, MACCS did come to be widely used for safety analysis of accidents at DOE *non-reactor* nuclear facilities despite the code developer's consistent warnings of the pitfalls, shifting responsibility to those analysts to ensure that their usage was correct.

Largely because authorization basis studies circa 1992 were performed without the comprehensive guidance and formal requirements of today, DOE agreed throughout its development that the MACCS2 project would result in improved DOE safety analysis for authorization basis, as well as support enhanced NEPA studies of DOE facilities and operations.

In 2000, DNFSB report TECH-25 caused huge controversy over MACCS2 QA that needed to be explained by the code developer, for the record, because this brief history had not been written. The Program Chair of this Session [Kevin O'Kula] played host to the pivotal 1992 initial meeting with DOE that led to the funding of MACCS2. He encouraged me to write this paper.

The primary lessons learned from the development of MACCS2 are related:

> 1)a code developer cannot anticipate how their tool will be used and they cannot control its usage by others, and
>
> 2)usage could not be controlled because of a subtle conflict of interest from a natural aversion to point out shortcomings of the product.

With the forthcoming release of MACCS3, this account may benefit the MACCS3 developers as well as the future MACCS3 user community. The widespread use of MACCS2 and its ongoing development are gratifying.

[End Note: In the course of converting this document to PDF format on December 17, 2009, correction of minor typos and other edits were made to improve clarity and update the author's contact information. In addition, the QA distinctions between an NQA-1 "licensing code" and a "research code" like MACCS2 have been emphasized in light of the fact that MACCS2 calculations are being used to support the Severe Accident Mitigation Alternatives (SAMA) analyses required for the license renewal of commercial nuclear power plants. It seems to me that the code's QA shortcomings and the lack of input justifications are again being ignored, just as they were prior to DNFSB TECH-25 and the veritable firestorm that soon followed. D.C.]

17 "Quality Assurance," DOE Order 5700.6c, Department of Energy, Washington, DC (1991).