Story behind the Story on the Development of the ARS "Big Red" Draintube Plow with Laserplane Automatic Grade-Control System, by James L. Fouss, Ph.D., P.E.

Preface:

The U.S. Department of Agriculture (USDA) Agricultural Research Service (ARS) is the scientific and engineering research agency whose mission is to develop new and improved technologies to enhance agriculture and food production for public benefit. One of ARS's principal areas of research is soil and water management and conservation which is carried out at a national network of Federal research laboratories, many of which are co-located and cooperative with major Universities. The new knowledge, concepts, and technologies developed and demonstrated by ARS research are transferred to private sector agricultural producers and service providers (e.g., manufacturers) for implementation and delivery of improved products and services to the public.

Foreword:

This is a story about behind-the-scenes activities of ARS researchers, namely myself (James L. Fouss, Research Agricultural Engineer) and key ARS administrators, plus industry cooperators (e.g., the Caterpillar Tractor Co.) who were very important in the development and testing of the ARS "Big Red" Draintube Plow that helped to revolutionize the subsurface drainage industry in the early 1970s. This is a previously unwritten story, but has been told a number of times by Jim Fouss over the years to selected colleagues and individuals. Many of the events included in this story have never been published, especially the '*story behind the story*' parts.

Background:

By mid-1968, the corrugated plastic drainage tubing industry was well underway and growing quite rapidly, and a commercial version of a Laserplane grade-control system was almost ready for release onto the market for drainage and earth moving machines. However, the plowing-in of drains with plow-type drainage equipment had not yet caught on, and was not being worked on by industry, at least not in the U.S. One firm in England, *Badger*, had duplicated an early version of a research plow that had installed plastic mole-drain liners for a U.K. research project. It should be stated at this point that our ARS project staff had previously determined that many of the cable-laying plows used by telephone and utility companies were not easily adaptable to the installation of farm drainage corrugated plastic tubes, and they certainly weren't easily adaptable for laser-beam automated grade-control. ARS scientists discussed the possibilities for a draintube plow with various manufacturing firms such as the Caterpillar Tractor Co., Rome Plow Co., Towner Manufacturing Co., American Tractor Equipment Co., and a few others. It was learned that the industry did not have the technical competence and know-how to design a plow with the operational features, especially, the "floating-beam or -linkage principle," as was deemed desirable, if not necessary, for use in "plowing-in" subsurface drains. On some occasions industry representatives indicated that if ARS could provide a more advanced design, closer to what would be considered a pre-production prototype, industry could possibly take more interest in the idea. Modification of the design for the research prototype plow used from about 1963 through 1968 seemed too big a task for industry to undertake according to the representatives we contacted.

The Story behind the Story begins:
The story begins with a discussion period following a presentation that I made on "*Plowing in corrugated plastic drainage tubing with laser-beam automatic grade control*" at a Midwest Regional Convention of the Land Improvement Contractors of America (LICA) held in Indianapolis, IN late in the month of January 1967.[1] At the end of my presentation I made the comment that our research had shown the new corrugated-wall plastic drainage tubing could be successfully installed rapidly at design depth and grade with the laser-beam controlled drainage plow equipment. I then recommended that the drainage industry should consider developing a drainage plow for commercial use by drainage contractors. I noted that the plow should be designed to install the drain tubing deeper than our research prototype plow that was limited to about a 34-in. depth. A contractor asked me how deep, and I responded about 6-foot deep to allow for going through undulating areas in a field where that depth might be needed to keep a pipe on the design grade. I added the clarifying comment that it was not recommended to install the subsurface drains that deep as a normal practice. The contractor immediately snapped back, "That is crazy!" The contractor stated that he felt it would be impossible to put the drain pipe that deep and still keep it on grade with plow-type equipment. The discussions after that outburst are not recalled, although I probably had something further to say or made a comment about, but don't remember exactly what it might have been.

The story here jumps ahead to about a month or so later when I communicated my thoughts about the possible implications of the discussions with contractors following my presentation in Indiana through my normal reporting channels to Headquarters Program and management officials, namely: Dr. C.A. Van Doren (Chief, Corn Belt Branch, St. Paul, MN.), Dr. C.H. Wadleigh (Director, Soil and Water Conservation Research Div. (SWCRD), Beltsville, MD.), Dr. Jan van Schilfgaarde (Assoc. Dir., SWCRD), and also Mr. T.W. Edminster (Administrator, Agricultural Research Service (ARS), USDA, Washington, DC). I relayed my thoughts that the whole concept of the plowed-in corrugated plastic drain with laser-beam grade-control could likely die if we (ARS) did not take the next step. I outlined that next step (*which I had not intended to do prior to that*) was to design and fabricate a drainage plow capable of the 6-ft. operating depth and equip it with the Laserplane system that would be becoming available for drainage contractors in the not too distant future from the Laserplane Corp. I do not recall, but I may have added that in our earlier discussions with industry representatives they suggested we develop the larger plow with a design closer to a production model for their consideration in possible manufacturing and sale. I continued that once the larger plow was designed and fabricated, it would need to be mounted on a larger Caterpillar tractor than we had available, such as a D-8 or perhaps a D-7E, that we could probably acquire from military excess property. Then the plow with an adapted Laserplane system would have to be field tested to document its grade-control accuracy at the deep (6-ft.) operating depth. Finally, the plow would have to be demonstrated at contractor field-days to show its performance to contractors, drainage industry reps, and farmers to get their buy-in for the new technology. It was asked by one or two ARS administrators if I had a design in mind for the larger plow, and I recall replying "No", but I would have to work on that to develop a design. Approval was not given (as I recall) at that time

[1] The presentation at the National LICA Convention in Indianapolis, IN. was given about 3 weeks after the first presentation & demonstration of the Laser-Beam Automatic Grade-Control System for subsurface drainage equipment to drainage contractors, Agricultural Extension Agents, USDA Soil Conservation Service engineers and technicians, and industry reps at the 1967 winter meeting of the Ohio Chapter of LICA held in Worthington, OH.

on the calls, but approval was given verbally a few months later (probably at a summer ASAE Meeting) to proceed with the task to design the deep drainage plow; however, details of those conversations are not recalled.

The Draintube Plow Design Phase:
As the design process for the new plow began in early 1968, I was glad to have completed the entire machine design series of courses in Mechanical Engineering at The Ohio State University, taken as a part of my Ph.D. coursework. Another fortunate event happened a short time later when I was successful in hiring through an American-Polish Agricultural Engineering Exchange Program an experienced Mechanical Engineer (Zibignif Stolarczyk) with several years of engineering design in Poland. This engineer was hired through the ARS–Ohio Agr. Exp. Sta. Cooperative Agreement, which was the employment method used by ARS scientists to hire non-U.S. citizens for up to one year to provide key expertise needed on specific research or development projects. During that one-year period of employment the Polish Engineer serviced as a very valuable and experienced assistant to me on the plow design project.

Many alternative designs were considered and evaluated as a part of the plow design project and the resulting design was considered a compromise to provide the best performance based upon earlier experience and trials with research prototype plows. Attention was given to the reported performance of various foreign plows newly developed in England and W. Germany in arriving at specific design features for the new plow. The principle design requirements included a nominal operating depth of 6 ft. in a medium clay soil and a long floating beam with sufficient rigidity that springiness did not cause a grade control problem. In that regard, T-1 type steel, which had four times the ultimate strength of regular structural steel, was specified in the plow design. To provide stability for the crawler tractor in a heavy draft situation, our original design thought was to move the Cat D-7 (or D-8) fuel tank and operator seat to provide a position behind the diesel engine compartment to mount the hitch-point for the main plow beam. That position for the hitch was near the center-of-gravity for the crawler chassis, and the downward draft force component would have maintained the crawler tracks flat on the ground and reduced rearward tipping of the crawler chassis. But, when an Administrator in the Beltsville office learned indirectly about this idea, I was sent a brief message by Mr. Edminster that stated, "*Jim, You will NOT modify the D-7 Caterpillar tractor, but will use it as it comes from the factory*."[2] Thus, it then became the design objective for the plow to be connected to the crawler tractor in as simple a design as possible and with a minimum change in the hydraulic system or tractor chassis. In the final design, it was decided to hitch the plow at the rear side of the bulldozer blade on the Caterpillar tractor. The dozer and its accompanying hydraulic cylinder control was standard equipment on the crawler tractor (*as it came from the factory*). This design feature of using the CAT hydraulic cylinders to raise or lower the dozer blade controlled or adjusted the operating depth for the drainage plow. The laser-beam control hydraulic components, activated via solenoid valves, were connected into the CAT dozer hydraulic system to automatically change the dozer blade position and therefore adjust plowing depth during drain installation. The

[2] It is of interest to point out that several years later when the Hoes Plow, manufactured by Hoes, Inc. in W. Germany, was available in Europe and the U.S., the plow beam hitch-point was located between the tracks just behind the Dutcz Air-Cooled Engine compartment - about where Jim and Zibignif wanted the hitch on the Cat D-7 or D-8 in their initial plow design proposal. *Also see the Addendum-2 story in Appendix.*

basic tool-bar mounted plow blade that was used for the research prototype plow was also used in the new plow design. The tool-bar width was maintained at 11 ft. It was decided that a large size plow, that is, one with a 6 ft. operating depth capability, should be designed and fabricated rather than a smaller version for the research project. In the Midwest, a smaller plow, with depth capability around 4.5-ft., would have been more practical, but the design, fabrication, and testing of such a plow would have left several technical questions unanswered about the design and function of larger plows. It was reasoned that the design for a 4.5-ft. plow could be obtained in the future with relative ease by scaling down the design of the 6-ft. plow; we felt that the reverse was not necessarily true. The resulting plow design was very complete and extremely well documented with a full set of India Ink engineering drawings (Zibignif was also an excellent draftsman).

Funding the Plow Construction by Industry:
Once the plow design was completed, which took nearly a year, the task began to try and come up with the funds to have it fabricated by industry. Since my Engineering Technician, Norm Fausey, and I had already fabricated two research prototype plows in the earlier phases of the research project, it was desired to have the new plow fabricated by industry. Industry would have to do it in the future if the project was successful. The cost estimate to fabricate the plow and mount it on a crawler tractor was $25,000.00, a lot of money in the early 1970's for ARS project research and development budgets.

There is another story-behind-the-story on my activities, and the activities of others, to finally come up with the funds. Many individuals wrote letters and voiced support for my proposal to fabricate and test the new plow, but I was not aware of their behind-the-scene efforts at the time. Many years later when office files for the old Soil and Water Conservation Research Division were cleaned out,[3] I received copies of letters that were written on my behalf to support proposals that had been made. One letter was written by Dr. Glenn O. Schwab, my major professor in the Agricultural Engineering Dept. at The Ohio State University, who wrote to ARS administrators expressing that he could not understand why they did not support me and my research better. Another was a letter written by Dr. van Schilfgaarde to my Corn Belt Branch Chief, Dr. Van Doren, requesting that he consider providing additional funding for my special drainage plow project. I was not aware until after reading Dr. van Schilfgaarde's letter to Dr. Van Doren many years later just how powerful the Branch Offices were in budget matters. I had directed my requests for extra funds mostly to Dr. Wadleigh, our Division Director, but only after asking Dr. Van Doren if it was OK. I recall him saying to go right ahead and give it a try.

In August 1969 both Dr. Wadleigh and I were to attend a meeting at MacDonald College in Quebec, Canada, to make invited presentations to the Canadian Society of Agricultural Engineers (CSAE). Dr. Wadleigh's presentation was to be a key note type presentation (as I recall) on the benefits of long-term field research. My presentation was to report on the design of the large draintube plow for installing corrugated plastic drain tubing. The deep plow design had been completed by mid-year 1969. A few weeks before we were to travel to the meeting, Dr. Wadleigh called by phone to inform me that USDA had just declared Canada foreign travel and

[3] The clean out of the old SWCRD files was during 1972 when ARS was reorganized from the research discipline Divisions structure in Beltsville, MD into regional Areas structure with each Area responsible for all research discipline needs within the multiple states assigned in each Area.

only Administrators would be authorized to travel there or to attend meetings at Government expense. When I started to express my disappointment, Dr. Wadleigh interrupted me and said he had worked out a way that would allow me to attend the meeting too. He outlined to me the wording to put on the official request for travel approval. Since the communication from the CSAE group inviting both Dr. Wadleigh's and my presentations at their agricultural engineering meeting had been sent to the Soil and Water Conservation Division headquarters' office of ARS, the acceptance and approval for both presentations were given and communicated back from Dr. Wadleigh's office and not my office. Subsequently Dr. Wadleigh made the request that I attend the meeting with him and make the presentation on the drainage plow design. Thus, Dr. Wadleigh's and my presentations were both contributions from the SWCR Division of ARS in Beltsville, MD (i.e., Headquarters). Dr. Wadleigh had one other request for assistance from me on the trip, and that was for me to stop for a brief consultation visit with Joe Bornstein, an ARS agricultural engineer stationed in Burlington, VT. I had known Joe for nearly 10 years (since my early days in ARS). Dr. Wadleigh instructed me to provide technical advice to Joe on a new subsurface drainage project he was assigned to conduct in VT. After the stop-over in VT, I was to travel on to Quebec and attend the meeting with him so that I could present my invited paper.

Dr. Wadleigh made his presentation on the CASAE program first and it was on a 100-year old field experiment growing wheat that was conducted in the U.K. For some reason I recall key details of his excellent presentation better than my own talk. My presentation (an invited talk) followed next on the program and was on the **new plow design**, not its performance, because the plow had not yet been fabricated. My presentation included slides made of several engineering drawings to illustrate both an overview and details for special features of the plow's design. During the question & answer session after my talk a contactor asked when I was going to build the plow so it could be tested. I replied that a request had been made to ARS for the extra funds to have the plow fabricated by a commercial machine shop in accordance with the design drawings, but I had not received the needed funding at that time. The same contactor then asked who should they address the matter with about the funding, and I indicated that perhaps Dr. Wadleigh could provide an update on the matter. (*I hesitated a moment in my response because it was putting Dr. Wadleigh on the spot, but that was my reply to the follow-up question.*) So, the contractor immediately asked Dr. Wadleigh if he could provide an update for the group. Dr. Wadleigh stepped back to the front of the conference room and indicated to the group that he had not intended to make any public announcement about the matter at the meeting, but since the question was asked he said that his intentions were to inform Jim following the meeting that the Agency had come up with the additional funding needed to have the new plow fabricated by a commercial machine shop for testing. That was the first I knew or had heard that I might be getting the additional funds that had been requested to build the new plow. Dr. Wadleigh turned to me and commented that we should talk about this after the meeting, and motioned to the back of the conference hall. That "*talk about this*" by Dr. Wadleigh is another mini-story that I will never forget. The talk with Dr. Wadleigh was actually a lecture (or story) he gave me about 'Jimmy', a backup quarterback on a football team who had been pestering his coach all season long, asking that he be allowed to carry the ball. In the final game of the football season the first-string quarterback was knocked out on the 1-yard line short of making a winning touchdown. The coach looked over the bench and did not see anyone with any ball handing experience, except Jimmy in practice sessions. So, he finally handed Jimmy the ball with the caution, "You have been wanting the ball all season long, so here it is, but God help you if you drop it." (*The*

$25,000 football in my mind.) I don't remember in the story whether a touchdown was made on that final play, but I think a winning touchdown was made in the story. The follow-up to this lecture a few years later has a happy ending, and it is described in Addendum-1 included in the Appendix to this story. Upon returning to Columbus, Ohio, our ARS team immediately began to help me write up the contract with an industry shop to fabricate the new ARS Draintube Plow. The bidding process for the construction contract was handled by the ARS Headquarter Office in Beltsville, MD and our ARS Business Office located in Fort Washington, PA; we did provide the names of some firms who had expressed an interest in the drainage plow fabrication project.

Contract for Fabricating New Draintube Plow:
The contract to fabricate the new Draintube Plow was awarded in the summer of 1970 to Process Equipment Co. in Tipp City, Ohio (near Dayton, OH). The contract price was $21,900 for construction, mounting, and initial field testing. The Laserplane System for the plow was handled under a separate purchase contract. Process Equipment Co. was the parent company that founded Laserplane Corp. only about three years before. The Laserplane Corp. offices were located about 3 miles west of the Process Equipment fabrication plant.

A key clause in the USDA-ARS contract stated that when fabrication of the plow had progressed to the point that it was only about three months from being ready to mount it on a D-8 Caterpillar Tractor for initial testing, that Process Equipment was to notify ARS so arrangements could be made to have a D-8 tractor shipped to their fabrication plant for mounting the plow. Even prior to awarding the fabrication contract, a formal request was placed for a D-8 Caterpillar that might become available from Army or Air Force Military Surplus Property. ARS Headquarters had arranged for our Research Location in Columbus, OH, and naming me (Jim Fouss) as the contact person, to be listed as the Number 2 priority in the U.S. for the first D-8 CAT to become available on military surplus. Only other military units were at a higher priority (i.e., #1). But as luck or events would have it, we received the notice of the need for the D-8 CAT from Process Equipment, but we did not have a tractor yet or even any hints that one would be available soon. I recall talking to Dr. van Schilfgaarde on the phone and telling him that I was in trouble on the contract because we had not been able to find a D-8 on military surplus. Then I related to him that there might be a way of obtaining a tractor for use in conducting initial testing and perhaps some field trials, but I would have to check with Mr. John L. ("Jack") Diamond (an agricultural engineer) at Caterpillar Tractor Co. to see if perhaps the company could loan a tractor for our use a short period of time. Dr. van Schilfgaarde gave me the go ahead to call Jack and find out. [*Jack had been an industry cooperator on the plowed-in plastic drainage pipe research project since the late 1950's, before I was employed at Ohio State in 1960 to take over the project. Jack maintained contact with me after I was assigned to the project and also during the time when we were designing the new large drainage plow.*] When I placed the call to Jack he was already aware (*it seemed to me*) of the progress on the new plow construction, and when I told him about my problem, he asked what did I need? I replied that we needed a "*super*" D-7 or a D-8 CAT that could be shipped to Process Equipment in time for mounting the new Draintube Plow. He asked me to give him a little time, and he called me back in only about two or three hours and reported that he had found a D-8H CAT that we could use for awhile (*it was from the Caterpillar Proving Grounds in Peoria, IL*). Jack asked exactly where we wanted it shipped to at the Process Equipment facilities. He agreed to ship the tractor to Process Equipment at Caterpillar's expense. All communications for loan of the D-8H were via phone, and nothing official was written down.

Concurrent Modeling and Computer Simulation of Drainage Plow-Laserplane Dynamics:
Concurrent with the fabrication of the new draintube plow, a mathematical model was derived to describe the dynamic response of the plow, namely, the response or change of plowing depth with hitch point elevation changes. This model was programmed on an electronic analog computer to simulate the operation of the draintube plow. The Laserplane automatic control system was also modeled and simulated on the computer in combination with the plow. This analysis work was a part of my Ph.D. research project and is fully documented in my dissertation.[4] The combined plow-control system simulations provided a method to study and determine the optimum adjustments for automatic depth and grade control at various simulated ground surface conditions and at different installation ground speeds. Those simulation studies also provided an excellent means of determining the optimum position for mounting the Laserplane Receive Unit on the Plow beam (frame) to insure achieving the best depth and grade-control accuracy. The plow model and simulations were checked by conducting field tests with the research prototype plow and good agreement was found. Resulting from this work was the development of field testing procedures which identify and determine magnitudes of principal operational parameters of a draintube plow. These same parameters were necessary to effect an accurate simulation of the plow on the computer.

Draintube Plow initial testing and field demonstrations:
After the D-8H Cat tractor arrived at Process Equipment and mounting of the plow was completed, I conducted the initial field testing on a Saturday morning in a field close to the Process Equipment fabrication plant. The initial testing showed the plow depth and grade could be easily controlled with its "floating-beam" principal of operation, and in my evaluation of its performance I considered it excellent. With this successful initial testing, a payment of one-half the cost of the fabrication contract was made by ARS to Process Equipment Co., and the tractor and mounted plow were returned to the fabrication plant to complete the construction project. The Laserplane Grade-Control System was installed on the tractor and plow for a total cost of $10,000, however only about $5,400 remained available from our ARS project budget that Fiscal Year to provide all on-board or mounted components of the Laserplane System on the plow and tractor. The Laserplane transmitter ("command post") was loaned to ARS by the Laserplane Corp. for conducting field trials. Finishing touches were added to the tractor and plow by Process Equipment. One key finishing touch was the bright Chinese Red paint that I selected to give good contrast between the Yellow color of the CAT and the mounted plow frame. The many pictures taken of the plow at field demonstrations resulted in its being called the "Big Red Plow" by those who seen it in operation and took hundreds of pictures.

During the period when the plow was being mounted on the tractor and the initial testing conducted. I again called Jack at Caterpillar and thanked him for his rapid response and cooperative assistance on the project. I asked Jack about what did he have to promise to some administrator at Caterpillar in order to loan the tractor to us. He admitted that there was a bit of a "catch." He had agreed with a Caterpillar administrator that we could demonstrate the new drainage plow, mounted on the D-8H CAT, installing corrugated plastic drain tubing with Laserplane Grade-Control at a Caterpillar sponsored field demonstration and equipment show to

[4] Fouss, James L. 1971. Dynamic Response of Automatically Controlled Mole-Drain Plow. Ph.D. dissertation, Department of Agricultural Engineering, The Ohio State University, Columbus, OH; 133 pp., Mar. 1971.

be held near Monticello, IL in mid-August 1971. I agreed that we should be ready to do that by that time, but we would need help because my technician was tied up on his own research work for an advanced degree at Ohio State, and we may not have the funds for shipping the equipment, etc. But, Jack responded that Caterpillar would foot the bill for all freight, etc., and would provide the field crew to help during the field demonstration. In fact, Jack himself helped in the field, as did the Chairman of the Board for Laserplane Corp., Mr. Robert Studebaker.

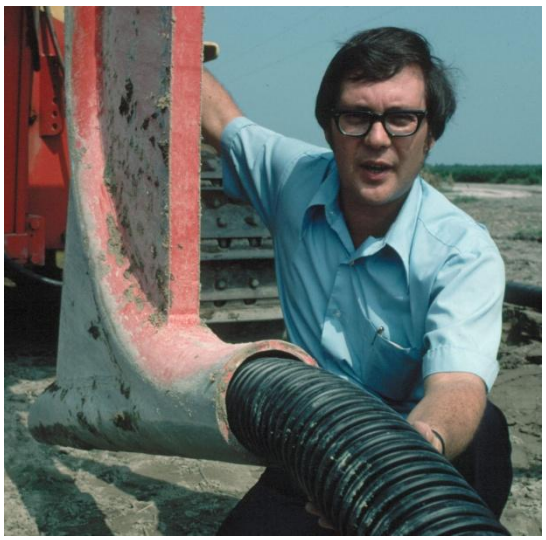
Caterpillar sponsored Drainage Field Day
Monticello, IL; August 1971.

Jack Diamond (CAT), Jim Fouss (ARS), and
Bob Studebaker (Process Equip./Laserplane)

The Cat field demonstration was a very successful event. It was also a very memorable event for my entire family as we took our travel trailer and camped near the field demonstration site and my wife and the kids stayed in the field and helped out during the field demonstration of the new drainage plow. The pictures below show my wife, Judy, painting numbers (in feet) on the back of the plow blade to display how deep we installed the corrugated tubing. Several contactors kept asking how deep we were going, so we fixed it!! With the plow out of the ground, I explained the combination plow-blade and tube-feeder boot design. I, *of course*, operated the plow myself, as no one else was yet trusted to do it (ha), or at least no one else at the demonstration site had prior experience on the plow. My limited, but adequate, experience operating the plow was only

Judy painting plowing depth in FT. on plow blade for contractor's info

Plow Starter Trench at Main



Jim explains the Plow-Blade Tube-Feeder for 4-in. dia. corrugated plastic draintube

during the initial field test trials after the plow was first mounted on the Caterpillar tractor, and again after the Laserplane control system was installed. As a final checkout of the plow's performance I installed about 500-ft. of corrugated plastic drain tubing. The construction contract for the new plow was completed to my satisfaction and the final payment to Process Equipment was made. This was all done about a month before the equipment was moved from Ohio to Illinois for the first field demonstration.

We successfully demonstrated the plow-in installation of about 3,000 feet of drainage tubing per hour during the CAT field demonstration, and we were asked on the third day to slow down or we would run out of field space for the field demonstration. A truly successful field day and it exceeded the expectations of the Caterpillar sponsors, in large part due to our participation in it.

Second Field Demonstration at the Ohio State Farm Science Review:
Immediately after shipping the plow to Ohio State, it was setup again for another field demonstration at the September 1971 Ohio State Farm Science Review. The original commercial Laserplane system on a wheel-type tile trenching machine had been demonstrated at the 1968 Farm Science Review held on the same site near the OSU Airport. A relatively new Zor Plow (similar in design to the U.K. Badger research plow) that was manufactured and sold in Canada was equipped with a Laserplane system and shipped to Ohio State for demonstrating at the field day too. The Zor Plow was mounted on an Allis-Chalmers crawler tractor, and it became apparent that the operator was trying to outrun the ARS Plow during the field demonstration. On the second day of the field demonstration, Ron Reeve (ARS Research Investigation Leader in our office at OSU) wanted to learn how to operate the tractor and ARS plow. He asked me to sit with him on the tractor while we installed one drainline. When the Zor Plow operator noted that I was not operating the plow myself, but had allowed Ron to sit in the tractor seat, he decided that would be a good time to race us when installing a drain. Ron was operating the plow a bit slower than I had been, and when he noted that the Zor Plow was going to overtake and pass him as he was laying the adjacent drainline, he asked that I please take over the tractor seat. We switched

Drainage contractors, farmers, and drainage industry representatives observing the ARS Big Red Plow installing corrugated plastic drain tubing at 1971 OSU Farm Science Review

places and I speeded the tractor up some to just barely stay ahead of the Zor Plow. I expressed to Ron that we would limit our ground speed to about 150 ft./min. to insure good grade-control accuracy, even if the Zor Plow began traveling faster than that. Our earlier test results had shown only fair to poor grade control accuracy at ground speeds faster than the 150 ft./min. It was apparent that the Zor operator was going to pass us when he blew the engine on the AC crawler. As a result, the Allis blown engine also blew the race in which we did not want to participate.
The number of drainage contractors at the Ohio State Farm Science Review in 1971 probably numbered close to 100, and there were several hundred farmers who viewed the plow in operation. The contractors and farmers would follow along with the plow as the installation of each drainline lateral was begun, but at the high ground speed none of them kept up for the entire length of the 1,000 ft. drain lines that were installed. At this field show we also installed about 3,000 linear feet per hour, or 3 drainlines per hour. We nearly ran out of field during the week of the Farm Science Review, and likely would have if the Zor Plow Allis-Chalmers tractor had not blown its engine. It was another successful field demonstration of the ARS Draintube Plow's performance with Laserplane grade-control.

The story does not end here, however, as there is one more chapter regarding the Cat D-8H and its delayed return to the Caterpillar Tractor Co. Proving Grounds in Peoria, Illinois.

Follow-Up Field Testing of Laser Receiver Position and Grade-Control Accuracy:
Following the Ohio State Farm Science Review we experienced an extended period when it rained almost every day and we could not return to the Farm Science Review site to complete planned final field testing of the plow. The extended rainfall delayed our returning the borrowed D-8H to the Caterpillar Tractor Co. in Peoria, IL. The Caterpillar Co. administrative office did make an inquiry soon after the Farm Science Review about when we would be returning the tractor to Peoria. I called Jack Diamond about the inquiry and he explained to the administrative staff that the rainy weather was delaying our follow-up testing that Caterpillar was also interested in, and that we would return the tractor just as soon as the weather improved and the few additional tests planned were completed.

We finally got a break in the weather and in a 3-day period, with Norm Fausey's and Ron Reeve's help, we were able to complete the few field tests really needed. Performance of the ARS plow was studied and evaluated in those specific field tests at the Ohio State demonstration site. The results indicated the new plow controlled with the Laserplane system could install the corrugated drain tubing quite accurately to specified depth and grade. Some limited testing was done for different mounting positions of the Laserplane Receiver Unit on the floating-beam of the plow to determine the effect on grade-control accuracy. Unfortunately, many of the detailed field data collected during those specific tests were misplaced or lost in my transfer from Ohio to South Carolina several months later. Some summary results were available and subsequently reported in technical papers presented and published on the plow's performance. Additional field testing for grade-control accuracy was conducted a few years later when the plow was mounted on another Caterpillar tractor, as discussed in a following section of this story.

After the follow-up testing of the plow's performance was completed at the Ohio State site, the plow was removed from the tractor and arrangements were made for a low-boy trailer to haul the tractor back to Peoria. Once the tractor arrived back at the Caterpillar Proving Grounds in Peoria,

Jack called to inform me that it had arrived just fine. Again, I thanked Jack for all his help on the project and especially for sponsoring the successful demonstration at Monticello, IL. I extended a special thanks to Jack for his arranging that we could keep the plow long enough for the second demonstration at the Ohio State Farm Science Review and the special follow-up field testing.

That is the end of the part of the story concerning the borrowed Caterpillar tractor used for the initial field trials and demonstrations, but the story doesn't end here for the ARS Big Red Plow.

The field testing and evaluation procedures developed while we had the borrowed D-8H CAT were used in later studies of the new plow's performance. However, a sufficient number of field tests could not be conducted to fully evaluate the Laserplane controlled performance of the ARS Big Red Plow before the loaned Caterpillar tractor had to be returned in October 1971 to the CAT Proving Grounds. As noted above, additional field testing for grade-control accuracy was conducted a few years later when the ARS Big Red Plow was mounted on another Caterpillar tractor, as discussed in a following section of the story.

Initial Loan of the ARS Plow and Laserplane Control System:
The draintube plow and Laserplane grade control system were loaned to the U. S. Bureau of Reclamation, headquartered in Denver, Colorado in mid-1972 for the purpose of conducting subsurface drainage trials in Kansas. The Bureau arranged for the rental of a D-8H Caterpillar tractor on which the plow and laser equipment were mounted. I was not available to assist the Bureau in that project because it occurred at the same time I was transferring from Columbus, OH to the ARS Research Center in Florence, SC to continue my research career. Fortunately, Ron Reeve in my office at Columbus was available to assist and advise the Bureau on the plow's operation in Kansas. For the Bureau project, corrugated plastic drainage tubing of 4-in. diameter, with and without nylon filter wrapping around the tube, was installed to evaluate drainage outflow. The test drains were placed in a grassed waterway area where excess water frequently prevented grass cover from growing. The trial was also designed to evaluate the compaction of soil around the cavity (mole channel) formed by the point of the draintube plow blade. However, a direct comparison with other installation methods, such as a high-speed trenching machine, was not made in the trial installation by the Bureau.

Next Chapter for Draintube Plow in ARS:
Finally in 1973 a D-7E Caterpillar tractor with hydraulically controlled bulldozer blade was obtained from Army Surplus and it was shipped to Process Equipment Co. The D-7E was a smaller (shorter) tractor than the D-8H, therefore the draft-beam links on the Draintube Plow were too long making the plow's blade trail too far behind the tractor. I re-designed the draft-beams, removing a 3-foot section from their length, and had the sections welded back together. The revised plow along with the Laserplane grade-control system was then mounted on the D-7E and shipped by rail freight to Florence, SC where I was stationed.

Grade-control accuracy tests were conducted in 1974 for the shorter floating-beam plow mounted on the D-7E Cat. The results of those grade-control accuracy tests were very good and were published in the **Drainage Contractor** magazine (a 1978 issue, printed in Ontario, Canada). Those field test results are included in the "*story behind the story*" on the research and development for the laser-beam grade-control system. New subsurface drainage and water-table

control projects were installed with the ARS Plow at the Florence, SC ARS station in 1974 and 1975. Tests were also conducted with the Laserplane Receiver mounted on top of the bulldozer blade to determine how accurately a small land area could be bulldozed and graded. The Laserplane controlled dozer blade was fairly accurate in doing land grading only when the ground speed was quite slow.

ARS Draintube Plow with Laserplane Automatic Depth & Grade-Control System Mounted on a D-7E CAT Installing 4-in. dia. Corrugated-Wall Plastic Draintube.

After I left Florence in mid-1976 (*to what I call my 6-year Sabbatical Leave to Industry, at Hancor, Inc. in Findlay, OH*), a request was made to ship the plow to Baton Rouge, LA for installing subsurface drainage experiments in sugarcane cropland. After a few years there it was shipped to Fresno, CA for drainage installations in irrigated cropland. For both of the moves of the plow from Florence to Baton Rouge and then onto Fresno, I was called by someone in ARS (cannot remember who) and I was asked if it was "OK" to move and loan the equipment to others in ARS. I was no longer employed in ARS on either occasion, but my name was somehow attached to the tractor-plow ARS Property as the contact person. My "OK" for the loan was given, of course (ha). I visited the ARS location in Fresno during the late 1970s and again operated the tractor and plow to check it out, and found that they were taking reasonably good care of the tractor and plow. I understand that requests for a loan of the ARS Plow were also made by the ARS Units in Florida and Oregon, but those requests were evidently not approved.

When I returned to ARS employment in mid-1982 at Baton Rouge, LA, the plow was again shipped by truck to Baton Rouge for my continued use. I was surprised that the Mid South Area

Director's office paid the $5,000 freight bill to have it hauled from Fresno, CA to Baton Rouge. I think he may have been told to do that by the ARS National Program Staff in Beltsville, but I never knew for sure. Our ARS Team in Baton Rouge used the plow to install various drainage experiments on sugarcane and corn/soybean cropland over the next several years. I modified the ARS plow blade by adding a soil "lifting-plane" similar to my re-design of a Hoes Plow (mfg. in W. Germany) that I had purchased during my research and development work at Hancor, Inc. I wrote and published an ASAE Paper on the re-designed blade for the Hoes Plow and "floating" draintube feeder attachment behind the blade. When the founder and owner of the Hoes Plow Co. in W. Germany read this publication, he traveled to the U.S. and visited with me in Ohio during 1978. Mr. Hoes asked me why I welded on his plow. At first I was taken back a bit by his direct question, and almost laughed about the question since I had purchased the plow, but I refrained from laughing as it would not have been polite. I explained to Mr. Hoes my engineering reason for the soil-lifting plane design change on the plow blade was to reduce the draft requirements about 30% in a medium clay soil. I later learned that upon his return to W. Germany the soil-lifting plane design on the plow blade was adopted for their future Hoes Plows.

All testing and anticipated research uses for the ARS Plow were completed by around 1996. Consideration was given to leasing or donating the ARS Plow to interested Soil and Water Conservation Districts in the southern U.S., but arrangements could not be made to do that. An attempt was made to donate the Caterpillar tractor and mounted ARS Draintube Plow with the Laserplane System to the American Sugar Cane League for use by Louisiana sugarcane growers, but the effort was not successful because of limited interest by the League. Thus, the plow was removed from the Caterpillar tractor and the plow was sold for scrap steel (*it was made of high-strength T-1 steel, which was 4 times stronger than regular structural steel*). The D-7E Cat bulldozer was donated by ARS to the Louisiana Agricultural Experiment Station. The Cat remained available for local ARS use whenever needed (it was still a great bulldozer), and the LA Exp. Sta. shop staff maintained it in very good condition.

When my decision to get rid of the ARS Plow was approved by ARS, I announced and discussed it beforehand at one of my Location Unit staff meetings. Sam Rogers (*who had retired by that time*) attended the staff meeting just to keep up with our activities. After my announcement, Sam stood up and made the statement, "Oh Lord, the World is coming to an end! Jim is getting rid of his Plow!" End of story for the Big Red Plow development phase of the ARS drainage innovation project.

Wrap-Up Discussion on Drainage Plow Development Project:
Industrial and contractor interest in the design of a new ARS draintube plow did not increase as much as anticipated earlier, probably because of the agricultural related economic downturn that was beginning to occur in the U.S. during the latter half of the 1970s. One additional plow, similar to the ARS large plow design, was manufactured by the Process Equipment Company for a contractor in Ohio. That plow operated with the same principle in the field, however, in transport position it could be moved like a semitrailer pulled behind a truck.

In spite of the lack of interest by U.S. firms, the development of new designs for drainage plows continued in England, Europe, The Netherlands, and Canada. By the late 1970s and early 1980s several new drainage plows were available in the U.S., Canada, England, The Netherlands, and

throughout Europe. All of the new plows that became available (e.g., Hoes in W. Germany, Badger in England, Krac in Canada, Steiger in Canada, Zor in Canada, Barth-Hollandrain in The Netherlands, and more recently Inter-Drain in The Netherlands, Bron in Canada, and Wolfe in Canada) were equipped with Laserplane, or RTK-GPS, type of depth and grade control systems. It appeared that the mounting positions for the laser, or RTK-GPS, receiver units on the foreign plows were close to the optimum position guidelines established in the ARS research for the optimum Laserplane receiver unit mounting position on the ARS Draintube Plow. The foreign activity in drainage plow design and production still did not create interest by U.S. firms by the early 1980's into the 1990's for developing a design of a drainage plow manufactured in the U.S. The foreign plows have satisfied the global market demand, and for the most part have been good performing drainage plows.

What Might Have Been Wrap-Up Comment by the Author:

As I completed writing this story about the development of the ARS Big Red Plow and its impact on the innovation of subsurface drainage methods, one unresolved matter came to mind. It occurred to me that if we had been fortunate enough to have acquired a D-8H Caterpillar tractor from U.S. Military surplus property in time such that we would not have needed to borrow a tractor from the Caterpillar Tractor Co. for the early field trials and demonstrations, some key developments in the plow's design might have been very different. If we could have had our own Caterpillar tractor, then I believe that I might have been able to convenience Mr. Edminster that the modification I had in mind to locate the plow hitch point behind the diesel engine and near the center of gravity of the crawler tractor had some important engineering advantages. That hitch point location would have provided some positive engineering design features, namely: (a) more dynamic stability for the crawler tractor in heavy draft conditions; (b) a significantly narrower plow linkage configuration without the problem of excessive width when transporting from job to job; (c) it would have been a plow design closer to possible production prototype, and thus (d) a U.S. manufacturer might have given the design favorable consideration for production and sale. The design would have required relocating the tractor's diesel fuel tank, the tractor operator's seat, and the tractor and hydraulic operational controls. The plow's design may in fact have come close to the design of the Hoes drainage plow manufactured a few years later in W. Germany. From an engineering standpoint the design of the total system including the tractor, plow, and Laserplane control were tied together dynamically in an integrated functional system for optimum performance to install subsurface corrugated plastic drain tubing.

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JLFouss; 06/15/2015

APPENDIX

The following side-stories have been added about special events, communications, encounters, and discussions that occurred throughout the plow design, testing, demonstration, and reporting phases. The separate events discussed in these side-stories were not covered in the main text above, because of the need to link the discussions about each event with later events not yet covered in the story. Placing the side-stories here will hopefully make it much clearer to the reader on how each event fits in with the overall story about the ARS Big Red Plow. /*Jim Fouss*/

Addendum-1:

This follow-up mini-story covers one-on-one discussions with Dr. Jan van Schilfgaarde and Dr. Cecil H. Wadleigh while I was attending ARS meetings in Beltsville, MD in the spring of 1972, prior to my transfer to Florence, SC. I stopped into Dr. van Schilfgaarde's office to update him on my plans for moving to Florence, as he was the administrator who had asked me to consider transferring to Florence because my expertise in drainage was needed there. Prior to my visit, Dr. van Schilfgaarde had been promoted to the Director of the Soil and Water Conservation Research Division, as Dr. Wadleigh had retired. While I was visiting with Dr. van Schilfgaarde, he informed me that Dr. Wadleigh had indicated he would like to see me the next time I came to Beltsville. Although Dr. Wadleigh had retired from ARS, he continued to work as an official ARS Collaborator for a number of years afterward. An office had been set up for Dr. Wadleigh in the old Soil Science building at Beltsville. Someone on Jan's staff led me back to Dr. Wadleigh's office. We had not seen each other since the 1969 meeting in Canada. Dr. Wadleigh asked me if I recalled the conversation we had after giving our talks at that meeting, and I told him yes, and added that I remembered it quite well. He asked if I recalled the "*football*" story he told me during that discussion, and I again said that I remembered it also well. I further mentioned to him that I had learned that he told similar types of stories to other young ARS engineers and scientists when he was trying to make or emphasize a specific point to them. He acknowledged that yes he was guilty of doing that to several scientists over the years. Then he asked if I recalled what I said after the "football" story. I replied that I did not remember anything that I might have said, but recalled that I was happy about getting the money and probably had something to say as was "normal" with me, and we both laughed. He then related that I reacted much differently than all the other scientists he had told similar type stories too, because I didn't say much of anything afterward. He related that most of the other scientists would typically ask, "And what if I do drop the football?" He added that I just took the ball and ran with it! He seemed very proud of that outcome, and especially I'm sure because the project to build and test the drainage plow worked out so well (*and again I thought, but didn't say it out loud, "thank goodness"*). We chatted on for awhile and then I went back to Dr. van Schilfgaarde's office, and he asked if I got to see and talk with Dr. Wadleigh (*with kind of a grin on his face*). I acknowledged that I did, and then mentioned to him that he evidently knew in advance what the discussion with Dr. Wadleigh would be about. He admitted that he did, and then I asked him, "Well then I'll ask you, what would have happened if the Big Red Plow had not worked?" His reply, with no further follow-up at that time, was simply, "Jim, its best that we not talk about that!" Thus, I knew they had talked about that possibility among the administrators at Beltsville, probably before they provided me with the $25,000 I had requested to have the plow fabricated by industry. Then, a few years later, when both Jan and I were attending an ASAE meeting in Chicago, he decided to tell me the "*rest of the story*," and it went something like the following: He related that the administrative staff in Beltsville had two or three discussions before making the decision to provide me with the requested $25,000, but all of them

were not certain in their minds that the plow would work at the 6-ft. depth I was intending it to install drains. They were especially concerned whether the laser-system could control depth and grade on the drain pipe when installed so fast and deep. One of the administrators had said that maybe the old Indiana drainage contractor was right, that it was a crazy idea. But, since I had been so "cock-sure" (*in Jan's words*) that the engineering design proposed would work in my earlier discussions with them, and in my follow-up writings to them requesting the large amount of funds, that NONE of them wanted to be the one to tell me NO. So, they decided to go ahead and give me the funds requested and hoped for the best. But he then added that it was very good indeed the plow worked. He added his praise on me for just how well the laser-controlled plow worked, and how effective my help was to contractors and the drainage industry in adopting the laser-controlled drainage plow for almost all future drainage installations. It is my belief that soon afterward Jan submitted the paperwork for the USDA-ARS Superior Service Award (called the Silver Medal Award), one the highest honors that are given by ARS and USDA. I was presented the award by the Secretary of Agriculture at a Washington, D.C. ceremony in May 1972. Judy was invited to attend that ceremony with me, and afterward we were invited to the ARS Administrator's office, Mr. T. W. Edminster, the person who had hired me into ARS in 1960. I have a group picture of that occasion in Mr. Edminster's office.

Addendum-2:

An interesting phase of the plow design work, and one that had an equally interesting connection to W. Germany several years later concerning the design of the Hoes Drainage Plow, is covered here. I had conducted an earlier analysis of the draft characteristics for the drainage plow when mounted on a crawler tractor and concluded that it was desirable to position the plow hitch point forward of the rear axle drive on the tractor, even to the point of mounting the hitch as far forward as practical on the crawler chassis. The original tool-bar mounted research plow that I designed had forward hitch points along each side of the crawler tracks. The tool-bar plow was fabricated in the Agr. Engr. shop at Ohio State with the help of my engineering technician, Norm Fausey, and a student employee, Martin V. Cummingham (a great welder). The forward positioned plow hitch was used in the design so that the downward component of the draft for the plow would increase the loading under the crawler tracks, thus improving traction and prevent the tractor from rearing or tipping backwards as occurred for an earlier plow hitched to the drawbar on the gear-box chassis at the rear of the tractor (which is behind the rear axle of the crawler tracks).

Because of the excessive width of the research tool-bar mounted plow, the forward hitch point on the crawler tractor (like a D-7 or D-8 Cat) for the new larger plow was proposed in the tentative design to remove the tractor seat, fuel tank, and operator controls and place them on a side-mounted platform. This design configuration provided a space centered in the tractor and immediately behind the diesel engine to mount the plow hitch point. This design concept would have created a narrow plow frame, rather than the wide tool-bar as used on the research proto-type plow. During this design process for the large plow, the National Program Staff (NPS) and ARS Management Team in Beltsville had evidently remained very aware of the progress we were making with the design development. Before completing the design details for this special hitch point on the crawler, I received a rather specific message from Mr. T. W. Edminster (on one of those Government Memo pad sheets that was one-half page long), that stated I was **not** to modify the design of the Caterpillar Tractor, but was to use it as it came from the factory. I did

not want to give up the forward position for the plow hitch point, so I went to plan #2 for the large plow hitch design. Plan #2 was to use a dual-beam design with one beam on each side of the tractor's engine hood and above the crawler tracks. This provided a narrower design than on the research tool-bar mounted plow. The plow hitch was then designed for mounting on the back-side of a bull-dozer blade (a factory supplied component) on the crawler tractor. It was not as clean a design as I would have liked, but it implemented the forward hitch concept I wanted to retain in the plow's design (for the reasons stated above). In retrospect, it was very good that Mr. Edminster suggested (directed) this, and that I complied, because we were not able to obtain our own tractor from military surplus, and had to borrow one from the Caterpillar Tractor Co. for initial testing and field demonstrations. We probably could not have modified the design of the tractor loaned by the Caterpillar Tractor Co. The reason that I chose not to try and change Mr. Edminster's mind about my original idea for the plow hitch design that would have required modifying the Caterpillar tractor is explained in *footnote*.[5] A related *side-story* about this plow hitch design occurred several years later, probably about 1978 or perhaps 1979 when I was still the Vice President for Research and New Product Development at Hancor, Inc. The Hoes Drainage Plow, developed in W. Germany, became available and immediately popular in the U.S.A. It had a hitch point location immediately behind the turbo-charged and air-cooled diesel engine, in a location similar to what we had proposed for the ARS Draintube Plow design several years before. I happened to meet Mr. Edminster at an ASAE Meeting in Chicago and we discussed the rapid expansion of the laser-controlled drainage plow equipment world-wide for installing corrugated plastic drainage tubing. I asked him if he had seen the W. German Hoes Drainage Plow, and he acknowledged that he had. He further stated that he had noted the plow's hitch location on the tractor, which was similar to what I had proposed several years before. I indicated that the Hoes design appeared to me as one of the better plow designs, and that I had acquired a Hoes Plow for my development research at Hancor, Inc. I related to "Ed" (*as I learned to call him in later years*) that I had modified the design of the Hoes plow blade by adding a front-edge soil-lifting plane (plate) that decreased the draft required to pull the plow by about 30%. This design change made the W. German manufacturer somewhat disgusted with me until I had the opportunity to explain directly to him the reason for the design change on the plow blade. He returned to W. Germany and fabricated future Hoes plows with a similar design that included the soil-lifting plane on the leading edge of the plow blade. I made it a point during that hall-way discussion with Ed in Chicago so long ago not to "*rub it in*" about the plow hitch design feature that I had been effectively told not to use in the late 1960's. Ed and I had great respect for each other I felt, and I did not want that to change. I now wish that I had acknowledged to Ed during the conversation that it was a good thing we did not design and fabricate the plow such that the Caterpillar D-8H borrowed from the Caterpillar Tractor Co. would have required modification in order to mount the plow for testing and field demonstrations.

[5] The reason I did not want to try and explain the large plow hitch design to Mr. Edminster was because in an earlier stage of the drainage equipment development project he had suggested to me that I should not use the laser-beam in the grade-control system, because it was too expensive. At that time, with no other good options in mind, I chose to proceed with adoption of the laser-beam into the proto-type grade-control system assembled and tested on the research proto-type drainage plow. Another "story-behind-the-story" has been written about events and difficulties encountered in the successful development of the Laser-Beam Grade-Control System. Key events in that story are as dramatic as events described above in the Big Red Plow story. The laser system was successful, thank goodness.

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[6] Printed copies or PDF files on a CD (or Flash Drive) for some of these publications have been provided as Reference Sources to The Ohio State University **Drainage Hall of Fame**; Food, Agriculture, & Biological Engineering Department, Columbus, OH; these papers and the Ph.D. dissertation are maintained in the Drainage History Library of the Drainage Hall of Fame.