VARIABLE RATE TECHNOLOGY & ITS APPLICATION

What is Variable Rate Technology?

VRT uses data and automation to apply fertilizer, crop protection products, seeds and even irrigation water at different rates in different locations without a grower having to change application rates or make multiple passes manually.

What is VRA?

VRA is an abbreviation for variable rate application, which is a method of applying varying rates of inputs in appropriate zones throughout a field. The goals of VRA are to maximize profit to its fullest potential, create efficiencies in input application, and ensure sustainability and environmental safety.

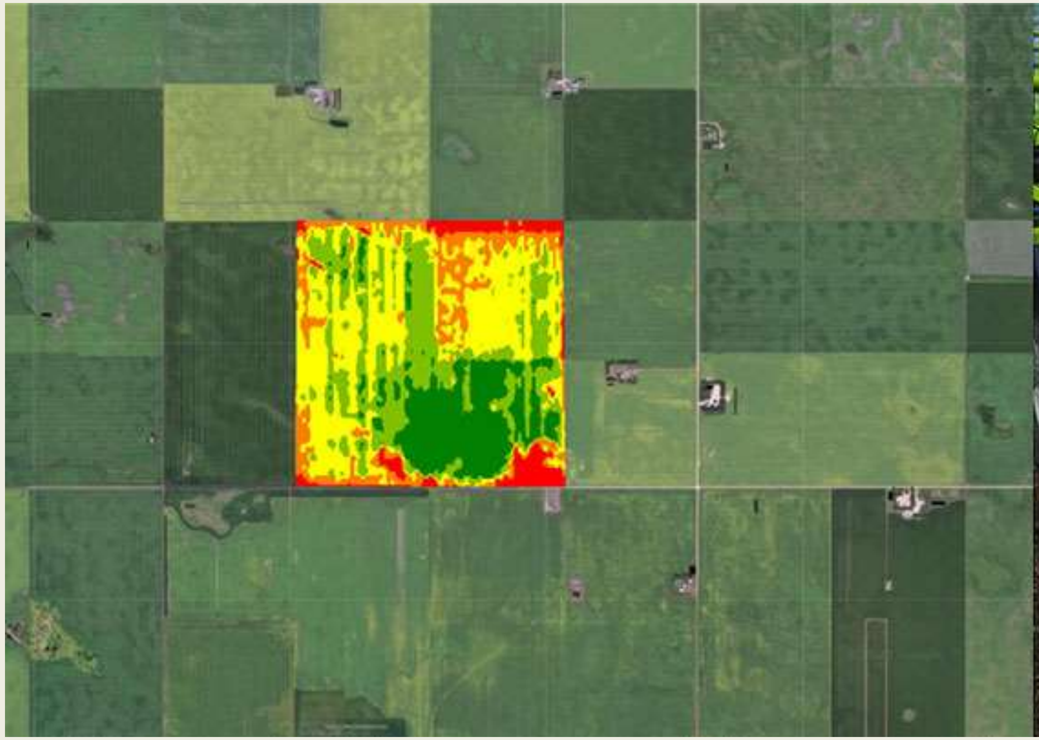
INTRODUCTION

- There are a number of questions that must be answered before establishing a site-specific crop management (SSCM) program. Many of these questions are economic, some are agronomic and environmental, and others are technology-related. This publication is intended to discuss variable-rate devices that are available, while providing an understanding of which technologies might best fit a cropping system and production management strategy.

- Most farmers have practiced a form of variable-rate application (VRA) with a conventional sprayer. A conventional sprayer applies a chemical that is tank-mixed with a carrier (usually water) using spray nozzles and a pressure-regulating valve to provide a desired volumetric application of spray mix at a certain vehicle speed.

- Any change in the boom pressure or vehicle speed from that of the calibration results in an application rate different from the planned rate. Applicators have used this to their advantage at times. For example, when observing an area of heavy weed infestation, the applicator can manually increase the pressure or reduce the speed to apply a higher (but somewhat unknown) rate of herbicide.

VARIABLE RATE TECHNOLOGY



VARIABLE-RATE APPLICATION METHODS

One important technology-related question is: What methods of variable-rate application of fertilizer, lime, weed control, and seed are available? There are a variety of VRA technologies available that can be used with or without a GPS system.

The two basic technologies for VRA are: map-based , sensor-based.

- **Map-based VRA** adjusts the application rate based on an electronic map, also called a prescription map. Using the field position from a GPS receiver and a prescription map of desired rate, the concentration of input is changed as the applicator moves through the field.
- **Sensor-based VRA** requires no map or positioning system. Sensors on the applicator measure soil properties or crop characteristics “on the go.” Based on this continuous stream of information, a control system calculates the input needs of the soil or plants and transfers the information to a controller, which delivers the input to the location measured by the sensor. Because map-based and sensor-based VRA have unique benefits and limitations, some SSCM systems have been developed to take advantage of the benefits of both methods.

MAP BASED VRA

- The map-based method uses maps of previously measured items and can be implemented using a number of different strategies. Crop producers and consultants have crafted strategies for varying inputs based on

  (1) soil type,

  (2) soil color and texture,

  (3) topography (high ground, low ground),

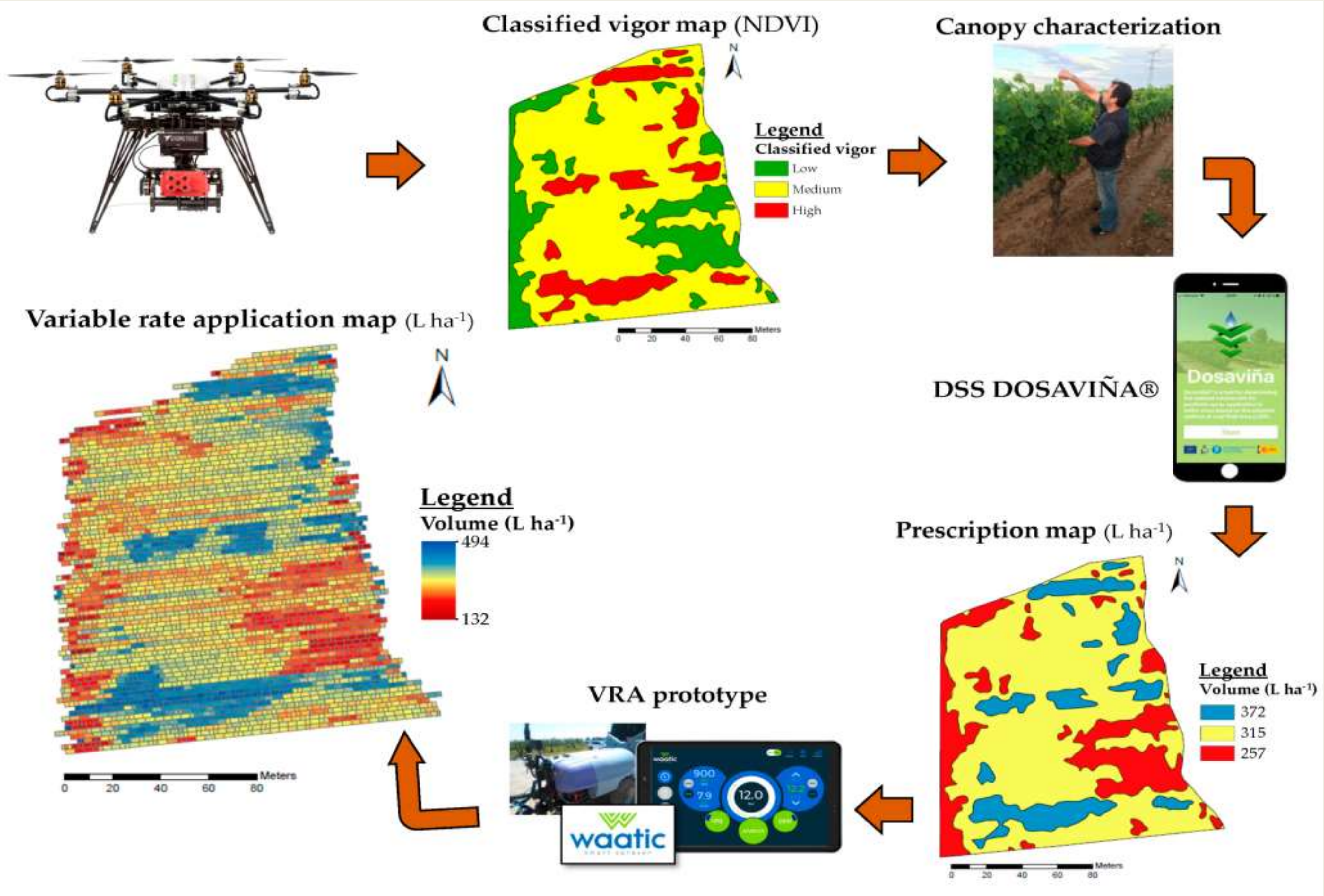
  (4) crop yield,

  (5) field scouting data,

  (6) remotely sensed images, and

  (7) numerous other information sources that can be crop and location-specific.

- Some strategies are based on a single information source while others involve a combination of sources. Regardless of the actual strategy, the user is ultimately in control of the application rate. These systems must have the ability to determine machine location within the field and relate the position to a desired application rate by “reading” the prescription map.



Classified vigor map (NDVI)
Legend
Classified vigor
Low
Medium
High
Meters
0
20
40
60
80
Canopy characterization
DSS DOSAVIÑA®
Dosaviña
Prescription map (L ha-1)
Legend
Volume (L ha-1)
372
315
257
VRA prototype
waatic
Variable rate application map (L ha-1)
Legend
Volume (L ha-1)
494
132
N

For example, to develop a prescription map for nutrient VRA in a particular field, the map-based method could include the following steps:

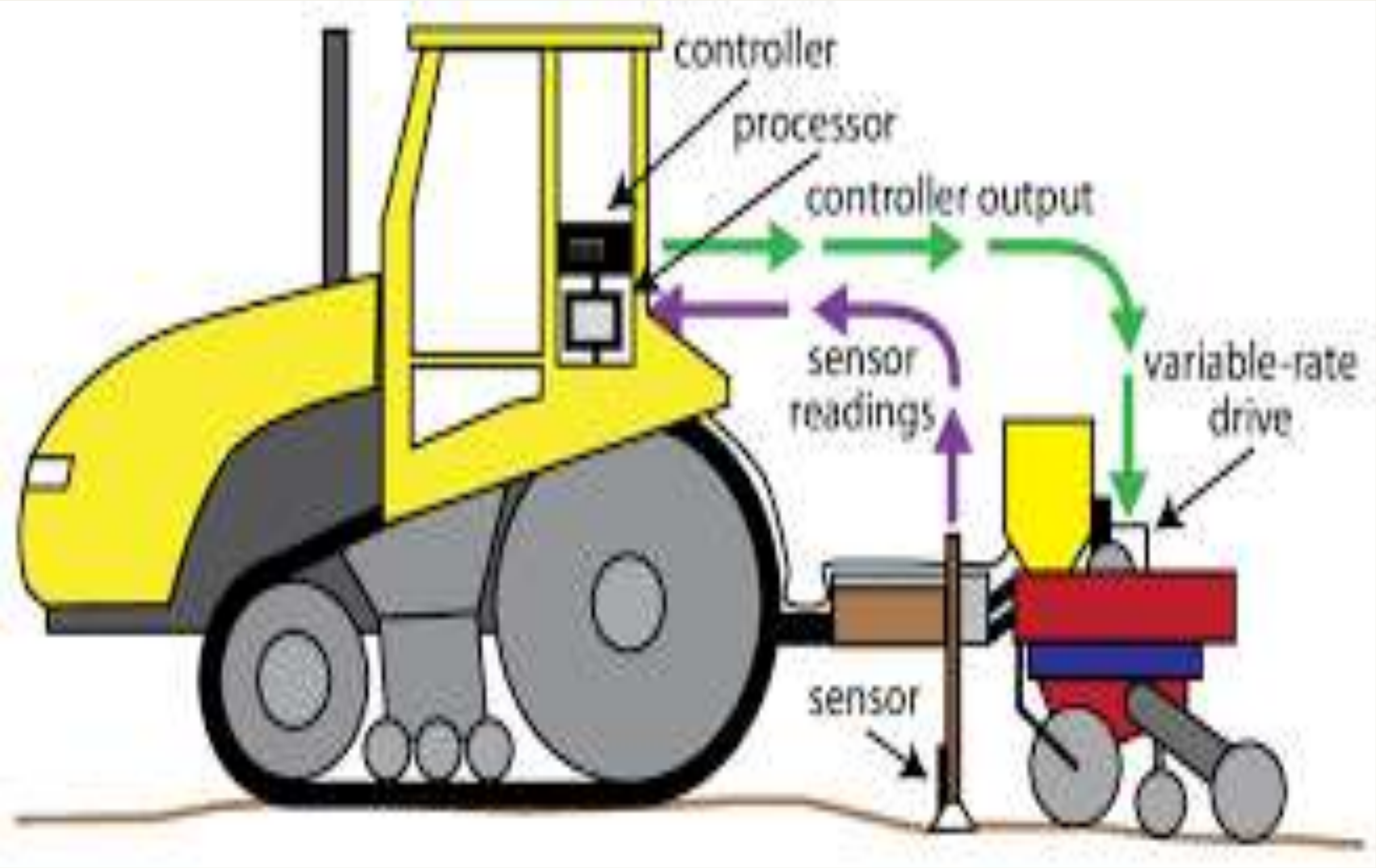
- Perform systematic soil sampling (and lab analysis) for the field.
- Generate site-specific maps of the soil nutrient properties of interest.
- Use an algorithm to develop a site-specific nutrient prescription map.
- Use the prescription map to control a fertilizer variable-rate applicator.

A positioning system is used during the sampling and application steps to record location of the sampling points in the field and to apply the prescribed nutrient rates in the appropriate areas of the field.

SENSOR BASED VRA

The sensor-based method provides the capability to vary the application rate of inputs with no prior mapping or data collection involved. Real-time sensors measure the desired properties — usually soil properties or crop characteristics — while on the go. Measurements made by such a system are then processed and used immediately to control a variable-rate applicator.

The sensor method doesn’t necessarily require the use of a positioning system, nor does it require extensive data analysis prior to making variable-rate applications. However, if the sensor data are recorded and geo-referenced, the information can be used in future site-specific crop management exercises for creating a prescription map for other and future operations, as well as to provide an “as applied” application record for the grower.


controller
processor
controller output
sensor
readings
variable-rate
drive
sensor

SEEDING VRA

- Planters and drills can be made into VRA seeders by adjusting the speed of the seed-metering drive. This will effectively change the plant population.
- VRA seeding is accomplished by separating or disconnecting the planter's seed-meter systems from the ground drive wheel.
- By attaching a motor or gear box (to change speed of the ground wheel input), the seeding rate can be varied on the go. Most of these devices will be matched with a prescription map and can have two or more rates.
- A two-rate scenario may be a system that reduces the seeding rates outside of the reach of a center-pivot irrigation system, while multiple rates may be needed to adjust for soil types (water-holding capacity) and organic matter.

WEED CONTROL VRA

- For map-based weed control VRA systems, some form of “task computer” is required to provide a signal indicating the target rate for the current location. Second, a system for physically changing the application rate to match the current prescribed rate is required.
- Different types of control systems on the market today that are adaptable to VRA.
- 1. Flow-based control of a tank mix.

  2. Chemical-injection-based control, with the subset, chemical-injection control with carrier.

  3. Modulated spraying-nozzle control system.

All these systems evolved out of the desire to automatically match application rates to variations in groundspeed, eliminate much of the error in application that could occur if groundspeeds change from the calibrated setup.

With the application rate managed by an electronic system, the ability to apply variable rates is a logical next step. This requires that the prescribed application rate, or “set point,” be changeable according to the rate prescribed for that location.

FLOW BASED CONTROL SYSTEMS

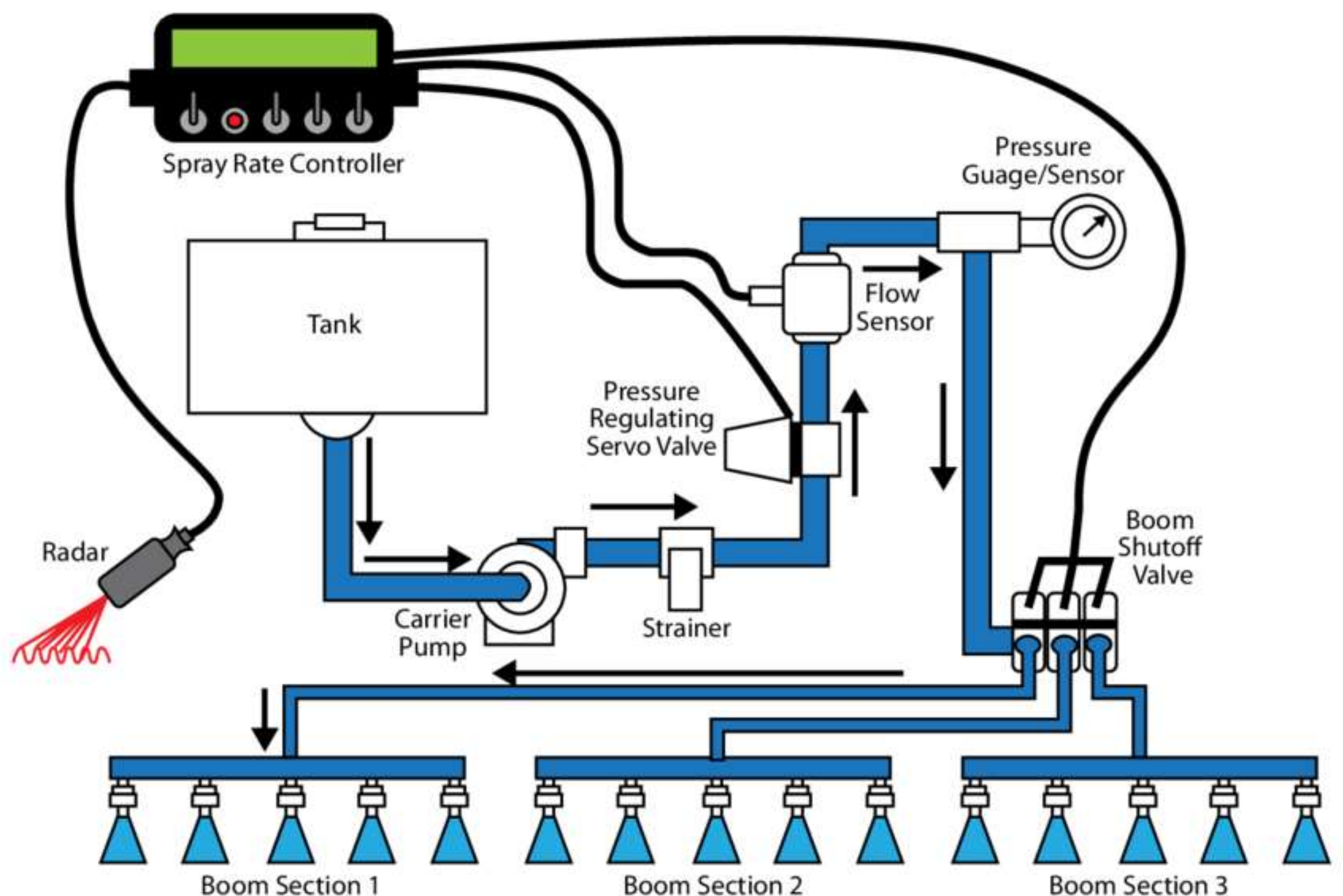
- The flow-based control of a tank mix is the simplest of the three types discussed here. These systems combine a flow meter, a groundspeed sensor, and a controllable valve (servo valve) with an electronic controller to apply the desired rate of the tank mix (figure 4).
- A microprocessor in the console uses information regarding sprayer width and prescribed gallons per acre to calculate the appropriate flow rate (gallons per minute) for the current groundspeed. The servo valve is then opened or closed until the flow-meter measurement matches the calculated flow rate. If a communication link can be established between this controller and a “map system,” a VRA can be made.
- These systems have the advantage of being reasonably simple. They are also able to make rate changes across the boom as quickly as the control system can respond to a new rate command, which is generally quite fast (three to five seconds).

- As with any technology, flow-based controllers have limitations. The flow sensor and servo valve control the flow of tank mix by allowing variable pressure rates to be delivered to the spray nozzles.

- This can result in large changes in spray droplet size and potential problems with drift. Some systems will warn you when the pressure is outside the optimum operating range for the nozzles.

- The operator can adjust vehicle speed to return the pressure to an acceptable range. This is the most widely used system. Its standard operating procedures specify that the operator must mix the chemical in the spray tank with the carrier and will generally have to deal with some leftover tank mix.

- However, this is a relatively simple system that should meet most needs while giving operators the capability of a single herbicide VRA.



Spray Rate Controller
Pressure
Guage/Sensor
Tank
Flow
Sensor
Pressure
Regulating
Servo Valve
Radar
Boom
Shutoff
Valve
Carrier
Pump
Strainer
Boom Section 1
Boom Section 2
Boom Section 3

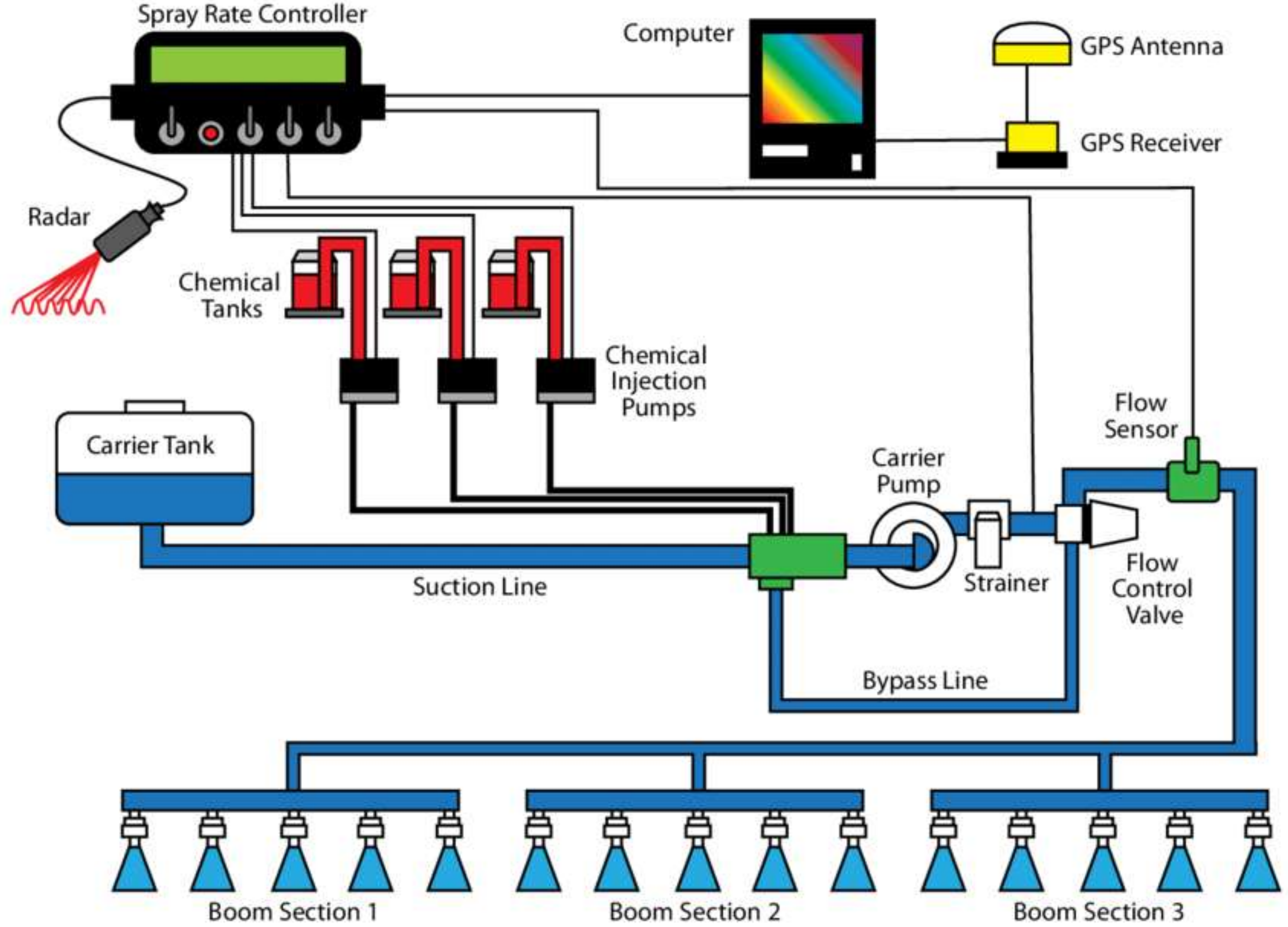
CHEMICAL DIRECT-INJECTION SYSTEMS

- An alternative approach to chemical application and control uses direct injection of the chemical into a stream of water. These systems (figure 5) utilize the controller and a chemical pump to manage the rate of chemical injection rather than the flow rate of a tank mix.

- The flow rate of the carrier (water) is usually constant and the injection rate is varied to accommodate changes in groundspeed or changes in prescribed rate. Again, if the controller has been designed or modified to accept an external command (from a GPS signal and prescription map), the system can be used for VRA.

- Chemical injection eliminates leftover tank mix and reduces chemical exposure during tank mixing. An additional advantage of this system is that the constant flow of carrier can be adjusted to operate the boom nozzles to provide the optimum desirable size and distribution of spray droplets.

- The principal disadvantage for variable-rate control is the long transport delay between the chemical-injection pump and the discharge nozzles at the ends of the boom. The volume within the spray plumbing (hoses and attachments) must be applied before the new rate reaches the nozzles.
- This can cause delays in the rate change and “Christmas tree” patterns of application as the new concentration of chemical works its way out through the boom.
- For example, a simulation of a farmer-owned broadcast sprayer (60-foot boom divided into five sections) indicated that nearly 100 feet of forward travel would occur before a newly prescribed rate would find its way to the end nozzles of that sprayer. However, a properly designed plumbing system and properly matched nozzles can shorten the reaction time. Some control systems will look forward (knowing location and speed) and make the required adjustments. These limitations have led to systems that use both carrier and injection control. All manufacturers would recommend VRA be used in conjunction with carrier control as described below.


Spray Rate Controller
Computer
GPS Antenna
GPS Receiver
Radar
Chemical Tanks
Chemical Injection Pumps
Carrier Tank
Flow Sensor
Carrier Pump
Strainer
Flow Control Valve
Suction Line
Bypass Line
Boom Section 1
Boom Section 2
Boom Section 3

DIRECT CHEMICAL INJECTION WITH DIRECT CONTROL

- Chemical injection with carrier control requires the control system change both the chemical-injection rate and the water-carrier rate to respond to speed or application-rate changes. One control loop manages the injection pump while a second controller operates a servo valve to provide a matching flow of carrier. A perfect system of this type would deliver a mix of constant concentration as if it were coming from a premixed tank.

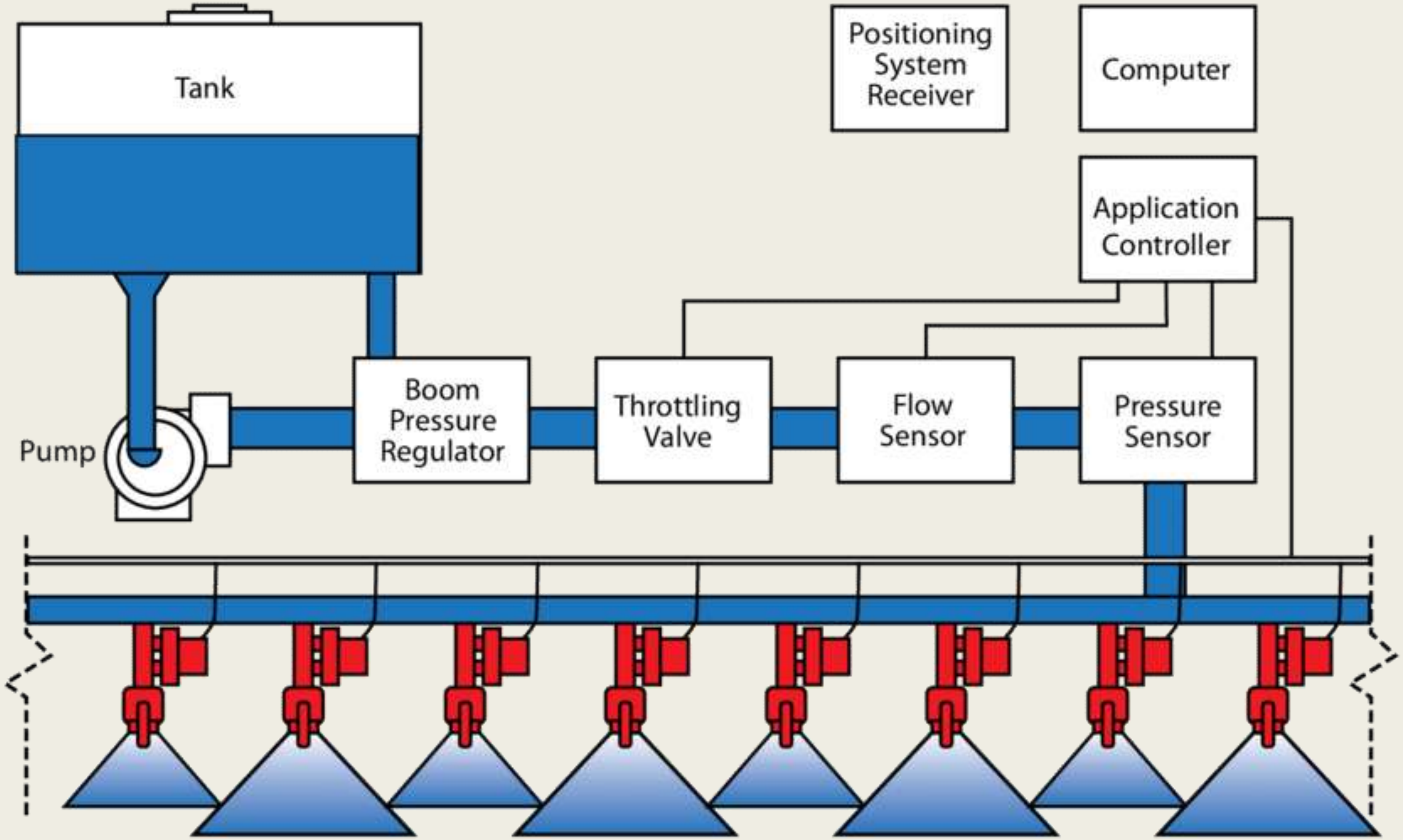
- The system can have many of the advantages of both of the earlier systems. Direct injection of chemicals means that there is no leftover mix to worry about, and the operator is not exposed to chemicals in the process of tank mixing. Changeover from one rate to another occurs as quickly as both chemical and carrier controllers can make the change, which is usually very fast.
- Disadvantages include a more complex system with higher initial cost and the problem of delivering varying amounts of liquid through the spray nozzles as rate change, with the resulting changes in droplet and spray characteristics. If you do a lot of spraying and wish to avoid the hazards of tank mixing, these systems will give you a great deal of control over your spraying operations and offer the capability of VRA of herbicides from a prescription map.

MODULATING SPRAYING NOZZLE CONTROL SYSTEMS

- Modulated spraying-nozzle control (MSNC) systems permit VRA with spray drift control under a wide range of operating conditions. MSNC controls the timing and duration of discharge from nozzles. High-speed valves are used to regulate the amount of time that spray is delivered from conventional nozzles. The systems offer the ability to change flow rate and droplet size distribution on the go. A brief description of the system follows.

- MSNC-equipped sprayers use conventional sprayer nozzle assemblies that work in conjunction with direct acting, in-line solenoid valves. Figure 6 is a schematic of a spraying system that incorporates modulated spraying-nozzle control. The system operates under the direction of a microprocessor and an application controller that responds to signals from flow and pressure sensors.

- The basic concept behind MSNC spraying is to operate each nozzle at full design pressure and flow during periods when a flow control valve is open. The key is to vary the amount of time that the valve stays open to produce variation in the flow rate (thus, application rate) without changing droplet size distribution or spray pattern. A fast-acting, electrical, solenoid-controlled nozzle assembly (figure 7) is mounted directly to a conventional nozzle assembly.



Tank
Positioning System Receiver
Computer
Application Controller
Pump
Boom Pressure Regulator
Throttling Valve
Flow Sensor
Pressure Sensor

- MSNC systems are equipped with solenoids that operate at a frequency of 10 Hz. This means that solenoid position can be cycled between open and closed 10 times per second, as directed by a controller that responds to input from a computer and a set of sensors. A cycle of events (valve open/spray/valve close) takes place in one-tenth of a second.

- In order for MSNC systems to operate most effectively, valve response must be quite rapid. An electrical signal to each valve is used to produce one of two flow conditions: full flow (completely open valve) or zero flow (completely closed valve). The solenoid-operated valves take only about 4 milliseconds (ms) or 0.004 second to respond to an electrical signal.

- Changing valve position from open to closed and back (or vice versa) would take 8 ms during any 0.1-second cycle. In actual practice, this translates into a minimum duty cycle (amount of time the value is open for flow) of about 10 percent and a maximum duty cycle of about 90 percent if the control system is changing valve position during each 0.1-second time period. The MSNC system can also be operated at a full-open (100 percent duty cycle) setting as well.

- Because flow rate from each nozzle is governed by the amount of time (duty cycle) each flow-control valve stays open, the percentage of full, rated, nozzle flow would be equal to the duty cycle expressed as a percentage. This results in a range of flow rates from each nozzle of approximately 9-to-1, although the MSNC systems have been advertised with a more conservative rating of flow-control range at 8-to-1.

- For example, let’s say that a standard nozzle has a rated capacity of 0.8 gpm at a pressure of 40 psi. The MSNC system is very effective at reducing nozzle flow rates while maintaining droplet size distribution and spray pattern characteristics. Therefore, standard procedure/ strategy is to install nozzles that will meet the maximum flow demand in a particular spraying situation.

- The MSNC system is then used to reduce rates as needed. A benefit of using larger nozzles is the reduced likelihood of plugging.

- In addition to controlling nozzle flow rates at a given system pressure, the MSNC system can be operated at reduced pressures to increase droplet size and reduce drift potential in locations and under atmospheric conditions in which drift would likely cause damage. Application rates could be maintained, even as system pressure is lowered, by increasing the amount of time the nozzle remains open during a minute.

- ❖ Opening and closing nozzles as a sprayer travels through the field might appear to be a risky proposition. If a nozzle is held closed, even for an instant, no liquid will be discharged. Surely there will be areas of a field missed during normal operation of the sprayer! This is addressed by using a 1/20-second (1/2-cycle) “phase shift” of adjacent nozzles. When one nozzle is off, the nozzles adjacent to it are on. To increase spraypattern overlap and minimize the effect of the “pulses and pauses” produced at the nozzles, these sprayers are equipped with wide spray-angle nozzles (110-degree angle versus the more-common 80-degree angle).

- ❖ The potential benefits of using a chemical-application system that permits the tailoring of both application rate and droplet-size distribution throughout a field include the ability to:
  - Produce a broader range in flow rates with much more consistent spray characteristics than conventional sprayers.
  - Vary nozzle flow rates and/or travel speeds over a wide range without affecting spray pattern or droplet-size distribution.
  - Vary droplet-size distribution without changing application rate to minimize drift potential near sensitive areas or to increase spray coverage needed for some contact-type products.

MSNC technology can also be used to apply VRA nutrients. While drift control is not a major issue in fertilizer application, the MSNC provides yet another option for applicators wishing to take advantage of site-specific crop management methods

ELECTRONIC BOOM CONTROL

- There are areas of the field that should not have chemicals applied. For example, a grass waterway is a best management practice (BMP) to reduce erosion impacts from a field, but if a nonselective herbicide is sprayed to the area while passing over the section, much damage to the BMP will result.
- By mapping these areas of the field, a boom control can automatically turn the boom (or sections of the boom) on and off to prevent application to selected areas. The controller can also automatically turn the boom section off if the boom section is in a previously applied area (figure 8), eliminating overlaps.
- It also eliminates skips by turning boom sections back on after leaving a previously applied area. If the sprayer goes over an area that has already received an application (figure 8), the controller detects the overlap and shuts off individual sections or nozzles of the implement to prevent the unnecessary usage of additional chemicals.
- When spraying odd-shaped fields, grass waterways, or obstructions in a field, this boom control can have a tremendous benefit. Because an automated boom section-control device requires a capital investment, applicators should weigh the cost of the machine against their potential savings on inputs before purchasing the equipment. However, one Virginia farmer using the technology indicated a 15 percent savings in inputs (crop protection chemicals and liquid fertilizers) due to automatic boom control.