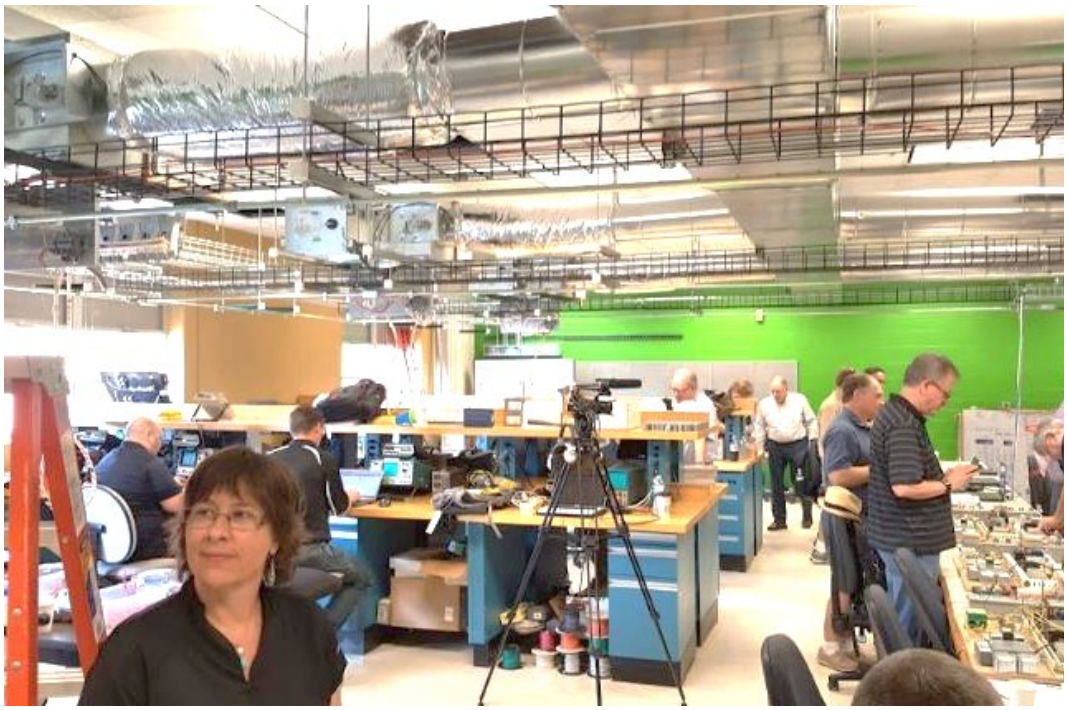
ASSOCIATES OF APPLIED SCIENCE A.A.S. DEGREE

GEORGIA PIEDMONT TECHNICAL COLLEGE
INDUSTRIAL DIVISION

Building Automation Systems- Program Development



National Science Foundation - National Center for Building Technician Education

GEORGIA PIEDMONT TECHNICAL COLLEGE

BEST
Building Efficiency for a Sustainable Tomorrow

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Revised 2025

BUILDING AUTOMATION SYSTEMS

Program Documentation

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Catalog description

Building Automation Systems Technician

Building Automation Systems Technician – Degree Program
BAS3

Program Description

The Building Automation Systems Technician program prepares students for a career in the building automation systems industry. This industry encompasses a broad range of current and emerging technologies to control building-related electrical and mechanical systems efficiently. The program prepares students to enter the building automation industry capable of marketing, installing, designing, servicing, and troubleshooting complex commercial control systems. Students will have demonstrated proficiency in HVAC/R commercial systems, control theory, logic and programming, installation, system design, and integration. Graduates have also completed an industry-based internship course which is coordinated through the program.

Link to Building Automation Systems Technician - Degree Option; see **Appendix A**
https://www.gptc.edu/programs/building-automation-systems/

Georgia Piedmont Technical College also has a diploma option which can be contrasted with the degree option disseminated in this document by clicking on the following link.
Link to Building Automation Systems Technician - Diploma Option; see **Appendix B**
https://www.gptc.edu/programs/building-automation-systems-2/

Program design rationale and key elements

Georgia Piedmont Technical College's Industrial Division has expanded its Air Conditioning Program, founded in 1964, to also offer diploma and degree-level awards in both Commercial Refrigeration and Building Automation Systems (BAS). The BAS program, documented here, found its' beginnings in curricula and coursework originally developed by industry partners and deployed at the Georgia Piedmont Technical College's (GPTC) R.S. Andrews Academy in 2000. Industry partners, eager to hire new talent, made significant donations of time, material, and curricula to support the initial training which led to employment for a significant percentage of those who participated. In 2007, with the demonstrated support of industry, and the employment opportunities available in the Atlanta area for BAS technicians, GPTC began the process of

developing a credit-based program in BAS which would prepare students to enter the building automation industry capable of marketing, installing, designing, servicing, and troubleshooting complex commercial control systems.

Goal

Prepare students to enter the building automation industry capable of marketing, installing, designing, servicing, and troubleshooting complex commercial control systems.

To attain this goal, the student must exhibit competencies and meet both institutional and programmatic level outcomes as follows:

Institution-level Outcomes

- Exhibit Effective Communication Skills
- Exhibit Effective Analytical Skills
- Exhibit Independent Learning Skills
- Exhibit Informational Literacy Skills
- Exhibit Socio-Cultural & International Awareness

Programmatic-level Learning Outcomes (PLO's)

- Demonstrate the ability to correctly & safely install control devices
- Demonstrate the ability to identify, classify, and state the application of commonly-encountered control devices
- Demonstrate the ability to effectively troubleshoot control device problems
- Demonstrate the ability to create a comprehensive control system database
- Demonstrate the ability to interpret construction controls drawings and specifications
- Demonstrate the ability to develop a comprehensive controls submittal package complete with controls shop drawings
- Demonstrate the ability to interpret and analyze controls schematics, pictorial diagrams, and sequences of operation
- Demonstrate the ability to install a communications network and initialize building controllers
- Demonstrate the ability to design & construct a complex control panel of controllers and controls peripheral devices to perform a given function
- Demonstrate the ability to properly wire all standard inputs & outputs common to the controls industry
- Demonstrate the ability to properly tune a proportional / integral control loop
- Demonstrate the ability to effectively communicate in a written and oral fashion

Embedded course sequence including lab and lecture hours

Course Number	Course Title	Credits	Lecture Hrs.	Lab Hrs.	Pre/Co-Reqs
	FIRST SEMESTER				
AIRC 1005	Refrigeration Fundamentals	4	3	1	Program Ready
AIRC 1010	Refrigeration Principles & Practices	4	3	1	AIRC 1005
AIRC 1020	Refrigeration Systems Components	4	3	1	AIRC 1010
BUAS 1010	BAS Fundamentals	2	1.5	.5	Program Ready
MATH 1111	College Algebra	3	3	0	MATH 099 or Compass Score
	SECOND SEMESTER				
BUAS 1020	BAS Electrical Concepts I	3	2	1	AIRC 1010
BUAS 1030	BAS Electrical Concepts II	3	2	1	BUAS 1020
BUAS 1040	BAS Devices	3	2	1	BUAS 1020, 1030
BUAS 1050	BAS Network Architecture	3	2	1	BUAS 1040
MATH 1113	Pre-Calculus (or gen. ed. elective)	3	3	0	MATH 1111
	THIRD SEMESTER				
BUAS 1060	BAS Advanced Electrical Concepts	3	2	1	BUAS 1030
BUAS 2010	BAS Commercial HVAC & Controls	3	2	1	BUAS 1030
BUAS 2020	BAS Logic & Programming	4	3	1	BUAS 1030, 2010
BUAS 2030	BAS Design & Installation	4	2	2	BUAS 1030, 2010
ENGL 1101	Composition & Rhetoric	3	3	0	
	FOURTH SEMESTER				
BUAS 2040	BAS Integration	5	4	1	BUAS 1050, 1060, BUAS 2010
BUAS 2050	BAS Internship	3	0	3	BUAS 1060, 2020 BUAS 2040
XXXX XXXX	Area II - Social Science Elective	3	3	0	
XXXX XXXX	Area IV – Humanities Elective	3	3	0	

Total Credit Hours: 63

For detailed course descriptions and more information, please see **Appendix A** and https://www.gptc.edu/programs/building-automation-systems/

Development of current program structure

The initial course sequencing of the BAS program utilized a year 1, year 2 approach which relied heavily on pre-existing year 1 courses within the HVAC and Electronics programs to establish a foundation of mechanical, applied electrical, and psychrometric skills within the student. Year 2 courses focused on HVACR commercial systems, control theory, control logic and programming, installation, design, and application. The program was approved by the Technical College System of Georgia with this year 1, year 2 approach in late 2007. The advantage of the initial course sequencing was that it was built on pre-existing, proven courses and so less instructional staff was required in BAS initially and the program could grow gradually.

In 2010, the BAS program was modified at the request of the BAS Advisory Board to include nearly twice as many contact hours with the students in BAS-listed courses. The primary advantage of this approach was significantly more contact time for the students with BAS instructors who would primarily provide the year 1 foundational coursework, but with an applied-BAS perspective. Also, at the request of the BAS Advisory Board, specific courses were added to program which were thought to be beneficial. These included a BAS survey course, a BAS devices course, and a BAS networking course which were all new subject areas added to the first year of the program. The new course in the second year was a BAS integration course. The program continues to be delivered with this latest structure.

Rationale for course sequences

The first year focuses on development of foundational topics and skills primarily at the component level.

Semester 1
Students begin with HVAC courses in theory, psychrometrics, and components, as well as a survey course in BAS. In the HVAC courses, they learn basic system operation along with the function and purpose of various components within an HVAC system and how they work together. Students begin with safety training and then learn to solder, braze, how to use refrigerant gages, pressure temperature relationships, refrigerant handling, the basics of charging and recovering refrigerant from a system, and psychrometrics.

By the end of the first semester, students are prepared to test for their EPA refrigerant handling certification. Also required the first semester is survey course in BAS where students learn of the various career pathways available to them, practice their communication skills by writing reports about each of the four industry speakers who come to the classroom, learn about the basic skills requirements for each of the career pathways presented, and finally have a chance to visit and interview a representative of one of 10 industry partners they choose from. After the first semester, students should have a strong sense of the career path they wish to pursue, the required skills to be successful in that path, and have met industry mentors who may act as a resource to assist in attaining their goals.

Semester 2

In the second semester, students begin building their electrical, networking, and component-level BAS skills. Electrical skills are among the most highly valued by employers according to advisory board feedback, and therefore the skills developed in the second semester are carried forward and enhanced upon throughout the rest of the program in an applied fashion. Electrical topics covered are common to those found in any HVAC-related electrical course line-up, but with application and exercises related directly to the BAS industry.

The BAS component-level course is a deep-dive into BAS peripheral devices like sensors, transmitters, transducers, and various other components the students will encounter on a daily basis upon graduation. Upon completion of the course, students are able to identify, classify, and state the purpose and function of the most commonly used BAS devices in the industry. They are also able to immediately apply their newly attained electrical skills to interpretation of engineering data sheets for BAS components. Significant use is made of the Kele website for this course.
http://www.kele.com/home.aspx

The BAS networking course is based upon Comp TIA's Network+ textbook and certification. It introduces students to the key elements of communications, various functions and modalities of communications, network topologies, and physical media as well as the OSI model and other key networking fundamentals germane to the BAS industry. With further study, which is encouraged by the instructors, students are well on their way to attaining a Network+ certification.

Communication skills continue to be woven through second semester courses, through written reports and end-of-the-semester projects and group presentations which are a part of every BAS course. The BAS program makes significant use of the Purdue OWL

online resources to instruct students on style, business communication formatting, and properly citing research. http://owl.english.purdue.edu/owl/

Semester 3

The third semester begins the second year of coursework which moves from component-level introduction to systems-level thinking and instruction. Foundational skills are brought forward from year 1 and enhanced further. Projects are more involved and challenging, bringing multiple skill sets to bear, and communication skills continue to be practiced.

Advanced electrical concepts complete the electrical coursework for the student and focus on AC analysis of circuits which require college algebra and trigonometric concepts to fully understand. Students analyze waveforms, learn to use scope meters, cable analyzers, power quality meters, and oscilloscopes as diagnostic tools.

This semester first introduces the student to various commercial HVAC system types as classified by ASHRAE. https://ashrae.org/ Students learn how a building HVAC system operates as a system and how all the system components work together to maintain comfort. Air side and water side equipment is covered as well as their respective sequences of operation. Once the sequences are understood, the students learn the control strategies and methods for controlling the equipment to meet their required sequences of operation. Inputs and outputs are revisited from year 1 materials, and the theory of proportional-integral-derivative (PID) control loop control is covered and applied to loop tuning.

Concurrent to their introduction to commercial building systems, students develop their analytical and programming skills requisite to establishing control logic for automation systems in controlling systems to meet their sequences of operation. For this reason, the logic and programming course is taught concurrently with the commercial HVAC systems course. The course begins with Boolean gate logic and moves into application of this logic to relay wiring, and eventually into object-oriented program which is introduced first with the ALICE software which is a free download to students. http://www.alice.org/index.php

Students may also choose to take the BAS design and installation course in semester 3, which requires a significant amount of laboratory time and skills development outside of the classroom. The course requires students to demonstrate the ability to bend and install conduit, communications cabling, application-specific controllers, peripheral devices, and commission an operating BAS system to prescribed specifications. The

significant project of the course is a complete controls submittal package with engineering data sheets, building drawings showing sensor locations and network diagrams, sequences of operation for all equipment controlled, termination details for inputs and outputs, and complete control shop drawings. The project also requires students to learn and employ Microsoft Visio skills, which is the most commonly used shop drawing software in the industry. Microsoft allows a free 60-day trial download which students make use of. http://office.microsoft.com/en-us/visio/ There are also a number of online videos students use to learn the basic skills of Visio. This exercise supports the collegiate outcomes of independent learning and informational literacy.
This course requires a great deal of time and effort and is often considered a capstone project of the program. Due to this, the course is often taken in the students last semester.

Semester 4
The final semester focuses on a broad introduction to integration of various systems through prevalent communications protocols within the industry and the internship component where students are exposed to proprietary and open-protocol systems on the job. The networking and programming courses taken in previous semesters greatly enhance the students' ability to grasp integration concepts. Time spent on the job applying these skills also help to solidify concepts and skill sets introduced throughout the program.

Inputs for program design and development

It was felt that aligning the BAS program with as many established certifications as possible would benefit the student and increase the chances of differentiating themselves as they sought employment, and so these became key inputs in the design and development of the program.

For the first year HVAC-related coursework, the NATE ICE exams provided a starting point for selecting basic skills sets we felt could provide value to an automation technician. While not all of the skills sets would be taught within the automation program, the student could take a few more HVAC-related courses outside the prescribed curricula and be well prepared for ICE testing. http://www.natex.org/technicians/industry-competency-exams-ice/

Safety training is an important consideration in any construction-related field and is embedded within the HVAC course Refrigeration Fundamentals (AIRC 1005) which the

students take in the first semester. It is closely aligned with OSHA 10 training. https://www.osha.gov/dte/outreach/construction/index.html

The EPA 608 refrigerant handling certification was another input which we embedded within the program through the inclusion of HVAC courses which provide the students with the skills necessary to sit for the exam. The link to the subject areas of the test is here - http://www.epa.gov/Ozone/title6/608/technicians/certoutl.html
The BAS Network Architecture course (BUAS 1050) relies heavily on CompTIA's Network+ certification and associated training materials. http://certification.comptia.org/

ASHRAE's systems classifications and BACnet specifications also provided important initial input and had a great influence on the development of the BAS Commercial HVAC & Controls class (BUAS 2010), and the BAS Integration course (BUAS 2040).
https://www.ashrae.org/

The US Department of Labor and Georgia Department of Labor (http://www.dol.state.ga.us/) provided useful information related to job outlook within the HVAC industry at-large, but since the controls industry is not tracked independently, specific job data related to the controls field is difficult to obtain, and therefore most of the initial curricula input for BAS-related courses and topics came directly from previously taught controls courses at the GPTC R.S. Andrews Academy which were adopted from pre-existing industry training curricula. Curriculum was reviewed and enhanced through continuous and on-going feedback from the BAS industry advisory board.

Initially, the BAS advisory board met in January of 2009 to review the existing program outline and make specific recommendations for competency and student learning outcome inclusions and modifications. As students graduated from the program and went to work, feedback was obtained on a quarterly basis as to knowledge and skills gaps which were observed in graduates, which led to the 2010 revision and expansion of the program.

AAS degree options: Related degrees

The BAS A.A.S. degree is closely aligned with the Air Conditioning and Commercial Refrigeration programs of study. With two added semesters of courses, students often obtain an A.A.S. degree in Air Conditioning or Commercial Refrigeration which increases the breadth of job opportunities available to them. To compare the programs, links have been provided.

Commercial Refrigeration:
http://www.gptc.edu/content.cfm?PageCode=program_detail&programID=15

Air Conditioning:
http://www.gptc.edu/content.cfm?PageCode=program_detail&programID=11

Transfer institutions

As a PAHRA-accredited Air Conditioning program, students completing the Commercial Refrigeration or Building Automation Systems programs receive two years of credit within union HVAC apprenticeship programs.

The Building Automation and Commercial Refrigeration programs have an articulation agreement in place with Ferris State University in Big Rapids, MI. http://www.ferris.edu/

Industry involvement

Industry involvement - best practices

The BAS and Commercial Refrigeration advisory boards were critical to the development of both programs and the state-of-the-art curriculum and laboratory facilities which both programs enjoy.

With the lack of job outlook tracking by the GA Department of Labor and the U.S. Department of Labor, the original research necessary to support development of a program was provided by industry organizations like Siemens, Johnson Controls, and Kele Corporation in particular.

The BAS advisory board reviews curricula, makes on-going suggestions for improvement, provides continuous feedback regarding the skills sets of program graduates, provides guest lecturers, site visits, and ensures product support to the laboratory.

Key involvement areas of the BAS advisory board include:

- Curricula review and enhancements
- Continuous feedback on BAS graduate skill levels
- Keeps instructors abreast of industry advancements
- Provide factory training to instructors

- Guest lecturing
- Mentoring of students
- Site visits to branch offices and jobsites
- Product donations to the laboratory
- Initial laboratory design and continual improvement
- Valuable connections for student placement

Key curriculum recommendations of the BAS advisory board:

- Consolidation of BAS program courses into BAS instructor-led coursework versus entry-level courses taught by other departments
- Addition and enhancement of BAS networking and communication courses
- Employer expectations in skill sets necessary for entry-level employment
- Addition of a BAS course specific to sensors and peripherals commonly used
- Infusion of communication skills development in every BAS-listed course
- Encouragement to incorporate real-world, living laboratory pedagogy
- Infusion of problem-solving and analytical skills development in each BAS-listed course

Key individuals involved in making programmatic recommendations to and serving on the advisory board:

Barrett, Bill	Chief Engineer, Siemens Atlanta Branch Office
Bennett, Roger	CEO, Waypoint Systems (Alerton distributor)
Brimmage, Gary	Vice President, Energy Solutions Johnson Controls
Chu, Joanne	Sustainability Director, Georgia Perimeter College
Collins, Angela	Engineering Manager, Trane Corporation
Dunn, Chad	National Sales Manager, Triatek
Frazier, Wayne	CEO, Frazier Service Company
Geist, Pete	Branch Manager, Johnson Controls Atlanta
Grindstaff, Jeff	CEO, ALC of Georgia
Hall, Jim	CEO, Triatek
Harris, Mike	CEO, Harris Integrated Solutions (ALC distributor)
Iverson, Philip	CEO, HI Solutions & Aither Systems
Krause, Jeff	Manager, TCS Basys Controls
Lowe, Leonard	Chief Engineer, McKenney's Corporation
Lynn, Jason	Southeastern U.S. Sales Manager, Daikin U.S.
McGowan, Bill	International Sales, Delta Controls
Mitro, Rusty	Eastern U.S. Sales Manager, Delta Controls
Morgan, Scott	National Sales, TAC
Mulvey, Nigel	Manager, Commercial Controls of GA (Carrier Controls)
Pettingill, Kirk	Manager, Carrier
Scroggins, Jim	Engineering Manager, Johnson Controls Atlanta
Segal, Andrew	Chief Engineer, Waypoint Systems (Alerton distributor)

Smith, Trisha	Sales Manager, ALC of Georgia
Stromquist, David	CEO, Stromquist & Co. (Honeywell)
Taylor, Michelle	National Recruiter, Johnson Controls
Taylor, Wes	Training Manager, Carlyle Compressors
Thayer, Ernie	Commercial Sales Manager, Johnstone Supply
Vargo, Tim	CEO, Kele Corporation
Walker, Rusty	Chief Training Engineer, Hill Phoenix Corporation
Weigel, David	Chief Engineer, Kele Corporation
Williams, Jim	Engineering Manager, Southeastern Controls (Delta distributor)
Winkelman, Patrick	National Sales Manager, Distech Controls

Contact information for these individuals is available on request.

Labor market needs analysis

Research for BAS employment opportunities was done through direct interviews with Johnson Controls national recruiter, Michelle Taylor, Siemens branch offices, national sales managers and CEOs of controls companies both large and small. Also, basic online job searches were performed. Unfortunately, the controls industry in commercial buildings, estimated by Kele Corporation to be $4 billion dollars in the U.S. alone, has no independent job categorization and therefore isn't tracked independently.

Typical job titles and pay ranges for program graduates

The BAS program has been placing graduates into jobs within the controls industry since 2010. The Technical College System of Georgia has no formal tracking system to collect employment data directly about graduates. However, program instructors have a sense of what types of jobs students attain on graduation and this anecdotal evidence informs this section.

The most typical entry-point title for a program graduate is BAS service technician. Successful graduates find employment with various controls contracting firms and immediately acquire the product-specific training they need for proprietary equipment when they enter the organization. Most are paired with seasoned controls technicians for a period of time prior to handling their own service calls.

Some program graduates with pre-existing skills gained from a previous work history move quickly into a sales or project management position after acquiring the same proprietary factory training which service technicians receive.

Those without a work history related to or applicable to the controls industry start anywhere from $16 - $25 per hour, while those with pre-existing skills and/or degrees start anywhere from $22 - $50 per hour.

Program graduates have been hired into the following titles of jobs on graduation:

- Assistant Project Manager
- Project Manager
- Service Technician
- Commissioning / Start-Up Technician
- Building Engineer
- Integration Technician
- Graphics Developer
- Assistant Controls Engineer
- Project Coordinator
- Controls Salesman
- Control Systems Monitor
- Controls Installer
- Controls Distributor Counter Sales

Links to employment data

Government data on the HVACR industry (only current source for government data which also applies to controls industry encapsulated within HVAC workforce):

- U.S. Bureau of Labor Statistics: Work Environment for HVAC
- U.S. Bureau of Labor Statistics: What Heating, Air Conditioning, and Refrigeration Mechanics and Installers Do
- U.S. Bureau of Labor Statistics: How to Become a Heating, Air Conditioning, or Refrigeration Mechanic and Installer
- U.S. Bureau of Labor Statistics: Occupational Employment and Wages, May 2011, Heating, Air Conditioning, and Refrigeration Mechanics and Installers
- U.S. Bureau of Labor Statistics: Job Opportunities for Heating, Air Conditioning, and Refrigeration Mechanics and Installers

Alignment with industry certifications

Parts of the BAS program content are informed by and coordinated with the outcomes of the following certifications:

North American Technician Excellence(NATE) Technician competency exams cover the topics of: Heating Cooling, Air Distribution, Heat Pumps, Radiant Heating, Light Commercial Refrigeration, and Commercial Refrigeration Certifications. NATE certification topics and requirements inform how we develop course content in the Commercial HVACR program.

HVAC Excellence, ESCO Institute (EPA refrigerant handling certifications). Dedicated to certifying technicians, educators and programs to meet regulatory and industry standards. See "A Guide to the Certified Master HVAC Educator Core Exam" for competencies and resources.

CompTIA has the Network+ certification which proves beneficial to BAS program graduates and which guides coursework with the program itself as related to networking topics.

Safety training is an important consideration in any construction-related field and is embedded within the HVAC course Refrigeration Fundamentals (AIRC 1005) which the students take in the first semester. It is closely aligned with OSHA 10 training. https://www.osha.gov/dte/outreach/construction/index.html

LonMark International is an organization which promotes open communications between controls vendors. The GPTC BAS program instructs on the basics of LonWorks which is promoted by LonMark as one solution for peer-to-peer open communications. Much of the coursework in the BAS Integration (BUAS 2040) course covers open protocols and focuses primarily on LonWorks and BACnet. The LonMark Certified Professional (LCP) certification is one that students who further prepare themselves beyond the integration course may take.

The GPTC BAS program exposes students to the fundamentals of the Niagara framework and may set students on the path to attain their Niagara AX certification if they take a one-week course after graduation. GPTC has works with training providers of this certification to provide discounted rates for students.

Affiliations with industry organizations

Refrigeration Service Engineers Society (RSES) – GPTC's BAS program utilizes RSES training materials within the required HVAC coursework. The RSES trade magazine has featured both the Commercial Refrigeration and Building Automation programs at GPTC in their journal.

American Society of Heating, Refrigerating, & Air-Conditioning Engineers (ASHRAE) GPTC students established a student chapter of ASHRAE and attached it to the Building Technology Club on campus. The club quickly became the largest on campus with 75 paid members. GPTC students have received scholarships to attend ASHRAE conferences. They also receive discounted prices on ASHRAE guidelines, resources and publications. See educational resource publications listing.

AutomatedBuildings.com is an online resource organization which keeps students informed of happenings within the industry. Former students have published their experiences online including Ms. Stephanie Brown in December of 2010 under an article entitled *Dekalb Technical College Starts Building Automation Program.* Automated Buildings provides resources to students which enhances their education while in school.

Additional industry organizations

PAHRA The Partnership for Air-Conditioning, Heating, Refrigeration Accreditation (PAHRA) is an independent, third-party organization that is a partnership between heating, ventilation, air-conditioning and refrigeration (HVACR) educators and the HVACR industry that will award accreditation to programs that have met and/or exceeded industry validated standards. GPTC has been PAHRA accredited in its Air Conditioning programs for many years.

Air Conditioning Contractors of America (ACCA) Trade organization that promotes professional contracting, energy efficiency, and healthy, comfortable indoor living.

Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Industry organization focused on certifying quality equipment.

Council of Air Conditioning & Refrigeration Educators (CARE) industry supported organization dedicated to HVACR. Members are HVACR instructors, administrators and other HVACR industry personnel from across the United States

Heating, Air Conditioning & Refrigeration Distributors International (HARDI)

Represents companies that distribute, and support heating, air-conditioning, and refrigeration equipment, parts and supplies to serve installation and service/replacement contractors institutional maintenance staffs

Plumbing-Heating-Cooling Contractors-National Association (PHCC) has contractor members who manage businesses in residential service, new construction, commercial and industrial markets

Skills USA is a student success organization which promotes technical education as well as local, state, and national competitions in various categories. GPTC BAS students have met with success nationally in the engineering and design competitions sponsored by Skills USA.

Recruitment

Building automation is an industry which has traditionally been insulated from common knowledge. It's been closely aligned with the HVAC and building construction industries, but has had very few direct pathways for entry into the field. For this reason, recruitment often involves direct marketing to those either already within the industry or within a related field of endeavor.

Program entry standards

GPTC is an institution which serves a very diverse student population and is open to all, no matter their level of education. While students across the spectrum of experience and education have successfully completed the program and found employment, it's been our experience that students who exhibit some of the following characteristics are placed into BAS-related jobs with greater frequency upon completion:

- good written and oral communication skills
- academic preparation and motivation
- computer literacy and skills
- industry experience
- related technical skills
- independent learning capacity
- analytical and critical thinking skills
- fundamental math skills in algebra

Sources of potential students

GPTC has identified several methods and sources of potential students as follows:

- Current or former HVAC or related industrial technical program students and graduates
- Current or former Information Technology students
- Students with former field experience in electrical or mechanical work which can usually be identified through involvement with local trade associations

- Building engineers needing more controls-related training can be reached through local Building Owners and Manager Associations (BOMA)
- Prior military personnel exiting the service
- Local mechanical, electrical, and controls contracting firms which need training for existing employees - These firms can often be located through your respective state's website under licensing
- High school industrial or technology students are a potential source, but GPTC's experience is that this route takes significant work with high school counselors and often offers small returns

Program infrastructure

The BAS program requires significant staffing and supporting laboratory space to maintain a high-quality experience for students. Optimally, a robust BAS degree program should have two full time instructors, several adjuncts, and also leverage industry speakers to come into the classroom and lecture on specific topics. GPTC uses all of these strategies to provide instructional capacity for the program. Also, the BAS program sends new students to the air conditioning program for introductory courses in safety and HVAC principles, which reduces some of the weight on BAS instructors.

The BAS program offers courses only in the evenings, which encourages working adult students and also working professionals who provide guest lecturers to interact at the college. Further, all the courses require both a laboratory and online component.

When student rolls are full, all 9 BAS-listed courses can be listed and taught per semester, and students may enter the program during any term of the year. The limiting factors here are laboratory space and time, and also instructional availability of adjuncts and guest lecturers.

Equipment accessibility for controls training

A key element to successful implementation for the GPTC program was access to and space for the controls themselves and the equipment which would be controlled. Initially, the program was encapsulated within the existing 9,000 square foot HVAC laboratory. Later, the new Commercial Refrigeration and Building Automation Systems programs moved into a 4,000 sq. ft. space which formerly housed a machining program.

The commercial refrigeration equipment serves a dual purpose in providing education for both the Commercial Refrigeration students and the Building Automation students who have mounted sensors and control devices within all the lab's equipment for

monitoring purposes. The refrigeration equipment also utilizes a CPC control system with an LED access panel which provides an added dimension of controls exposure to BAS students seeking to enter the refrigeration controls field.

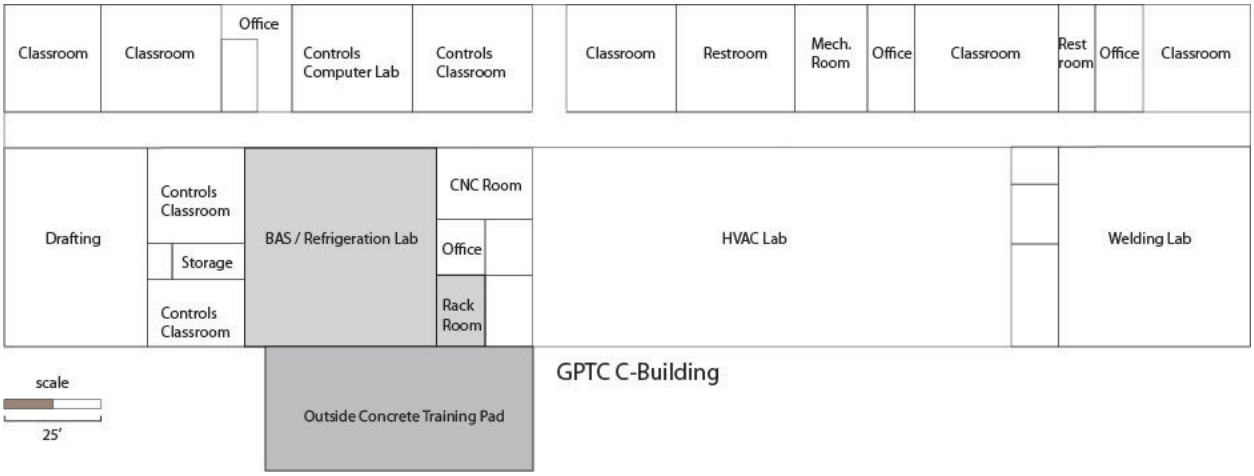
Electronics benches and flat workbenches which can seat over 40 students combined provide the necessary location for practicing input and output wiring, software instruction, and bench-top capacity for testing with oscilloscopes, function generators and network troubleshooting. Controls devices are organized within the drawers of each electronics workbenches and are inventoried on a regular basis by the students.

The C-building, where the program is housed, is a 29,000 sq. ft. facility which has been designated a 'living laboratory' by a former president, and therefore, students run network communications cabling throughout the building to support a network of controllers, sensors, and various monitoring and controls devices within the structure.

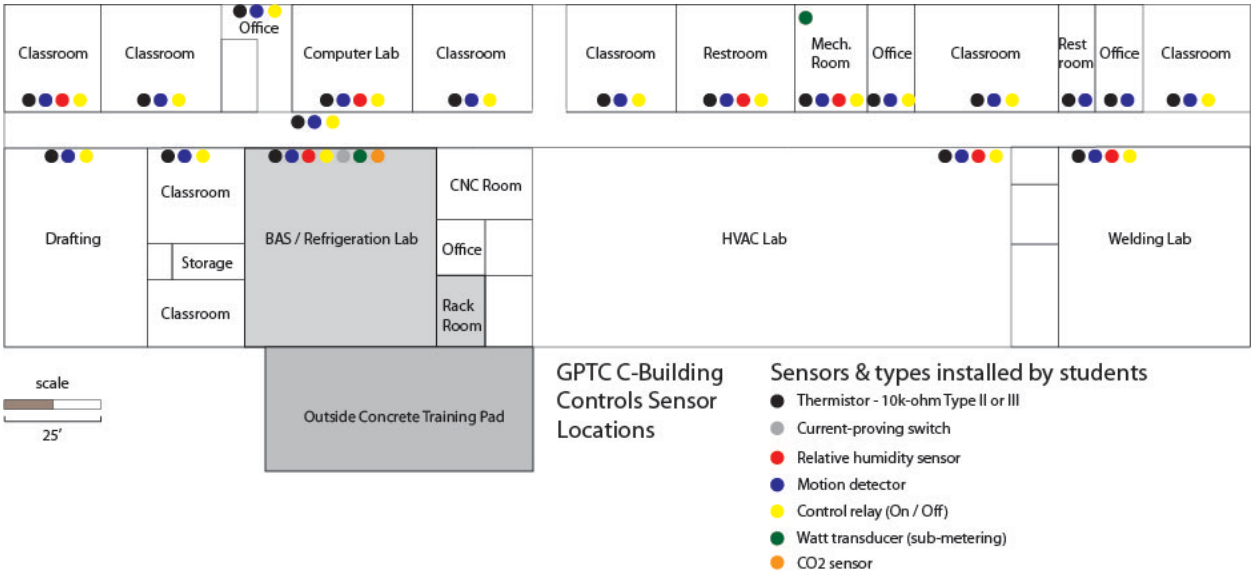
In 2010, students assisted in the design of a 'living laboratory' concrete pad addition to the facility which now supports water harvesting systems, solar photovoltaic and thermal systems, and condensing units for the rack refrigeration equipment where students also have installed supporting cabling and sensors. All the control components of the rainwater harvesting system and its supporting cabling and conduit were installed by BAS students. For more on the 'living laboratory' pedagogy, please see the pedagogy section of this paper and visit the AACC's SEED Center website for in-depth descriptions of how it's employed on the GPTC campus by BAS students.

Lab layout & elements

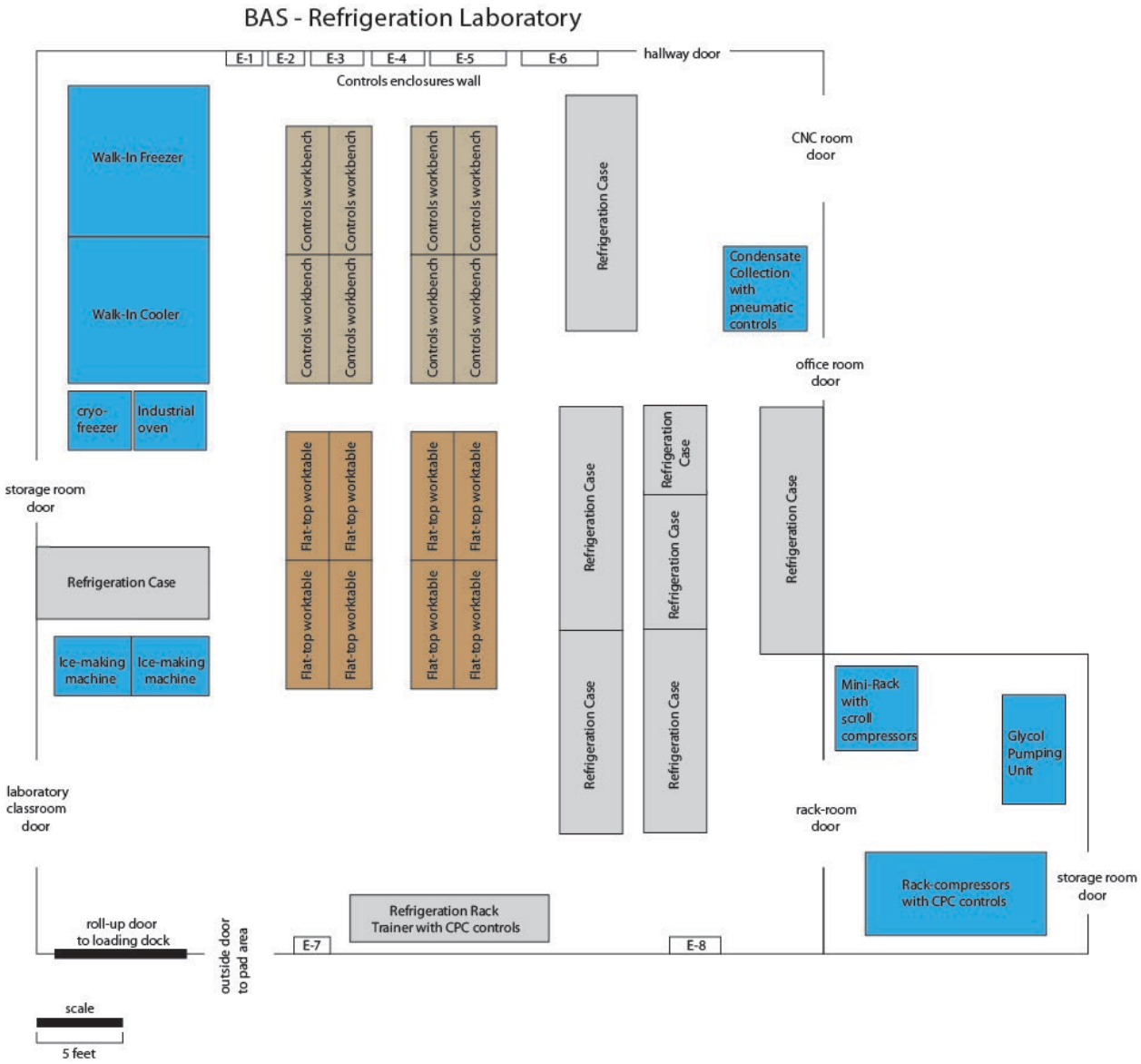
29,000 sq. ft. C-building at GPTC with associated controls training rooms & laboratory spaces:



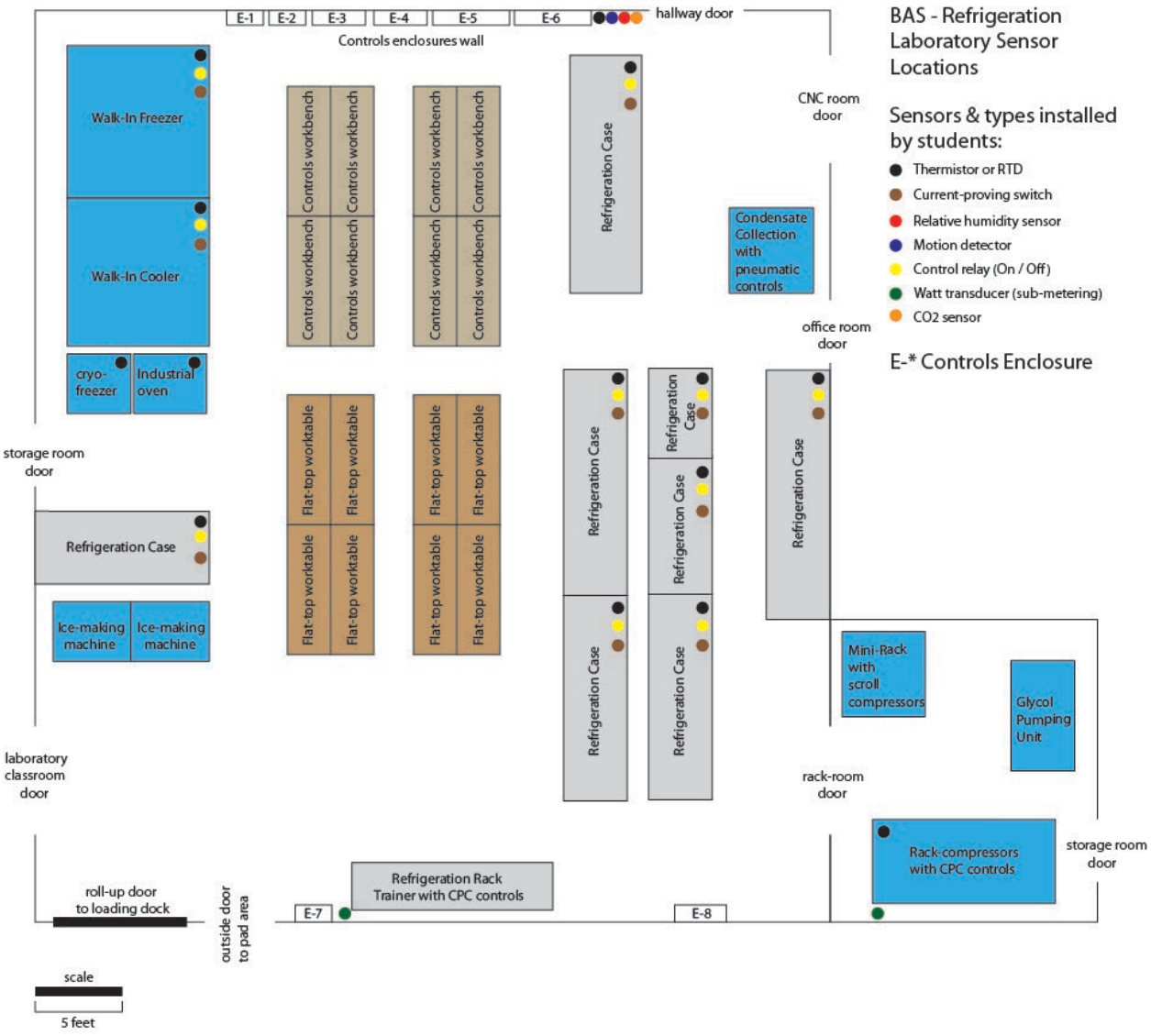
C-building @ GPTC showing and detailing sensor types and locations used as part of BAS program instruction:



C-building BAS / CR Laboratory Layout:



C-building BAS / CR Laboratory Layout with sensor locations and type:

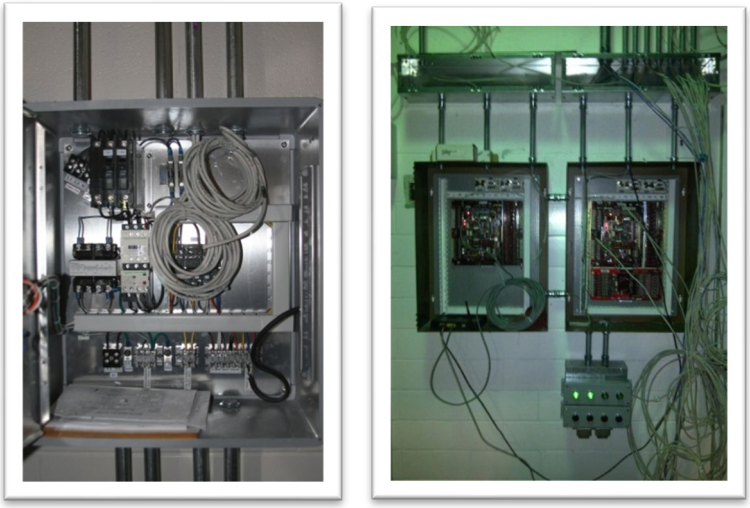


Photographs of instructional spaces:

BAS/CR Laboratory facing flat tables

BAS students wiring controllers next to electronics workbenches

Student control project in (BUAS 2020)



Samples of student-mounted controls, conduit & cabling (BUAS 2030)

Pictures of BAS students working in C-building, mounting conduit & sensors, running network cabling & commissioning control systems

Student practicing communication skills

Hill Phoenix Rack system with 3 compressors & CPC controls

Skills USA National Bronze Medal-winning Building of the Future inspired by Time Magazine's design by Architect William McDonough, shown here with controls exposed - final project included grounds and attractive cover - All performed by BAS students

Essential lab and building equipment

Mechanical Systems

- **Refrigeration:** Hill Phoenix rack refrigeration system with 3 compressors of various makes / Hill Phoenix secondary system with glycol pumping station / Hill Phoenix distributed refrigeration unit with 4 scroll compressors / Walk-in cooler & freezer top and side-mount units
- **Heat rejection:** Rack condensing units
- **Variable-Refrigerant Flow (VRF):** Systems by Mitsubishi and Daikin
- **Ice-Making Machines:** Several models in laboratory
- **Cryo-freezer:** Ultra-low temp cryo-storage unit in laboratory
- **Refrigeration Cases**: Various medium and low temp cases and merchandisers throughout the laboratory by Hill Phoenix
- **Air-side equipment:** VAV air-handling system with 2 VAV and 2 PIU boxes and VFD
- **Package**: Various package units
- **Residential Equipment**: Various makes of split systems, mini-split systems, high velocity systems, heat pumps, refrigeration trainers, furnaces, motors and motor controls, brazing stations, etc.

Controls

- **Peripherals:** Various devices to include thermistors, RTDs, pressure transducers, ice-cube relays, solid-state relays, current switches, fan-proving switches, CO2 sensors, humidity sensors, vibration transmitters, current transducers, damper actuators, valve bodies & actuators, programmable space sensors & controllers, watt-transducers, and much more.
- **Controllers & Vendors:** Various lines including Alerton, Automated Logic, Carrier, Contemporary Controls, Daikin, Delta, Distech, Easy/IO, Honeywell, Johnson Controls, Siemens, Trane, Triatek, Tridium, and others.

Lab equipment - function and application in classes

See individual course documentation for samples of controls equipment & application in classes

Tools & instruments

GPTC's BAS program requires students to provide their own tools in the hope that many will keep the tools upon graduation and be ready to go work. Oftentimes, students will qualify for local workforce development office support which will fund the cost of their tools. The BAS program maintains its own diagnostic equipment where the cost is impractical for the students. Scope-meters, power quality meters, oscilloscopes, infrared imagers, controls software, and other tools are maintained by the college.

Building Automation Systems Program
(All Tools Listed are Required for Each BAS Course)

Required Tool List for Program

1/ Tool Box
2/ Refrigeration Gauges with Quick Couplers
3/ Service Wrenches (1/4", 3/8")
4/ Safety Goggles
5/ Leather Gloves
6/ Pocket Thermometers (2) 0-20 deg. F.
7/ 6" Crescent Wrench
8/ 8" Crescent Wrench
9/ 12" Crescent Wrench
10/ 10" Channel Pliers
11/ Open Box End Wrench (3/8", 1/2", 9/16", 5/8", 3/4")
12/ Full Allen Wrench Set
13/ Respirator Masks
14/ Pocket Flashlight
15/ Tape Measure (25')
16/ Clamp-on Digital Voltmeter
17/ Wire Strippers 2 pair (1 small gauges, 1 medium gauges)
18/ 2 Control Screwdrivers (flathead)
19/ 4" Common Screwdriver (3/16" x 4")
20/ 6" Common Screwdriver (1/4" x 6")
21/ 4" Phillips Screwdriver #1 & 6" Phillips Screwdriver #2
22/ Conduit Bender with 1/2" & 3/4" Heads
23/ Needle Nose Pliers
24/ Wire Crimpers
25/ 9" Torpedo Level
26/ Full Nut Driver Set (1/4", 5/16", 3/8", 7/16", 1/2")
27/ 8" Lineman Pliers
28/ Conduit Bender with (1/2" & 3/4" Heads)
29/ 1 Infrared Handheld Temperature Sensor
30/ 1 Handheld Humidity Sensor
31/ Voltage Proximity Sensor (2) (1 Low Voltage & 1 High Voltage)
32/ Laptop Computer with Windows (Any brand will do)
33/ Echelon Lonworks Network Card (Either USB or PCMCIA)

Pedagogy

Problem-based learning

Problem-based learning (PBL) is a learner-centered pedagogy in which students explore a subject in the context of complex, multifaceted, and realistic problems. The goals of PBL are to help the students develop flexible knowledge, effective problem-solving skills, self-directed learning, effective collaboration skills and intrinsic motivation.

Through PBL, students:

- Become immersed in open-ended scenarios simulating real-life work situations
- Work in groups, identify what they already know, what they need to know, and how and where to access new information that may lead to resolution of the problem
- Explore a problem or scenario that is presented with missing information and is open-ended allowing for critical thinking and analysis, thus generating a range of solutions that have not been suggested before
- Determine if the problem suggested is the real problem or whether there is a different problem that needs to be solved

For more information on PBL visit www.learnpbl.com, which is another project funded by the National Science Foundation.

The GPTC BAS program utilizes **Living Laboratory** education throughout its courses. This type of pedagogy is complex and depends heavily on inter-institutional collaboration across departments from successful implementation. For more information on how this pedagogy is employed within GPTC's BAS program, please visit the AACC's SEED Center and read the whitepaper entitled *The Campus as a Living Laboratory: Using the Built Environment to Revitalize College Education*. (Authors: Todd Cohen / Brian Lovell)

Learning strategies outside of the classroom

GPTC's BAS program requires BUAS 2050, an internship course, to be completed prior to graduation.

Appendix A: Curriculum for Degree Option

GEORGIA PIEDMONT TECHNICAL COLLEGE

Curriculum Sheet

Building Automation Systems Technology

Associate of Applied Science Degree

BAS3

Curriculum

General Education Core **15**

Area I: Language Arts/Communication 3
- ENGL 1101 Composition and Rhetoric (3)

Area II: Social/Behavioral Sciences *(Choose ONE course)* 3
- ECON 1101 Principles of Economics (3)
- ECON 2105 Principles of Macroeconomics (3)
- ECON 2106 Principles of Microeconomics (3)
- HIST 1111 World History I (3)
- HIST 1112 World History II (3)
- HIST 2111 American History I (3)
- HIST 2112 American History II (3)
- POLS 1101 American Government (3)
- PSYC 1101 Introduction to Psychology (3)
- SOCI 1101 Introduction to Sociology (3)

Area III: Natural Sciences / Mathematics 3
- MATH 1111 College Algebra (3)

Area IV: Humanities/Fine Arts *(Choose ONE course)* 3
- ARTS 1101 Art Appreciation (3)
- ENGL 2130 American Literature (3)
- HUMN 1101 Introduction to Humanities (3)
- MUSC 1101 Music Appreciation (3)
- RELG 1101 Introduction to World Religions (3)

Elective: General Education *(Choose ONE course)* 3
- Any course from Area I, II, or IV above
- OR
- ENGL 1102 Literature and Composition (3)
- SPCH 1101 Public Speaking (3)
- BIOL 1111 Biology I (3) + BIOL 1111L Biology I Lab (1)
- BIOL 1112 Biology II (3) + BIOL 1112L Biology II Lab (1)
- CHEM 1211 Chemistry I (3) + CHEM 1211L Chemistry I Lab (1)
- CHEM 1212 Chemistry II (3) + CHEM 1212L Chemistry II Lab (1)
- MATH 1101 Mathematical Modeling (3)
- MATH 1103 Quantitative Skill and Reasoning (3)
- MATH 1113 Precalculus (3)
- MATH 1127 Introduction to Statistics (3)
- MATH 1131 Calculus I (4)
- MATH 1132 Calculus II (4)
- PHYS 1110 Conceptual Physics (3) + PHYS 1110L Conceptual Physics Lab (1)
- PHYS 1111 Introductory Physics I (3) + PHYS 1111L Introductory Physics I Lab (1)
- PHYS 1112 Introductory Physics II (3) + PHYS 1112L Introductory Physics II Lab (1)

GEORGIA PIEDMONT TECHNICAL COLLEGE

Curriculum Sheet

Occupational Courses **48**

Required Courses:

AIRC 1005 Refrigeration Fundamentals (4)
AIRC 1010 Refrigeration Principles and Practices (4)
AIRC 1020 Refrigeration Systems Components (4)
BUAS 1010 BAS Fundamentals (2)
BUAS 1020 BAS Electrical Concepts I (3)
BUAS 1030 BAS Electrical Concepts II (3)
BUAS 1040 BAS Devices (3)
BUAS 1050 BAS Network Architecture (3)
BUAS 1060 BAS Advanced Electrical Concepts (3)
BUAS 2010 BAS Commercial HVACR and Controls (3)
BUAS 2020 BAS Logic and Programming (4)
BUAS 2030 BAS Design and Installation (4)
BUAS 2040 BAS Integration (5)
BUAS 2050 BAS Internship (3)

Total Credit Hour (minimum): **63**

Appendix B: Curriculum for Diploma Option

GEORGIA PIEDMONT TECHNICAL COLLEGE

Curriculum Sheet

Building Automation Systems Technology

Diploma

BAS4

Curriculum

Basic Skills	**8**
ENGL 1010 Fundamentals of English I (3)	
MATH 1013 Algebraic Concepts (3)	
EMPL 1000 Interpersonal Relations and Professional Development (2)	
Occupational Courses	**43**
Required Courses:	**40**
AIRC 1005 Refrigeration Fundamentals (4)	
AIRC 1010 Refrigeration Principles and Practices (4)	
AIRC 1020 Refrigeration Systems Components (4)	
BUAS 1010 BAS Fundamentals (2)	
BUAS 1020 BAS Electrical Concepts I (3)	
BUAS 1030 BAS Electrical Concepts II (3)	
BUAS 1040 BAS Devices (3)	
BUAS 1050 BAS Network Architecture (3)	
BUAS 1060 BAS Advanced Electrical Concepts (3)	
BUAS 2010 BAS Commercial HVACR and Controls (3)	
BUAS 2020 BAS Logic and Programming (4)	
BUAS 2030 BAS Design and Installation (4)	
Occupational Electives: *(Choose one course.)*	**3**
AIRC 1030 HVACR Electrical Fundaments (4)	
AIRC 1050 HVACR Electrical Components and Controls (4)	
BUAS 2040 BAS Integration (5)	
BUAS 2050 BAS Internship (3)	
Total Credit Hour (minimum):	**51**

Appendix C: Required Textbooks

BAS Course (Cr. Hrs. / CRN #)	*Textbook Title*	*ISBN 13#*	*Author / Publisher*
BUAS 1010 (2 / 48936) **BAS Fundamentals**	Materials Provided		
BUAS 1020 (3 / 48937) **BAS Electrical Concepts I**	"AC/DC Principles" "AC/DC Principles Workbook" "Troubleshooting Elect. Systems"	978-0-8269-1350-0 978-0-8269-1351-7 978-0-8269-1791-1	Paul T. Shultz / ATP ATP Staff Mazur & Proctor / ATP
BUAS 1030 (3 / 48938) **BAS Electrical Concepts II**	"AC/DC Principles" "AC/DC Principles Workbook" "Troubleshooting Elect. Systems"	978-0-8269-1350-0 978-0-8269-1351-7 978-0-8269-1791-1	Paul T. Shultz / ATP ATP Staff Mazur & Proctor / ATP
BUAS 1040 (3 / 48939) **BAS Devices**	Materials Provided		
BUAS 1050 (3 / none yet) **BAS Network Architecture**	"CompTIA Network+ 2009"	978-1-59863-878-3	Dean / Cengage Learning
BUAS 1060 (3 / 48940) **BAS Adv. Electrical Concepts**	"AC/DC Principles" "AC/DC Principles Workbook" "Troubleshooting Elect. Systems" "Industrial Electrical Troubleshooting"	978-0-8269-1350-0 978-0-8269-1351-7 978-0-8269-1791-1 978-0-7668-0603-0	Paul T. Shultz / ATP ATP Staff Mazur & Proctor / ATP Lundquist / Delmar
BUAS 2010 (3 / 48941) **BAS Commercial HVAC Systems & Controls**	"Mech. & Elect. Equip. for Buildings,2e" "HVAC Control Systems" "HVAC Ctrl Systems Workbook" "Building Automation Control Devices & Applications"	978-0-470-19565-9 978-0-8269-0757-8 978-0-8269-0758-5 978-0-8269-2000-3	Stein / Wiley Auvil / ATP Auvil / ATP NJATC / ATP
BUAS 2020 (4 / 48942) **BAS Logic & Programming**	"Starting out with Alice, 2e" "Starting out with Java, 4e"	978-0-321-54587-9 978-0-13-608020-6	Gaddis / Addison-Wesley Gaddis / Addison-Wesley
BUAS 2030 (4 / 48943) **BAS Design & Installation**	"NEC 2011 Handbook" "Comm. & Ind. Wiring" "Ugly's Elect. Ref. 2011" "Ugly's Elect. Safety & NFPA 70E" "Ugly's Elect. Motors & Controls" "Ugly's Conduit Bending"	978-0-8776-5916-7 978-0-8269-2075-1 978-0-7637-9099-8 978-0-7637-6855-3 978-0-7637-7254-3 978-0-7637-8314-3	Early & Sargent / NFPA Barnett / ATP Jones & Bartlett Publishers Jones & Bartlett Publishers Jones & Bartlett Publishers Stanfield / Jones & Bartlett
BUAS 2040 (5 / 48944) **BAS Integration**	"Building Automation System Integration with Open Protocols"	978-0-8269-2012-6	NJATC / ATP
BUAS 2050 (5 / 48945) **BAS Internship**	No textbook required		

BEST Center Curricula, Resources & Recordings

Academic Programs
Georgia Piedmont Technical College - Building Automation Systems
Milwaukee Area Technical College - Sustainable Facilities Operations
Laney College - Commercial HVAC Systems
City College San Francisco - Commercial Building Energy Analysis & Audits

Professional Development Materials, Presentations & Videos
National Institutes
Building Automation Systems Instructor Workshops
Webinars (e.g., BEST Talks)

Faculty Profile Videos
Reports & Case Studies
Marketing Resources

BEST
Building Efficiency for a Sustainable Tomorrow

NSF National Science Foundation