UMES –NASA Collaborative Achieves Phase-I Mission Objectives

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Abstract

UMES-AIR (**U**ndergraduate **M**ultidisciplinary **E**arth **S**cience-**A**irborne **I**maging **R**esearch) project was partially funded by NASA Goddard Space Flight Center (GSFC) in the fall of 1999. The project has provided a platform for involving a group of more than twenty undergraduate students in mathematics, science, engineering and technology (MSET) curricula at University of Maryland Eastern Shore (UMES) in an "out of classroom" active learning and exploratory research experience in the field of remote sensing and its applications. The scientific objective of the project includes aerial imaging in the visible and infrared region of the electromagnetic spectrum, land survey, study of shoreline erosion, research in agricultural land use patterns, and environmental studies pertaining to algal blooms in the Chesapeake Bay. The project also has a strong focus towards educational objectives and involves more than twenty students from different MSET curricula at UMES. UMES, an 1890 Land Grant historically black university has a large minority population and all efforts are made to involve minority students to participate in the project activities. Success of the initial educational efforts and student teamwork, prior to year 2001 was reported in the 2001 Annual Conference of the American Society of Engineering Education (ASEE). During this period the efforts were directed towards payload design, system integration and management efforts for collecting remote images from a tethered blimp from a height of upto 500 ft. using a manual winch. Significant strides were made with the project during the year 2001. The Phase-I goal of collecting images from a helium filled tethered blimp from a height of 2500 ft. was successfully achieved by students working in close collaboration with the NASA/GSFC Wallops Flight Facility (WFF) engineers and technical /administrative personnel. Efforts have also been directed towards acquiring appropriate hardware and software for digitizing the collected images and performing image analysis as well as live broadcast of the blimp launch over the internet. In this paper we outline efforts related to acquisition and integration of an automated winch, design modifications of the payload to

acquire images with different band-pass filters from the remote cameras and initial results of image analysis.

1. Introduction

This paper describes a NASA-UMES collaborative project primarily involving passive remote sensing experiments using reflectance patterns in the visible region of the electromagnetic spectrum. Color and monochrome cameras mounted on a payload structure (gondola) attached to a tethered blimp are used to transmit remote images from the blimp as it ascends to pre-determined height above the ground. The images captured by the remote cameras have been successfully transmitted via transmitters mounted on the gondola and subsequently received on the ground using a receiver antenna and displayed and recorded on the TV-VCR Combo unit on the ground. The captured images are currently being analyzed using Multispec[1] an image analysis package developed at Purdue University. ERDAS[2], a commercially available software package, will also be used for image analysis in the future. Future plans of the project include experiments/applications in the infrared region. The scientific objectives of the project include generating information concerning vegetation data for precision farming applications, shoreline erosion, changing land use patterns and wildlife management. Initial tests and software analysis have been performed on surfaces that have distinctly different spectral signatures yielding useful data pertaining to land use patterns. The outcomes and achievements pertaining to the project prior to year 2001 were reported in the 2001 ASEE Proceedings [3]. It may be worthwhile for the interested reader to peruse the article to develop a more complete perspective for the progress of the project reported in this article.

II. UMESAIR Vision and Mission Statements and Phase-I Mission Objectives

At the outset it was decided via discussion among NASA personnel and involved faculty members that the project would be a vehicle to engage UMES students in a mission based project that parallels NASA and other government initiatives in the real world. In consultation with the students and keeping in mind the project goals and objectives the following Vision and Mission statements were identified:

(i)*Vision*: The vision of the UMESAIR project is to provide experiential learning primarily for undergraduate Science, Mathematics, Engineering and Technology (SMET) students. Students will interact in teams to investigate multi-disciplinary problems associated with applications of remote sensing.
(ii) *Mission*: The mission of the UMESAIR project is to design, build, and fly an instrumented payload to remotely determine coastal topographic and vegetation features.

A significant and immediate goal of the project is the education of the participating students. The participating faculty members, NASA engineers and university administrators recognized the limitations pertaining to instructional modes available within the university structure and the diversity of learning styles among its student population[4]. The broad vision for the project incorporated a means to integrate a variety of learning styles among students following Kolb's experiential learning cycle. Significant attention is paid towards exposing students through all four phases of the experiential learning cycle[5,6] involving *concrete experience (CE)*, *reflective observation(RO)*, *abstract conceptualization (AC)*, and *active experimentation(AE)* . Figure 1 illustrates the experiential learning cycle.

The activities within the project are designed to encourage all students to realize that while their individual inclination may be compatible with one or more of the four phases within the cycle, a holistic learning experience necessitates that they not only undergo *concrete experiences* but learn to *reflect* on these experiences as well. Furthermore, they are also made aware that their *reflective observations* should lead them to compare some of their conclusions with the *abstract concepts* that they are exposed to in the class room environment so as to be able to comprehend these concepts from a more individualized perspective. Finally the combination of the *abstract concepts* and intuitive knowledge gained from practical experience should guide them with regard to devising more active experimentations which will lead to new concrete experiences.

The project has provided a platform to promote teamwork and other learning outcomes advocated by Criteria 2000 of Accreditation Board of Engineering and Technology [7]. Combined with Kolb's experiential learning cycle, Criteria 2000 of ABET provided the guiding philosophy for the Vision of the project. It was also necessary to define concrete Mission Objectives to develop team activities consistent with the broad vision statement, as well as enable exploration of the frontiers of knowledge in the growing area of remote sensing and related applications.

The Phase-I Mission Objectives include:

(i) Design and development of a remote imaging device that would be flown as a payload on a tethered blimp upto a height of 2500 ft.
(ii) The imaging device should successfully transmit remote images to a ground station for viewing and recording.
(iii) The tethered blimp with all instrumentation will be flown over appropriate locations on UMES Campus and NASA/GSFC/WFF's Wallops Island.
(iv) The integrated system will include a winch with tether, a blimp, a ground station and the payload. Efforts will be made to ensure that the blimp can be raised and lowered in a reasonable amount of time.
(v) The system components will be conveniently transportable.
(vi) The project efforts will include detailed documentations. All launches will be performed using predetermined procedures and guidelines including safety regulations of Federal Aviation Administration (FAA) [8].

III. Project Enhancements and Achievements in the year 2001

Prior to year 2001 the UMESAIR project efforts were directed towards payload design, system integration and management efforts for collecting remote images from a tethered blimp from a height of upto 500 ft. using a manual winch. Significant strides were made with the project in the year 2001 and particularly in the summer of 2001. All the phase-I mission goals as listed above were achieved during this period by UMES students working in close collaboration with the NASA Wallops Flight Facility engineers and technical /administrative personnel.

III a. Automated Winch

While the manual winch was adequate for raising and lowering the blimp to and from a height of 500 ft., it needed to be replaced with a more efficient arrangement for blimp launches to higher elevations. A student team was entrusted with the responsibility of identifying/designing an appropriate winch for blimp launch to 2500 ft. In consultation with the authors of this article the student teams developed a set of specifications for the winch which included a cost budget of 4000 dollars, a spool capacity of 2750 ft. and a speed of retraction of approximately 100 ft./min so as to enable retraction of the blimp from a height of 2500ft. in less than 30 minutes. However, identifying/designing such a winch posed a significant challenge. Several alternatives were investigated including one with an electric generator powering an electric motor to turn the shaft of the winch spool. Eventually, a vendor was identified that was able to custom design the winch according to student specifications using a hydraulic drive with a lawn mower engine. The automated winch includes 5.5 hp gasoline engine that drives a 3.5 gpm pump developing 1500psi which turns a 7.3 cubic inch hydraulic winch motor developing average line speed of approximately 100 ft./min. The system also comes with a hydraulic fluid cooler and filter and 12 ft. hand held remote control. The purchase price of the custom designed unit was less than $3000. Figure 2 shows the automated winch system described above that is currently being used in the UMESAIR project. The automated winch not only allowed raising and lowering the blimp with relative ease but also allowed the elimination of elaborate rigid fixtures that were necessary for use with the manual winch. This also provided a step in the right direction towards ease of transportation of the integrated system from one place to another. Several blimp launches on UMES campus in the fall of 2000 and spring of 2001 were conducted with the automated winch to gain practice with the new equipment.

III b. Filter Switching Apparatus

It has been reported earlier [3] that the payload included both a monochrome and a color camera. It was necessary to adjustment the power supply design to successfully transmit images from both cameras, using different channels (frequencies), to the same ground station receiver. During any launch a ground station operator can manually change channels to receive images from either the monochrome or color camera. Moreover, it was decided to provide a capability to hold different band pass filters in front of the monochrome camera during the launch so as to allow or restrict certain characteristic frequencies in the image to pass through or get absorbed as appropriate for reception at the ground station. Providing this capability on the remote payload from ground provided a significant challenge. An apparatus was needed that would be lightweight, power efficient, and fit amongst the existing instrumentation in payload-gondola. The project payload-gondola has a long rectangular bottom, which has the cameras mounted down through as shown in Figure 3. A linear formatted filter switcher was needed to fit along with the structure of the gondola. A student team took up the challenge and designed and developed the device described below. A sophomore student (Mr. Matthew Watson) made a significant contribution in developing the device.

Figures 3 and 4 demonstrate the basic mechanical mechanism of the filter switcher. A string is wound around the shaft of a toy motor labeled as *A*, and is kept in tension around it by the spring labeled *B*. The pulleys labeled as *F* allow for the system to move the tray labeled as *D* back and forth across the camera labeled as *C* in a loop system. The filters are contained inside the tray and are labeled as *E*.

In addition to the problems involved with the mechanical aspects of the filter switcher there was also finding a means of controlling it from the ground. A remote controller system normally used with model airplanes was used to control the system. The problem faced with that system was that it wasn't compatible with our mechanical system that was designed for our gondola. A mechanical-electrical interface was needed to convert the partial rotary motion of the Radio Controllers servomotor into a controlling electrical signal for our mechanical system. Figures 5 and 6 show this system. *E* is the Radio control receiver, *B* is the radio controller's stock servo motor, *A* is a switch that functions as a double pole double throw switch, *C* is a student fabricated junction between the two, *F* is the input 6 volts to the radio control circuit, *D* is the 9 volt input to the switch, and *G* is the output line to the motor shown in the last section. This particular switch was chosen because it easily converts a rotary motion into a switched polarity output. Figure 7 shows the hand-held joystick controller used to activate the filter switching apparatus, as well as the modified payload-gondola.

With successful implementation of all modifications the project team was now ready to attempt the 2500 ft. launch of the blimp from NASA's Wallops Island. The project team visited the launch site at NASA/GSFC/WFF Wallops Island several times during the summer of 2001 to perform activities such as site inspection, equipment transportation and set-up, and to hold preliminary, intermediate and final meeting with NASA personnel. The 2500 ft. blimp launch was carried out successfully on August 1, 2001 at NASA's Wallops Island. During this launch the blimp was held stationary for about a minute at every 125 ft. during ascent, images were transmitted continuously throughout the flight. The channels were switched successfully to transmit both monochrome and color images from the monochrome and color camera on the payload respectively. The filter-changing device was activated successfully to acquire images with different pass-bands from the monochrome camera. The automated winch was successful in retracting the blimp within 30 minutes from the height of 2500 ft. thereby successfully executing all the phase-I field based mission objectives.

IIIc. Image Analysis

Since the inception of the project image acquisition and subsequent analysis has been the key deliverables of the project. Success of the field activities allowed acquisition of remote video recordings of the UMES Campus from a height of 500 ft. and specific location of the NASA Wallops Island facility from a height of 2500 ft. However, the phase-I mission objectives also included initial analysis of some of the frames of the acquired video recordings for land use pattern data. A student team with faculty and

NASA personnel supervision continues to investigate and study this aspect of the project. So far PIT(Photo Interpretation Toolkit) developed by NASA Applied Information Science Branch, Multispec a software environment developed at Purdue University and ERDAS a commercially available software tool developed by 3-D I Systems have been explored in the project. It was difficult to convert image frames from acquired video recordings into formats suitable for use with PIT hence it has been decided to discontinue further explorations with this software. The project teams continue to work with both Multispec and ERDAS. Some of the initial results using the Multispec software are reported here.

Both Multispec and ERDAS software can perform analysis on digitized frames of video images. An appropriate image analysis station has been acquired for converting the video recordings into digitized streaming video from which individual frames can be acquired and converted to appropriate format for further processing using the software tools mentioned before. A Silicon Graphics workstation with appropriate image conversion hardware and software is currently being used as the image analysis station for the project.

While the image analysis station with its appropriate hardware and software tools was necessary to work with the remotely acquired video images, initial efforts to learn the software could proceed with images acquired by a digital camera. Figure 8 shows analysis of an image of a flowerbed on UMES campus acquired with a digital camera from the ground. The analysis has been performed using Multispec. The software allows defining classes of a certain pattern or color in the image and then the software determines number of pixels in the image belonging to each class using variety of classification algorithms. An appropriate mapping of the pixels into real world dimensions would result in data that would indicate land use patterns for appropriately defined classes. The interested reader can learn more about the software by visiting the URL and /or downloading the software via internet[1].

Figure 9 shows analysis results using the Multispec software for a digitized frame of the video recording of images acquired from a blimp launch on UMES campus from a height of 500 ft.

Figure 10 shows analysis results using the same software for a digitized frame of the video recording of images acquired from the blimp from a height of 2500 ft. on the NASA Wallops Flight facility during the August 7, 2001 blimp launch.

Efforts are currently underway to analyze the image frames of the video recordings obtained from UMES campus and NASA Wallops Flight Facility using ERDAS. Multispec software is being explored by the project group to analyze the images from the monochrome camera as well.

IV. Accomplishments, Ongoing Efforts and Future Plans.

Project accomplishments in the year 2001 include 2 launches on UMES campus to a height of 500 ft. with all instrumentation and the integrated automated winch system. These flights resulted in video data of the campus from the earth-imaging cameras integrated in the first truss type payload structure designed and developed by UMES students in the year 2000 (Figures 3 and Figure 7). During the fall semester, the student team conducted two additional flights over the UMES campus with a new and improved payload gondola design (Figures 11a and 11b).

A significant achievement during the year included the close interaction of UMES project team with NASA GSFC's WFF personnel which resulted in a fully documented "Range Implementation Plan" and "Operation and Safety Directive" prior to the August 1 launch of the blimp with all instrumentation, automated winch and fully operational ground station to receive and record transmitted data from 2500 ft. This provided valuable exposure to the UMES students to operational procedures at NASA.

A student team worked closely with Information Technology personnel at UMES to provide a live webcast of the blimp launch over the internet. This trial launch was conducted on UMES Campus on August 14th 2001. This ability can be utilized for a variety of educational efforts in the future. In the future we hope to provide a live webcast of not only the launch but also the observations from the remote camera on the internet.

Also during the year 2001 student participants and the principal author of this paper made three presentations of the project at important conferences including 2001 ASEE conference in Albuquerque. These presentations not only provided the students important life experiences involving development and delivery of presentations using modern software tools but valuable exposure to professional conferences.

In accordance with Kolb[5] and the philosophy of continuous improvement, late summer 2001 efforts were directed to development of the improved structure and suspension arrangement for the payload gondola as mentioned earlier in this section. Figure 11a & 11b show new the structure, which will allow a more stable platform to acquire remote images from the tethered blimp. In the latter half of the fall semester of 2001 this new payload was flown on the blimp on UMES campus. These launches were restricted to 500ft. and were used to test the improved stability of new triangular design of the payload gondola. Payload instrumentation included a temperature sensor, a pressure sensor, a GPS unit, and associated data-loggers to record the temperature, pressure and blimp coordinates as the blimp was raised and lowered. Data analysis for these flights is underway. Temperature and pressure profiles will be correlated with GPS height information, and wind direction and magnitude may also be extracted from the GPS track.

These flights not only verified that the new structure provides improved stability during flight operations with the blimp but has also opened up educational and scientific opportunities in the field of instrumentation and data acquisition using the integrated blimp system. One of the project teams is continuing to work on remote imaging and transmission instrumentation on the new gondola for a future blimp launch. The students are also working towards integrating a digital camera and new and improved design for the filter switching arrangement. Also collaborative efforts will be conducted with a NASA infrared camera system possibly suitable for applications such as mapping of underground steam-pipes and other topographic features.

V. Conclusion

The UMES-AIR project continues to provide valuable experience for the UMES students in mathematics, science, engineering and technology fields. With progress of the project variety of educational opportunities have opened up which can continue to keep the students positively involved for a significant length of time in the future.

The UMES-AIR project is successfully producing educational outcomes related to teamwork, design process, remote sensing, system integration, communication skills development and internet technology utilization. Results to date show that systematic field efforts to obtain remote imaging, combined with subsequent image analysis, may be useful and practical for Earth science applications such as the monitoring of land use, shoreline erosion, and precision farming.

VII. Acknowledgment

The authors wish to acknowledge the support from University System of Maryland Board of Regents to continue the project activities in the year 2001. The initial grant from NASA Goddard Space Flight Center (Grant # NCC5-437) is gratefully acknowledged. Support from UMES administration, staff and faculty have also been a significant motivation for the students. The involvement of the NASA WFF staff for assisting with the project and in particular for the launch operation at their site is acknowledged with sincere gratitude. The students have carried the project and have done a wonderful job and we hope will continue to do so.

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Abhijit Nagchaudhuri is currently an Associate Professor in the Department of Engineering and Aviation Sciences at University of Maryland Eastern Shore. Prior to joining UMES he worked in Turabo University in San Juan , PR as well as Duke University in Durham North Carolina as Assistant Professor and Research Assistant Professor, respectively. Dr. Nagchaudhuri is a member of ASME, SME and ASEE professional societies and is actively involved in teaching and research in the fields of engineering mechanics, robotics, systems and control and design of mechanical and mechatronic systems. Dr. Nagchaudhuri received his bachelors degree from Jadavpur University in Calcutta, India with a honors in Mechanical Engineering in 1983, thereafter, he worked in a multinational industry for 4 years before joining Tulane University as a graduate student in the fall of 1987. He received his M.S. degree from Tulane University in 1989 and Ph.D. degree from Duke University in 1992.

GEOFFREY BLAND

Geoffrey Bland is a member of the NASA Goddard Space Flight Center, Laboratory for Hydrospheric Processes, Observational Science Branch, located at the Wallops Flight Facility, VA. Primary research activities are focused on the development and utilization of uninhabited aerial vehicles (UAVs) and associated sensors for Earth science related measurements. Previous work includes mission management and engineering support of sub-orbital sounding rocket and aircraft borne experiments. Bland is a member of AIAA, AMS, and AUVSI. Bland has also served on the UMES Engineering and Engineering Technology Advisory Committee since 1995. Bland received a BS degree in Aeronautics and Astronautics Engineering from Purdue University in 1981.

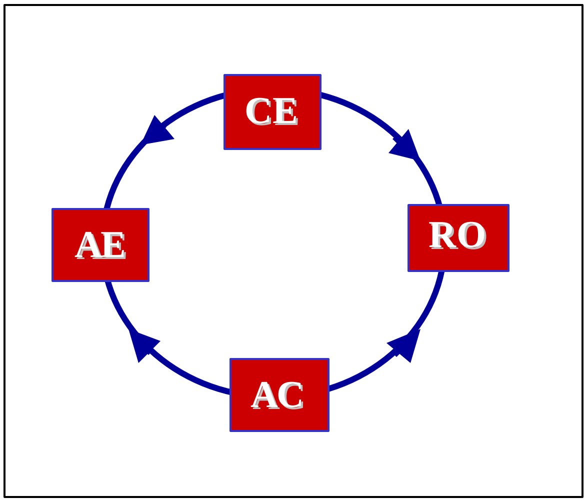


FIGURE 1

FIGURE 2

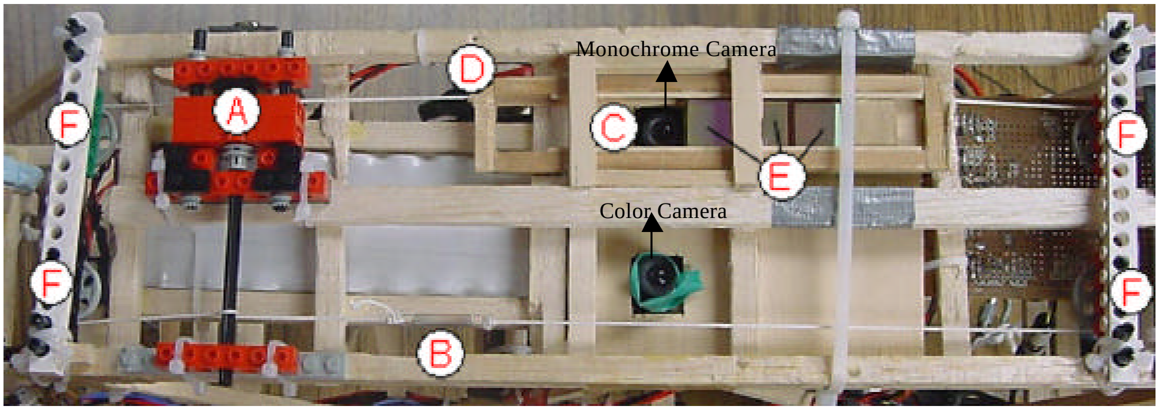


FIGURE 3

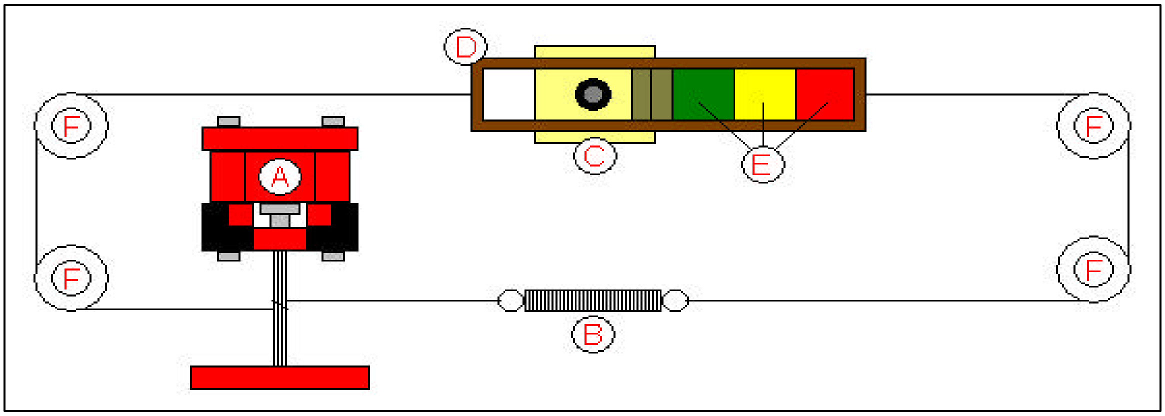


FIGURE 4

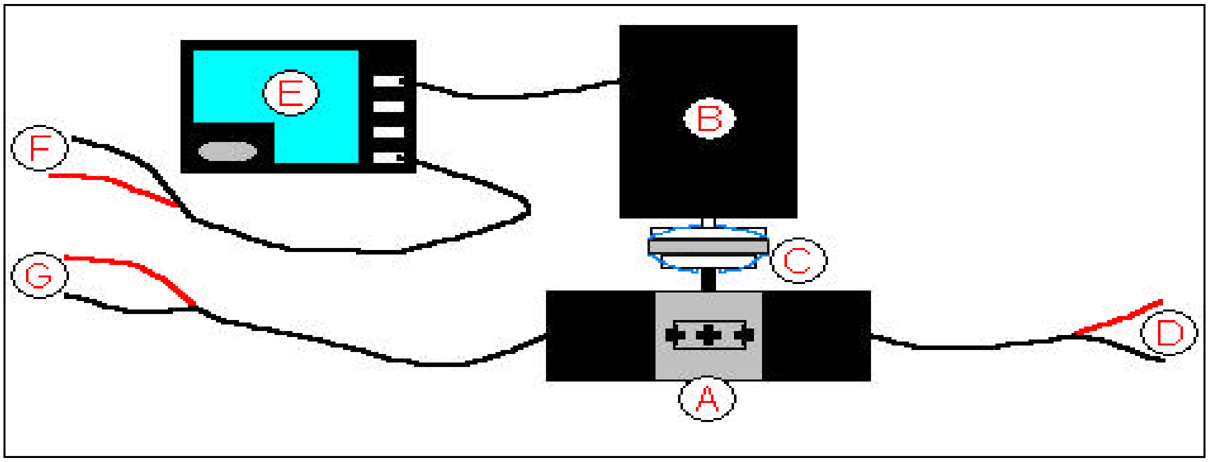


FIGURE 5

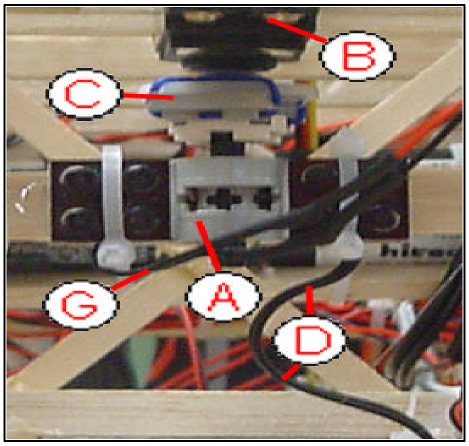


FIGURE 6

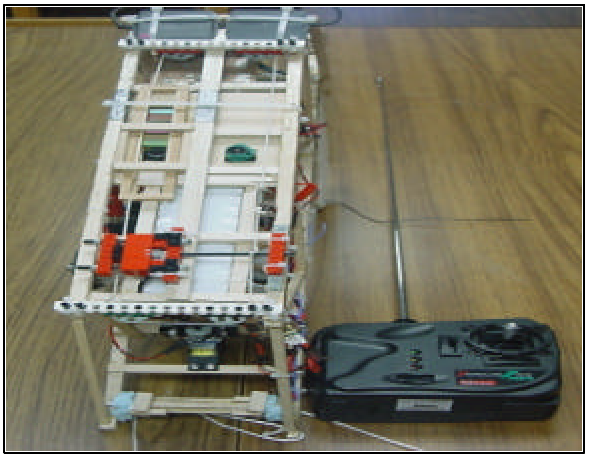
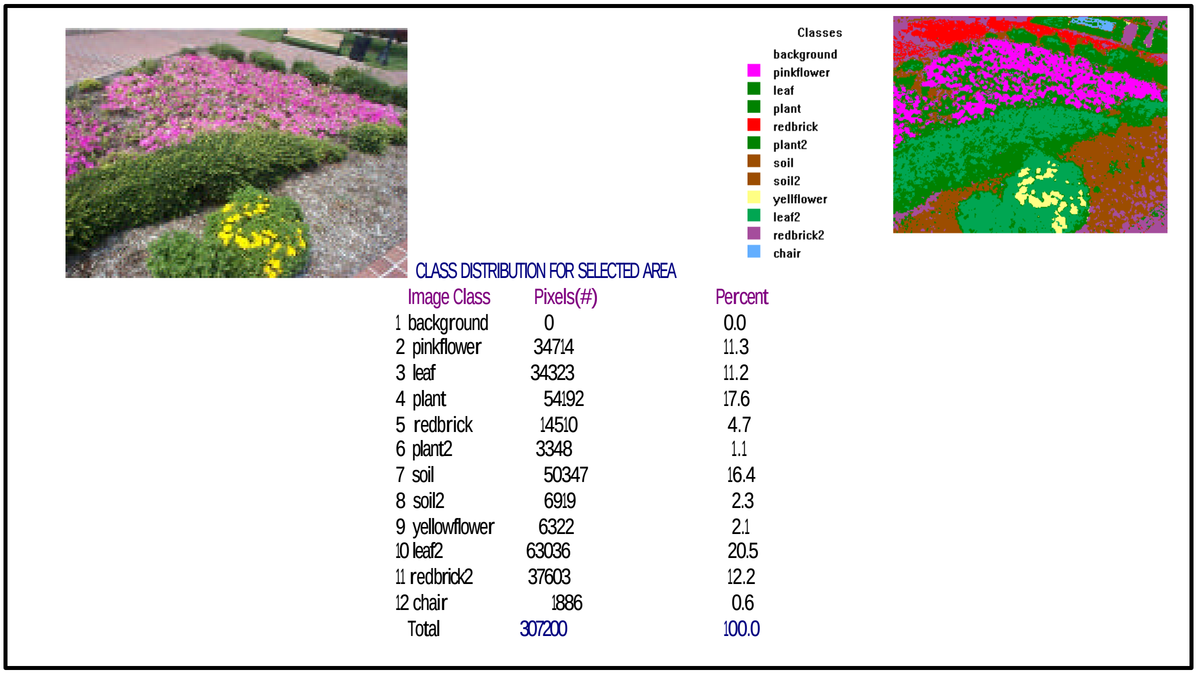


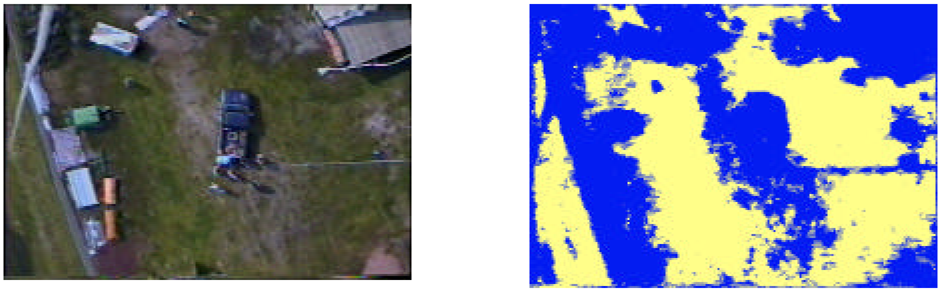
FIGURE 7



CLASS DISTRIBUTION FOR SELECTED AREA

	Image Class	Pixels(#)	Percent
1	background	0	0.0
2	pinkflower	34714	11.3
3	leaf	34323	11.2
4	plant	54192	17.6
5	redbrick	14510	4.7
6	plant2	3348	1.1
7	soil	50347	16.4
8	soil2	6919	2.3
9	yellowflower	6322	2.1
10	leaf2	63036	20.5
11	redbrick2	37603	12.2
12	chair	1886	0.6
	Total	307200	100.0

FIGURE 8



Remote true color picture taken directly from on-board camera

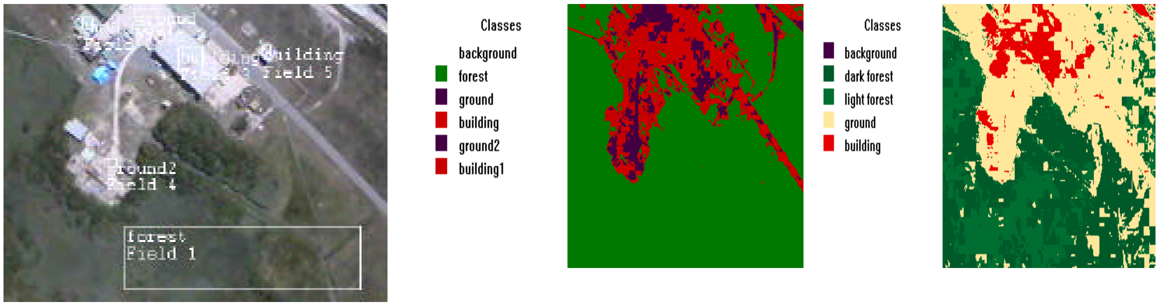
After image analysis with MultiSpec showing green areas in yellow and background in blue

CLASS DISTRIBUTION FOR SELECTED AREA

	Class	Pixel (#)	Percent
1	green	176407	50.4
2	not green	173513	49.6
Total		349920	100.0

End maximum likelihood classification

FIGURE 9



CLASS DISTRIBUTION FOR SELECTED AREA

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2	**forest**	**207091**	**74.7**
3	**ground**	**6980**	**2.5**
4	**building**	**22760**	**8.2**
5	**ground2**	**13473**	**4.9**
6	**building1**	**26944**	**9.7**

FIGURE 10

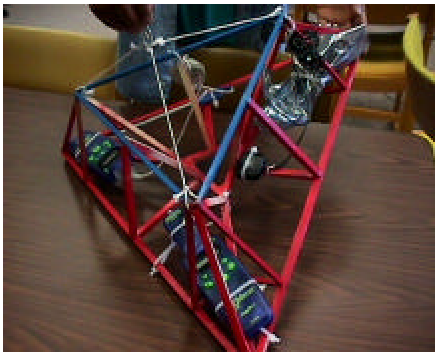

FIGURE 11a

FIGURE 11b