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13. ABSTRACT *(Maximum 200 words)*

Early strike forces of the future military are envisioned as being lightly armored to enable a rapid deployment. The increased vulnerability and operational tempo of lightly armored forces evokes the need for beyond-line-of-sight reconnaissance capability under the control of the troops on the ground. The objective of this work is to explore and evaluate system level concepts that fulfill this mission using an unmanned air/ground vehicle. Extreme Engineering has designed a UAGV according to specifications given by AMCOM. The UAGV is described in detail in this paper. It uses a ducted fan design with a Wankel engine fueled by JPA jet fuel. An aerodynamic shape and advanced fan design allow the vehicle to fly quickly and efficiently. Light, yet strong materials will be used for the vehicle body and wheel system, making this vehicle highly resistant to all types of environment. Communications and sensor equipment will be used to recognize the environment around the vehicle. Three computers will operate on board the UAGV to interpret and respond to the environment. A system has been designed to reduce the vehicle's acoustic signature to a practically undetectable level. Each vehicle system is detailed in this paper, and accompanying calculations, charts, and tables are included.

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Integrated Unmanned Air-Ground Robotics System

Final Report – Volume II

Submitted By:

Extreme Engineering

Contract DAAH01-98-0-R001-D.O. 105

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NASA MSFC	NASA Ames

The University of Alabama in Huntsville
April 26, 2001

Executive Summary

English

Extreme Engineering has designed a UAGV according to specifications given by AMCOM. The UAGV is described in detail in this paper. It uses a ducted fan design with a Wankel engine fueled by JPA jet fuel. An aerodynamic shape and advanced fan design allow the vehicle to fly quickly and efficiently. Light, yet strong materials will be used for the vehicle body and wheel system, making this vehicle highly resistant to all types of environment. Communications and sensor equipment will be used to recognize the environment around the vehicle. Three computers will operate on board the UAGV to interpret and respond to the environment. A system has been designed to reduce the vehicle's acoustic signature to a practically undetectable level. Each vehicle system is detailed in this paper, and accompanying calculations, charts, and tables are included.

UAGV Compliance List

The following list details the location of all specification compliances for the UAGV. The list shows the location in the CDD provided by the Army of every specification and the number of the page where that specification is dealt with in this proposal.

Specification:	CDD location:	Proposal location:
Versatile scout and pack animal for future force structures	1.1.1	2.4.1
Area/target reconnoitering	1.1.2	2.7.2
Terrain definition	1.1.3	2.7.2
Situational awareness	1.1.4	2.7.1,2.7.2
Autonomous and Semi-autonomous	1.1.5	2.7.1
Capable of human Interface	1.1.6	2.7.1,2.7.3
Can function without paylod	1.1.7	2.7
Can operate in nap of the earth mode	1.2.1	2.2
Operates 15-30 km from launch point	1.2.2	2.3.1,2.3.5
Capable of gather information at range	1.2.2.1	2.7.2
Enhances RSTA/BDA	1.2.2.2	2.2
Transmits using secure data links and C2 Structures BLOS	1.2.2.3	2.7.2
Possesses TF/TA hardware and software	1.2.2.4	2.7.1
Contains a degree of AI, ATR, and On-board decision making	1.2.2.5	2.7
Can carry 60 lb. payload	1.2.3.1	2.6.2
Can move to range in 30 min or less and Return in the same	1.2.3.2	2.3.5
Cruise speed of 30 km/hr	1.2.3.2.1	2.2.2, 2.2.3
Capable of landing in unprepared areas	1.2.4.1	2.4.1
Capable of VTOL	1.2.4.1.1	2.2.1
Maximize Survivability	1.2.4.3	2.7
Avoids sonic detection	1.2.4.3.1	2.7.2
Quiet Acoustic Signature	1.2.4.3.2	2.3
Operational Altitude of 0-500 ft. AGL	1.2.4.3.3	2.2
VROC of 250 fpm	1.2.4.3.4	2.2.1
Hover to full flight profile	1.2.4.4	2.2.1, 2.3.5
Operates at high, hot conditions	2.1	1.3.3, 2.2
Operates under adverse environmental Conditions	2.2.1	2.7.2
Operates under adverse geographical Conditions	2.2.2	2.4.1
Can operate from unimproved land Or sea borne facility day or night	2.2.3	2.4.1
Capable of operating through battlefield obscurants	2.2.4	2.7.2
Capable of point and click pre-mission	2.3.1.1	2.7.1

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Common Terms and Acronyms List

Word	Comments
AGL	Above Ground Level
AIAA	American Institute of Aeronautics and Astronautics
AMCOM	United States Army Aviation and Missile Command
BLOS	Beyond Line of Sight
CM	Communication
Concept Description Document	Document that details the customer's technical specifications for the UA/UGV
Customer	John Fulda and Jim Winkeler
EE	Electrical Engineering
EH	English
EM	Engineering Management
ESTACA	Ecole Superieure des Techniques Aeronautiques et de Construction
FLOT	Forward Line of Troops
Ft	Feet
IPT	Integrated Product Team
IRP	Intermediate Power Rating
JAUGS	TBD
JCDL	TBD
Joint Vision 2020	TBD
km	Kilometer
lbs.	Pounds
MAE	Mechanical and Aerospace Engineering
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
Payload	Item carried by the system having a specified weight
Phase I	Baseline review, conducted on conventional configuration using current and experimental technology, assess technologies clarify the Concept Description Document
Phase II	Alternative concepts review, development and evaluation of four prototype designs to meet customer specifications. Select a preferred design.
Phase III	Final Evaluation, detailed design specifications of selected design concept
Style Guide	Document that specifies the mechanics of writing documents required for the project
TBE	Teledyne Brown Engineering
TF/TA	Terrain following/terrain avoidance
UAH	The University of Alabama in Huntsville
UAV	Unmanned Air Vehicle
UAVG	Unmanned Aerial and Ground Vehicle

UGV	Unmanned Ground Vehicle
US	United States
VROC	Vertical rate of climb
VTOL	Vertical takeoff and landing

Team-Specific Terms and Acronyms List

Word or symbol	Comments
AOA	Angle of Attack
C	Blade chord
CDR	Critical design review
C_D	Drag Coefficient
C_L	Coefficient of Lift
D	Vehicle Dag
DDT&E	Design, development, testing, & engineering
DoD	Department of Defense
f_T	Frontal area of vehicle
IOC	Interim operational capability
LOS	Line of Sight
N	Number of Blades
PDR	Preliminary design review
R	Radius of Fan
ρ	Density of air
SRR	System requirements review
SDR	Systems design review
T	Thrust
TF/TA	Terrain Following/Terrain Avoidance
V_{roc}	Vertical rate of climb
V_{tip}	Velocity at the tip of the blade
W	Weight of vehicle

IPT 1: Feasibility of Unmanned Air/ Ground Vehicle (UAGV)

1.0 UAGV – Unmanned Air/ Ground Vehicle

1.1 The Need

The battlefield on which we fight is evolving as each year goes by. Warfare is becoming increasingly dangerous for the soldier. Because of this, the need for a hybrid unmanned aerial and ground vehicle (UAVG) is necessary. This vehicle would combine the attractive aspects of both unmanned aerial and ground vehicles.

This vehicle will be used for missions that are considered "dirty, dangerous and dull" for the soldiers. (Fulda, Winkeler) These are missions such as reconnaissance and surveillance in volatile areas or where the risk of a soldier losing his life is high. The missions that the military perform are increasingly more dangerous to the personnel performing them. Also, because technology has spread rapidly throughout the world the military must be conscious of the "CNN factor." (Winkeler, Fulda) The media reports on battlefield happenings daily and Americans do not like to see their sons and daughters die on television.

Another concern of the military is the size of the forces that will do combat on the field. The Army is looking towards lighter forces in the future. While lighter forces provide greater mobility for the troops it also makes the troops more vulnerable. Therefore it is necessary to improve the reconnaissance capability at the battalion level. The battalion is the smallest level of troops on the battlefield. This is the level where the UAVG will be the most useful.

This vehicle will not replace the soldier on the battlefield but rather aid him in performing his duties safely. When introducing new technology into the military the troops must accept it and must be willing to learn how to use the technology to their advantage. The Army makes great effort to produce tools to aid the soldier not replace him. Without this vehicle, the forces of the future will be not be able to perform their jobs safely and effectively.

1.2 The Requirements

The project started when AMCOM approached us with the idea of a UAGV. As the customer they provided Extreme Engineering with the Concept Description Document (CDD) to design to. This document lays out all of the requirements for the vehicle that AMCOM feels are important for the vehicle to be usable on the battlefield of the future. The UAGV must be designed for implementation by 2025. This gives time for development and testing of the concept. The Army wants the vehicle to be in full production by 2025.

The customer has given a specification that will be met as closely as possible by Extreme Engineering's UAGV. The vehicle must be able to travel at least 15 kilometers from the launch point in 30 minutes or less. The customer requested this because the vehicle will be primarily used for reconnaissance and surveillance. This means that the troops can send it to range and have it return in less than an hour thereby allowing the vehicle to be sent in many different directions through the day.

The vehicle must have a cruise speed of at least 30 kilometers per hour, and a vertical rate of climb of at least 250 feet per minute. These requirements were given for various reasons. The 30 kilometers per hour satisfies the requirement that the vehicle be able to go to range in 30 minutes or less. We understand that the 250 feet per min VROC was chose because this is the average height of a building in most areas. Also, this is a sufficient VROC when the vehicle is required to take evasive actions.

It is required to have VTOL capability, and autonomous and semi- autonomous operation. The VTOL capability is an important aspect of the vehicle because it has affected the way the vehicle had to be designed. This is an important factor because the vehicle must be able to move in any terrain; therefore the VTOL capability is useful in wooded areas. This capability is also important in the avoidance of danger.

The customer also put forth a requirement that the vehicle be able to carry a payload of 60-120 pounds. We understand that this payload will primarily be a reconnaissance package that will require no power or interface with the vehicle. However, the payload may be something other than this package and therefore the vehicle must be able to operate with or without the weight of the payload. The UAGV must be able to function as specified in the air, on the ground, and in all weather conditions

1.3 The Solution

Extreme Engineering has designed a UAGV, the XTR-1, which will meet most of the requirements given by the customer. The XTR-1 will have an elliptical shape to prevent excessive drag on the vehicle. XTR-1's major systems are the engines, ducted fan, and wheels. The XTR-1 is shown in Figure 1.

The vehicle is fairly lightweight, coming in at around 480 pounds. Also the XTR-1 is capable of VTOL and has a VROC of 250 feet per minute. The vehicle can fly at 30 kilometers per hour during forward flight. 12 thrust vectoring ports, 6 on either side, provide the VTOL. During forward flight these ports provide directional control for the vehicle. The thrust required for forward flight will be provided by the PDE. The PDE is very small dimensionally and is very lightweight. However even though it is small it provides a great deal of power. The XTR-1 has wings and a tail fin to provide extra lift and stability. The extra lift reduces the amount of power the engines must provide.

The XTR-1 has high ground mobility by utilizing semi spherical wheels on movable struts. These wheels are powered by the Wankel engine and are front wheel drive. The wheels are made from Abs plastic, which is a strong lightweight material. The struts are made from an aluminum-beryllium composite. This material is very strong and can be cast into many shapes.

The XTR-1 has a complete sensor package allowing the vehicle to operate without the payload. The vehicle will utilize radar, acoustic sensing, TF/TA, and communications platforms. The sensors will allow the XTR-1 to operate in adverse weather conditions such as fog or smoke. The communications will allow the vehicle to be capable of LOS and BLOS communications. The primary BLOS communication will be a high frequency band. The vehicle will be semi-autonomous due to the fact that some human interface will be required.

1.3.1 Concept Overview

Extreme Engineering has designed a UAGV, which will incorporate many new and existing technologies to meet the needs of the customer. The vehicle will use a small, powerful, ducted fan to provide lift. The ducted fan will be powered by a Wankel engine, which will be fueled by JP-8. The UAGV will use a sensor package including acoustic sensor, mapping radar, fiber optic gyroscopes, and other sensors. Computers will use TF/ TA software packages to navigate terrain, combined with other programs to process information. The UAGV will also use a combination of communication systems, including IFF and multi-directional antennas, to communicate with various sources. Each system is described in further detail later in this report. The UAGV design was chosen because it best meets customer requirements.

Figure 1: Artist Drawing of "XTR-1"

1.3.2 Dimensional Properties

The XTR-1 is 7 feet long with a diameter of 3.5 feet. The wingspan of the vehicle is 3'4" on either side of the vehicle. There will be a tail fin to provide stability to the aircraft. The XTR-1 will be capable of carrying the required 60-pound payload. This payload will be located on the top of the vehicle over the center of gravity of the vehicle. The fuel tank will be located directly under the payload and will deliver fuel to both the PDE and the Wankel engine. The fan is located at the front of the vehicle behind a nose cone. The airflow from the fan will be directed into a duct where it will be compressed into a 6-inch duct. From there the flow will be forced through 12 two-inch thrust-vectoring ports. These ports will provide the lift for the VTOL capability and provide directional control during forward flight. The nose cone makes the vehicle more streamline and prevent the airflow from hitting a flat face. The wheels will be semispherical and made from ABS reinforced plastic. These wheels will be connected to the vehicle using movable struts. This allows the vehicle to move over rougher terrain without turning over or stopping. Figure 11 shows the cross section of the XTR-1. The Wankel engine powers the wheels and the vehicle will be front wheel drive.

The sensors will be located all over the body of the vehicle. The highest concentration of sensors will be on the top of the vehicle towards the front. Theses sensors will be behind a windshield to reduce drag.

Figure 2 shows a three view drawing of the vehicle. This drawing has a few of the major dimensions on it.

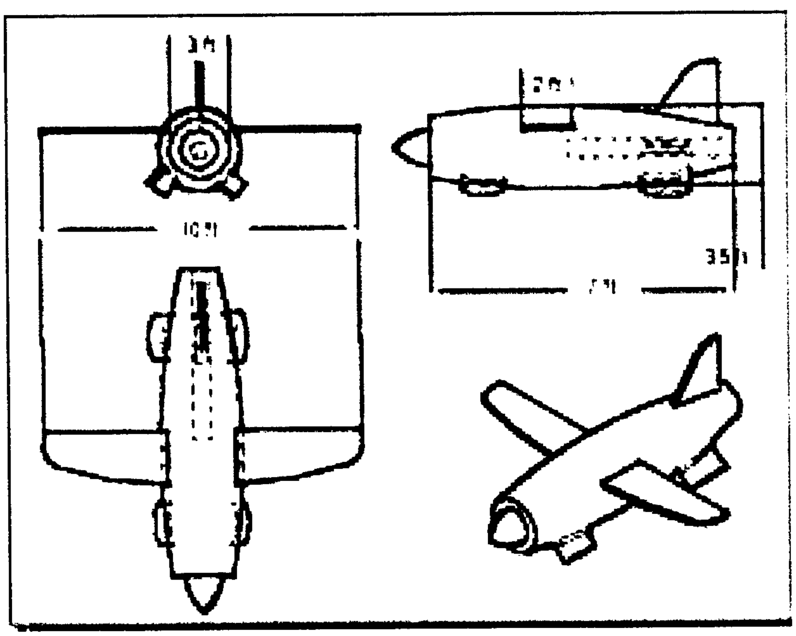

Figure 2: Three-View Drawing of "XTR-1"

1.3.3 Operations Scenario

The UAGV will be given a mission, and launched from the trailer of an Army Hum- Vee. It will rise with a VROC of 250 feet per minute, to an altitude of 500 feet above ground level, where it will cruise at a speed of 30 kilometers per hour. When required to do so, the UAGV may land and travel on the ground for brief periods of time. Using both air and ground operations, it may travel up to 15 kilometers. The vehicle will be capable of functioning with or without a 60-pound payload, and in any weather conditions. It will be capable of independently navigating terrain and avoiding obstacles. It will return to the point of launch within 30 minutes.

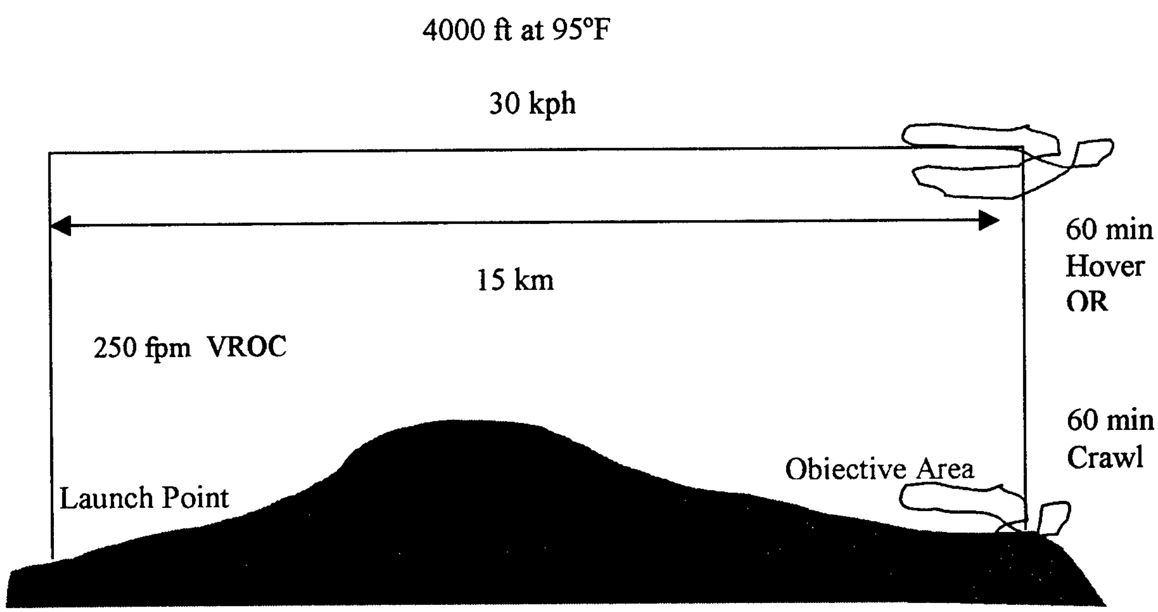

Figure 3: Operations Scenario

1.4 The Performance

The vehicle needed by the army is required to fly to range in 30 minutes or less and hover or crawl on the ground for an hour and then return. This gives an overall endurance for the vehicle of 2 hours. This is important in calculating the power required for the mission.

The XTR-1 meets almost all of the requirements set forth in the CDD. The one requirement that is not met is the need for full autonomy. This could not be met because the vehicle will need some human interface. However Extreme Engineering exceeded a few requirements. These would be the forward velocity of the vehicle, the range from launch point, and the amount of payload it can carry. The XTR-1 is capable of flying at 54 kilometers per hour and is more efficient at this speed. The vehicle can go up to 30 kilometers from the launch point using the same power requirements of the vehicle. Also, the vehicle can carry up to 80 pounds of payload. The XTR-1 will be capable of BLOS communications by using HF band. Table 1 provides a summary of the of important aspects of the vehicle

The XTR-1 will require 100 hp to perform its mission. This number includes the power to operate the ground package, hover, and fly. However, this does not include any power that the payload may require.

The XTR-1 is capable of meeting the Army's need cost effectively. By both engines using the same fuel this reduces the cost of having to provide two different fuels for the vehicle. If two fuels were used more components would be needed in the vehicle. This would add more weight, which would increase he power required for the vehicle. Therefore the most cost effective version of the XTR-1 is to have both engines operate off of the same fuel.

Table 1: Final Concept Evaluation

CDD Requirement	**Requirement**	**Assessment**	**Remark**
Range from launch point	15 km	**Meets**	**Capable of moving to more than 15 km**
Cruise Speed	30 km/hr	**Exceeds**	**Efficiently runs at 54 km/hr**
VROC	250 ft/min	**Meets**	**Provided y Ducted Fan**
VTOL Capability	Yes	**Meets**	**Provided by Ducted Fan**
Payload:	60 lbs	**Meets**	**Restricted to less than 80 lbs.**
Operational Altitude	0 to 500 ft AGL	**Meets**	
Hover to full flight profile	Yes	**Meets**	**Hover provided by ducted fan, Full flight provided by PDE**
Operation	Autonomous or Semi-autonomous	**Does not meet**	**The vehicle is Semi-Autonomous**
Acoustic Signature	Near Quiet	**Does not meet**	**The PDE can be very loud**
Communications	BLOS	**Meets**	**Provided by HF band**
Deployment	2025	**Meets**	
Communications	Operates without Payload	**Meets**	**Has a complete sensor package**
Ground Robotics	Ground Mobility	**Meets**	**Can operate on the ground**

1.5 The Implementation

Final planning and design for the UAGV should begin now, in order to ensure successful completion of the project by the year 2025. While many elements of this vehicle are based on existing technology, some areas of its design will require further study and development. Three key technologies that require development or investment for the concept to be ready by 2025 are communications, sensors, and propulsion muffler technology. Testing and manufacturing of the vehicle will also take time. By beginning the project now, a fleet of UAGVs will be ready for use by the year 2025.

Work will be needed to develop computer and robotics programs relating to vehicle autonomy. Sensors, communication systems, and computers exist today that could theoretically allow a UAGV to function independently. However, no system exists that integrates all the necessary elements into a fully autonomous system. However, with some time invested into writing the necessary computer programs, an autonomous system should be entirely feasible by the year 2025.

When all designs and systems have been completed, manufacturing processes must be planned and begun. First, a prototype must be built and tested. Then, manufacturing of the final product may begin. This may take months or years, depending on the number of vehicles required. Planning ahead will allow the necessary number of UAGVs to be produced on schedule.

The design, testing, and manufacturing processes for the UAGV will take time to complete. Beginning these processes immediately will allow the project to be completed in a timely fashion. The vehicle can be ready for use in the year 2025.

2.0 Technical Description of Methods Used

The following section will describe in detail the XTR-1.

2.1 System Engineering

Systems Engineering was responsible for ensuring that the components of the vehicle worked together. The following sections will describe the overall guidelines and assumptions made for the vehicle and the assumed mission scenarios. These assumptions were made to help the team design the XTR-1.

2.1.1 Overall Guidelines and Assumptions

In order to produce the UAGV for the customer, Extreme Engineering designed to meet the minimum requirements set forth in the CDD (Appendix A). This seems more feasible because the vehicle has a 25-year design life. Throughout this design life, technologies will improve enabling for higher strength to weight ratios and lower weigh to power ratios. Also, although there are no current fully autonomous systems, computer technology is progressing by leaps and bounds. This technology may soon make fully autonomous systems a reality.

Guidelines:

- Vehicle range of 15 km (9.3 miles)
- Payload of 60 lbs
- From base to operational range in 30 minutes
- Minimum cruise speed of 30km/hr (18.6 miles/hr)
- Minimum VROC of 250 ft/min
- Semi-autonomous flight

In order to design the vehicle assumptions were made to begin the iterative process of sizing the engine and fan.

Assumptions made are:

- The vehicle would weigh 450 lbs.
- The lift coefficient of the wing would be 1.
- NACA 4412 at 4 degrees AOA standards were assumed for the wing.
- NACA 2412 at 8 degrees AOA standards were assumed for the fan blades.
- A cord length of 2 inches was also assumed for the fan blades.
- The vehicle was assumed to fit in a standard Hum-Vee trailer.
- Performance of systems could be increased as technology increases

2.1.2 Assumed Mission Scenarios

From the CDR two mission scenarios were assumed since the customer did not provide one to Extreme Engineering. The first mission scenario addresses Risk Management and the second scenario addresses when and where the XTR-1 can be used.

2.1.2.1 Mission Scenario 1 (Risk Management)

A small unit is on patrol in a highly volatile war zone, when over the radio comes a transmission warning of possible danger ahead. Unsure of what the danger is, the unit quickly stops their Hum-Vee and initializes the UAGV they have been carrying on a trailer. The UAGV then lifts vertically off the transport trailer. Where it can obtain a birds eye view of possible threats at a height of 250 feet above ground level. Here the UAGV can hover above and report back to the soldiers what, if any, the threats are. If there are obstacles hindering the view of the vehicle at this altitude, it can simple land near the obstacle in order to gain a clearer view of what possible threats lie ahead. Once data has been acquired the vehicle can once again lift off and fly horizontally back to the unit. The extent of the threat can be determined while the soldiers are out of harms way.

2.1.2.2 Mission Scenario 2 (Rain or Shine)

An American Army has received word of a possible enemy offensive. The area around the base is considered secure. However, torrential rains and difficult terrains have made it difficult for conventional means of surveillance as well as for soldiers to perform their daily rounds near the base. This is no problem for the UAGV. It has extensive sensors and communications equipment, which can detect and transmit information even in extreme weather conditions.

2.1.3 Overview of Subsystems

Mechanical Configuration consisted of determining the materials to be used in the body of the vehicle. The frame is to be made of a titanium and aluminum alloy. The skin is made of an ABS plastic composite. Also, mechanical configuration determined the size of the vehicle and the location of the system embodied in it.

VTOL capabilities involved primarily ducted fan technology. The ducted fans consist of a duct and a fan. The fan having 16 blades and incased in a 3 foot diameter duct draw air into a ducting system which diverts the air flow into 12-2 inch diameter ports which have the capacity to direct the air flow in the direction needed for flight. The fan is powered by a Wankel engine, which is fueled by JP-8 fuel. A battery and alternator are required for the operation of the engine. The issues of storage and delivery of fuel to the engine are confronted by the fuel tank and the fuel pump. The flight computer deals with all controls for the system, such as throttling and vectoring of the ports.

The horizontal flight of the vehicle is based around the pulse detonation engine. The engine consists of a chamber filled with fuel vapor. An igniter then ignites this vapor. Like a small rocket, the directed explosion causes a thrust. The PDE will also use JP-8 fuel. This simplifies the fuel storage for the vehicle. However, a separate fuel pump is required. As the PDE provides the power for horizontal flight, wings are still necessary to provide lift. The directional control for the vehicle is the same as that of contemporary fixed wing aircraft. The flight computer controls the system.

Ground Robotics determined what system would be used to enable the vehicle to maneuver on land. The ground aspect of the vehicle consists of 4-12 inch diameter half-sphere tires made of PTS grade fiber reinforced plastic. The drive train links the front two tires to the Wankel engine. The drive train consists of two drive shafts, a differential, two gearboxes and a clutch. The gearboxes and differential weigh less than 8 pounds combined. They are made of a beryllium and aluminum alloy. The flight computer will control the ground system.

Sensors and Communications determined all necessary sensors needed to meet the CDD. These sensors enable the vehicle to operate and to gather data. The information is then processed and used accordingly. Either the information is communicated to other parts of the vehicle or to an outside source. This system is the backbone of the vehicle. It controls everything. The flight computer takes input from the sensors and uses this information to control all of the mechanical components of the vehicle for stability. The communications equipment also takes information from the sensors and flight computer and can relay this information back to a base unit. Or from a base unit to the vehicle.

Figure 4 shows a cross sectional view of the vehicle. Flow charts representing each subsystem are available in Appendix F. These flowcharts describe what each group looked at to develop the ideas for the XTR-1.

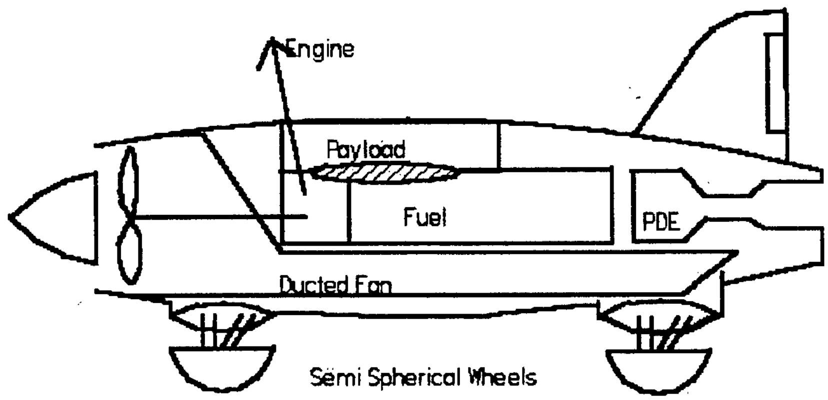

Figure 4: Cross Sectional View of "XTR-1"

2.2 Aerodynamics

The UAGV employs one ducted fan to achieve VTOL and wings to sustain forward flight. The ducted fan can be use to produce more lift during the horizontal flight. In order to control stability and maneuverability , this aircraft use a rudder fin on the back of the aircraft.

The following sections describe the proposed aerodynamics for the UAGV.

2.2.1 Approach

The design weight established in section (2.2.2) was used in sizing the major wing and ducted fan. A NACA. 4421 airfoil was selected for reasons that will be discussed later.

The planform area (Ap), tip chord (C_t), root chord (C_0),and mean aerodynamic chord (MAC) required to maintain horizontal flight were calculated as a result of this airfoil selection. The velocity, which we choose to make calculation, was 30 km/h

2.2.2 Ducted Fan Geometry

A study was conducted to determine the number of fan blades best suited for UAGV (the diameter and the speed of rotation). To have a VROC of 250 feet/min, the ducted fan needs to have geometry of 3' external diameter and 2"central hub

The blades will be in the shape of a NACA 2412 airfoil. These blades will be set at an angle of attack of 8 degrees to the rotation of the fan. This will provide a coefficient of lift of approximately 1.

The Power of the vehicle was calculated making a few assumptions. The C_D was assumed to be 0.008 and the weight of the XTR-1 was assumed to be 200 kg (441 lb). Using this information the drag was calculated using Equation 1. This number was found to be 3.48 N. Using this the thrust required to lift the vehicle was calculated using Equation 3. This gave a value for thrust of 2003.4 N. Using this value, Equation 2 was manipulated to give the velocity of the blades at the tip. The blades will rotate at about 12,500 rpm providing the appropriate thrust for the vehicle. From this the induced, profile, and parasite power was calculated. These values were put into Equation 4 to obtain the power required to lift the vehicle and let it hover. The power required was determined to be approximately 100 hp. These numbers were obtained using the equations for a rotorcraft, so therefore would be decreased due to the greater efficiency of directing the airflow in a ducted fan.

The fan will be made from AISI type 430 stainless steel that is annealed at 815 degrees Celsius. This is a strong lightweight material that will prevent excess weight of the vehicle. Aluminum 120 alloy pressed profile will be used for the 1/32-inch ducts. This is also a lightweight material. By using these materials the total weight of the ducted fan system will be 50.8 lbs.

Equation 1 $D=.5\rho V_{roc}^2 f_T$

Equation 2 $T=.5\rho V_{tip}^2 C_L C R N$

Equation 3 $T=W_g+D$

Equation 4 $Power=P_{induced}+P_{parasite}+P_{profile}$

2.2.2 Thrust Vectoring Port Geometry

There will be 12 thrust-vectoring ports on the vehicle, 6 on each side. These ports will be 2 inches in diameter and will be situated in groups of three. This will allow two sets on the front of the vehicle and two sets on the rear of the vehicle. The ports will face down for vertical lift and will retract during forward flight to help with directional control. Cylindrical shaped ports were chosen to prevent excess drag. Figure 5 below shows a diagram of one of the ports.

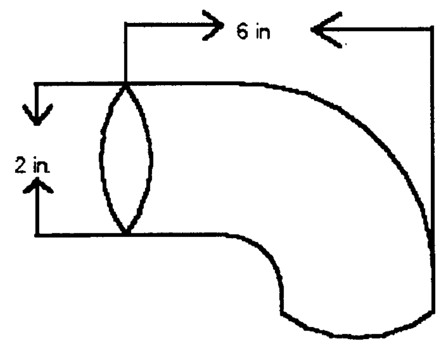

Figure 5: Thrust Vectoring Port

2.2.3 Wing Geometry

The wings of the aircraft will be NACA 4412 Airfoils with a cord of 2 ft. The wings will be positioned at an angle of attack of 4 degrees. This will provide a lift of 22.2 N per meter of wingspan or 16.4 lbf per foot when in horizontal fight flying at 30 km/hr. If the craft is flying at 54 km/hr, the lift generated will be 90 N/m or 66.4 lbf/ft. The faster speed would mean that the vehicle could stay in the air with minimal thrust/lift from the ducted fan with a wing of only 3' 4" on both sides of the craft. The airfoils shape is shown in Figure 6. (McCormick)

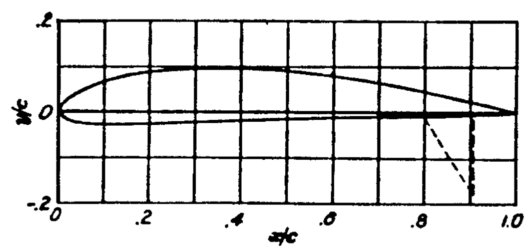

Figure 6: 4412 Airfoil Section

2.2.4 Body Geometry

The body of the XTR-1 has an elliptical shape to it. This was chosen to cut down on the amount of drag caused by the airflow. The vehicle was streamlined by adding a cover over the payload and by putting the sensors and cameras behind a windshield. By adding the windshield the cameras will not protrude from the surface of the vehicle, reducing drag. This is important because the power required for the vehicle is greatly affected by the amount of drag the engines must overcome.

2.2.5 Weight Establishment

The overall weight of the aerodynamic package is estimated to be 60 pounds. However, this does not include the wings or tail fin. The weights for these were added into the weight of the frame and skin. This is not very heavy however with improvements in materials through the years the weight will most likely be cut in half by 2025. Table 2 Shows a summary of the aerodynamics calculations.

Table 2: Summary of Calculations

Wing Airfoil	NACA 4412
Wing Span (b)	7 ft
Fan Blade Airfoil	NACA 2412
Fan Blade Chord	2 in.
Planform Area (A_p)	14 ft^2
Aspect Ratio	3.5
Root Chord (C_o)	2 ft
Drag	3.48 N
Lift	2003.4 N
Power	100 hp
Overall Weight of Subsystem	50.8 lbs.

2.3 Propulsion

This section gives an overview of the propulsion systems.

2.3.1 Description of Engines

The pulse detonation engein or PDE. is a simple concept with a simple desine. The base consept behind the PDE is that it uses a detonation of a fuel air mixture, instead of deflgration that conventional jet eneins use. With a deonation, a higher pressure is acheved, wich translates in to grater thrust. Sinse the same amunt or less fuel is used to acheve graitr thrust, the effency is a good deal higher than that of even ram jets. The PDE has a theoretical ISP efficiency of 20-30% improvement over the performance of ramjet technology.(Brophy) In addition to graiter effiency the unit is also lighter than it's convetional counterparts. Which endears it self to this projet. The actual machine workings are slightly more complicated. However, it is still far less involved that the standard jet engine.

2.3.2 Engine Controls

The control and sensor euipment must be controled completely by computer to acheve the small timing tolerancese. The injectors must be time cordinated with the exit of the detonation wave from the detonation chamber, and the predetonation. This also means that only hiperformance injectors and ignition equipment can be used. The sensory equipment is the key to the persition control system. The constant monitoring of the PDE's performance alows for nearly instantanious corections.

2.3.3 Weight Establishment

The weight of the propulsion system is another major factor in the weight of the vehicle. The overall weight of the system, which includes the PDE and the Wankel engine, is 125 pounds. This is one of the major sources of weight for the XTR-1. Extreme Engineering is hopeful that the weight of the propulsion system will significantly decrease by 2025, however the vehicle will still work even if this does not occur. Table 3 shows a breakdown of the weight from each of the propulsion components.

Table 3: Propulsion Weight

Weight	
Wankel Engine	20kg
JP-8 for Wankel	11.8kg
JP-8 for PDE	30.2 lbs
Battery	4.5kg
PDE Engine	15 lbs.

2.3.4 Wankel Engine

The Wankel Rotary engine is a low weight, high efficiency, and internal combustion engine. The purpose of the Wankel in the selected design is to provide the vertical lift upon takeoff, landing, and hovering. The Wankel will run on JP-8 fuel, which is readily available today for military use. Figure 7 shows a schematic of the Wankel engine.

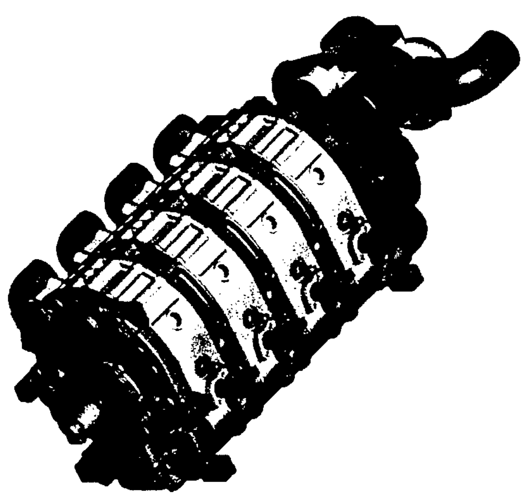

Figure 7: Wankel Rotary Engine

2.3.5 Pulse Detonation Engine

The pulse detonation engine (PDE) is being evaluated and developed as a potentially high-payoff new aeronautical propulsion system. The PDE represents a potential propulsion technology leap beyond the gas turbine engine.
Based on the results of several studies to date, the air-breathing PDE offers potential performance and life cycle cost payoff for both subsonic and supersonic vehicle applications. Potential application of interest are propulsion systems for tactical aircraft (manned or unmanned), missiles and subsonic/supersonic propulsion source for future hypersonic aircraft.

In PDE, core jet engine components such as fans, compressors, and turbines are not required. This will decrease engine weights and increase engine reliability.
Moreover PDE technology maximize the distance a plane can travel or given amount of fuel. The time required for detonation development has been measured as a function of fuel type, equivalence ratio, initial pressure, diluent type, and diluent concentration.

It has been estimated that in order for the PDE cycle to be competitive with conventional turbojet/turboramjet systems, they will be required to operate in the 75 to 100 Hz range with near stoichiometric fuel/air mixtures. This represents a cycle time of approximately 10 msec, requiring a propellant refill time in the 5 msec range.
Developing compatible air induction systems that will satisfy the above requirements, as well as provide adequate sealing from the high pressure, high temperature exhaust products, represents a major technology challenge.

Detonation in the PDE is a form of combustion that differs significantly from deflagration, the type of combustion found in conventional gas turbine engines , pulse jets, and rockets.

Deflagration is characterized by subsonic wave speeds, whereas the detonation combustion process occurs at high supersonic wave speeds relative to the unburned reactants (approximating Chapman-Jouquet C-J conditions). The detonation acts as an aerodynamic piston as it travel through the reactants gas mixture, raising the useable pressure by a factor of 7 to 8.

This constant volume combustion process is thermodynamically more efficient than the constant pressure deflagration combustion process and provide greater available energy for performing useful work.

For the case with ignition near the thrust wall, the following primary cycle events are illustrated in Figure 9:

1.Combustion chamber (detonation duct) is filled with detonable fuel/oxidizer mixture.

2.Detonation is initiated near the thrust wall(closed end of duct)

3.Detonation wave exit the duct. The duct is filled with burned gases at pressure and temperature levels considerably higher than ambient conditions.

4.The burned gases exit the duct in a blowdown process as rarefaction waves propagate forward from the open end of the duct.

5.The rarefaction waves, after being reflected off the closed end (thrust wall), exit the duct after most of the burned gases have been exhaust.

6.After the reflected rarefaction waves have been exhausted, the duct is at a near uniform low pressure level and ready for the purge of the remaining burned gases and subsequent refill of detonable fuel/oxidizer mixture; thus beginning a new cycle.

Until such time as actual PDE are on test stands, calculated performance number are only estimates.

However, in an effort to address realistic performance, the fill valve coefficients have been estimated at 80% and realistic component efficiencies have been used. The airflow is also assumed to be injected through choked flow rotary valves into the combustion chamber. Frequencies in the 70-100 Hz range are also assumed to be possible(an engine design study estimates that these frequencies are possible, but at a upper end of possible frequencies for annular designs)

PDE thrust is a direct function of engine volume and operational frequency.

A shock trap boundary-layer bleed system is used to help stabilize the terminal shock train. A major feature of the diffuser is a center body which allows a conservative area distribution and acceptable flow angles. The diffuser also includes a plenum aft of the center body, just forward of the engine face , to dampen engine-induced pressure waves.

The detonation chamber is a cylindrical tube about 9cm. long and 6cm. in diameter. Atached to this tube is an injector and a predetonation cylinder. The injector is equiped with an atomizer so the JP-8 fuel is more easily detonated. The predetonation cylinder is a smaller cylinder where the ignition of a small amount of fuel and oxidizer is preformed. In this smaler tube the fuel/oxidizer is in a state of deflagration wich is converted to detonation. The resulting detonation wave enters the detonation chamber wich in turn detonates the fuel/air mixture. The predetonation cylinder is used for two distinct reasons, that both mean higher

pressure. Less Fuel/oxidizer, wich burns hotter, can be used, and the presure needed for the deflagration to detonation transition is easier to obtain in the smaller tube. The ignition in the predetonation cylinder is started by an electrical ark. These operations are done at 100Hz. For this reason precision timing is critical.
Figure 8 shows a generic diagram of a PDE engine. (Eidelman)

An example of a test engine's performane can be seen in appendix E. This test model was done before 1993. While the exact numbers of the latest prototypes are not available there are some things that are known. For instance, the Navy has been working to run PDE's of heavier fuels.(Moser) Also, higher pressures have been achieved in many tests. Based on pressures seen in these tests the thrust can be calculated at 50% greater than the model represented in apendix D.(Bussing) From the base model several advancements are expected. The use of JP-8 fuel is expected to become a standard practice in the Navy. Fuel efficiency will most likely inprove with experience, as most devloping systems do. Also, the relatively low weight of 30.2lbs, has the potential to reduce as much as 5 or 6lbs. Lastly the aforementioned increase in pressure will yield greater thrust. For all these reasons the pulse detonation is a prime choice for this design.

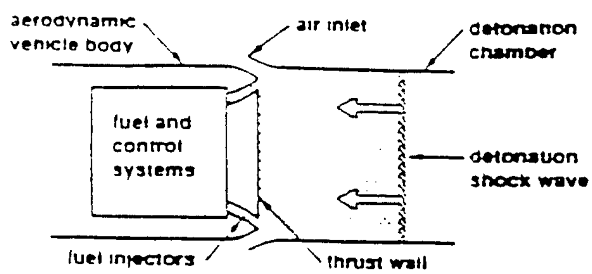

Figure 8: PDE Schematic

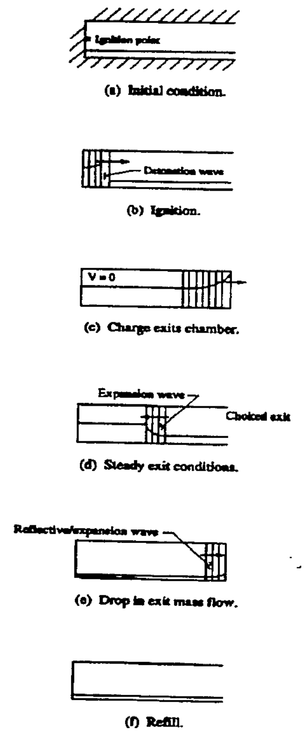

Fig. 12 Stages of the Pulse Detonation Cycle.

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Figure 9: Stages of the PDE

2.4 Drive System

2.4.1 Ground Package

In order for the ground system to be semi to fully autonomous, there needs to be a system established. The system for this vehicle will operate from an onboard CPU sharing ground command with flight command. The CPU will control all ground operations BLOS and in LOS. The system will encompass a degree of AI for movement and threat awareness duty.

The ground package robotics package consists of software enabling sensors to be useful in gathering data at ground level, movement of the vehicle while on the ground, and ground situation assessment. The package also consists of the mechanical mobility package employed to strategically place the vehicle in the proper surveillance area.

The communications and navigation structure will comply with JUAGs and will share map and target information with other DOD RSTA platforms. Communications are enabled through the use of Tri-band (TSS), which shall empower operation of any military or commercial satellite. C, X, or Ku-bands shall be employed. (Young)

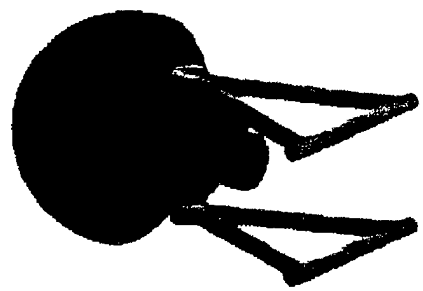


Figure 10: Diagram of Semi-Spherical Wheel

The mobility package shall find its way across natural and man-made ground terrain through computer manipulation of terrain avoidance radar. A 360-degree semispherical camera will handle visual identification. Figure 10 shows a diagram of the wheel assembly. (The Moment News)

The semispherical camera works off a semispherical reflective surface. The surface allows the computer to see in all horizontal directions down to ground level, allowing a higher degree of robustness in reaction to unexpected or complex situations. For example, if the vehicle is at standstill, monitoring a reconnaissance subject, and an enemy soldier wanders up from behind; the camera design will enable the CPU to detect the change in view from the rearward looking area. The vehicle will use Moving Target Indicator (MTI) software to determine friend or foe. The MTI software compares previous video frames to current frames. Any change in the frame requires further investigation and immediate reaction. The video will have a range depending on resolution. Software for the camera does correct for the spherical distortion. (Young)

The terrain avoidance radar package consists of radar searching in the direction of travel for positive or negative obstructions. A positive obstruction is something that is blocking the vehicle's path and a negative obstruction is a hole, such as a bridge out. If the computer senses, through radar, a positive or negative obstruction in transversing the landscape, it will inspect the situation visually by camera. The camera will allow the computer to compare visual images with stored or retrieved data or data from a fly-over. If the immediate path is determined impassible, the computer may seek alternatives for mobility. Stored data may be used in conjunction with intelligent algorithms in order to make a decision. (Young)

A preprogrammed map, provided by satellite imaging or other known mapping techniques, which enable mapping unknown areas, will accomplish maneuverability. The system will land, locate itself and proceed from there, directed by the mapping data. The target recognition system will use preloaded data to realized targets. Radar and video will scan suspect areas noting possible targets and comparing to those in memory. Surveillance will be recorded or transmitted to the base. Unrecognizable targets will be stored and transmitted for data collection to be communicated with authorities. (Young)

The ground computer will control vehicle movement through five actuators. These actuators provide physical control of the starter, clutches, transmission direction, speed, and steering. Ground movement will be utilized to improve reconnaissance and decrease enemy observation.

2.4.2 Materials

Beryllium aluminum 363 was chosen because of its low density and high tensile strength. Stainless steel cable was considered in order to eliminate the CV joints and additional gearbox, but added weight savings were realized by using beryllium aluminum 363 for all drive components.

Reinforced plastic wheels were chosen because of their calculated lighter weight than that of carbon fiber or rubber. The shape was chosen because of the lighter mass due to configuration in comparison with other configuration (see Appendix _).

Table 4 contains a summary of the materials used for each component of the ground system. (Matweb, Young)

Table 4: Summary of Materials for Ground System

Component	Material
Double A-arm Suspension Transmission/Differential Steering Shafts Drive Shafts Wheel Hub CV joints	Beryllium-Aluminum Alloy-363 Su = 42 ksi; Sy = 31 ksi Density = 2.16 g/cc
Semi-Spherical Wheels	PTS Grade Fiber Reinforced Plastic Su=29 ksi Density = 1.37 g/cc

2.4.3 Transmission

The Wankel engine that drives the ducted fan will power the ground system. This will be accomplished through the use of a transmission connected to the engine through a clutch controlled by the ground robotics computer. The transmission will be one of 1:1 input/output ratio with forward and reverse. A shaft connects the transmission to a right angle transfer box, which, in turn, is connected, by shafting, to a differential. The differential drives the front wheels with a 7.14 reduction in shaft speed. The reduction ratio will allow a 0 to 10-mph vehicular movement over a 500 to 2000 rpm engine range. CV joints will allow suspension movement with continuous power transfer. Electromagnetic actuators controlled by the ground robotics computer will accomplish steering. The ground robotics computer will also control engine speed.

Speed and direction will be controlled according to the purpose of movement. Movement will be dictated by threat, RSTA objectives and, terrain avoidance and how the ground robotics computer decides to act upon these situation requirements.

2.4.4 Weight Establishment

A lawnmower transmission is usually constructed of steel. A single speed, forward and reverse transmission weighs about 10 pounds. Therefore a beryllium aluminum transmission of similar dimensions and strength would weigh about 3.6 pounds. Beryllium aluminum has density of 0.078 lbm/in^3. The wheels will weigh about 5.31 pounds each. Actuators will weigh about a pound apiece. A small clutch will weigh 2.5 pounds and a hub assembly will weigh about 1.8 pounds. CV joints will weigh about 1.57 pounds each. Ground Robotics Mobility. Table 5 shows a list of each component and it's weight.

Table 5: Shaft Driven

Component	Weight (lb)
Wheels	21.25
Actuator	5.00
Transmission/Gearbox	7.20
Differential	3.60
Shafting for Drive	1.97
Shafting for Steering	2.64
Springs	4.00
Clutches	5.10
Hub Assembly	7.20
CV Joints	6.28
Total	64.93

2.5 Structures

2.5.1 Frame

For the frame a Titanium alloy was chosen. While aluminum would make the frame about 11 pounds lighter the strength that titanium provides is more attractive. Titanium has a much higher ultimate strength and a much higher yield strength. This means that the XTR-1 can take more abuse without the vehicle's frame failing. The frame dimensions were assumed to 90"x36"x45" for the purposes of calculating weight. The frame is what the wheels and the engines will attach to, so it is an important part of the vehicle. (MatWeb)

2.5.2 Skin

Two materials were considered for the skin of the vehicle, high-carbon fiber and an ABS plastic polymer known as Primatran. The ABS plastic is 40% glass fiber reinforced, which provides strength for the material. The ABS was chosen because it has a density about half that of carbon fiber. The thickness of the skin was assumed to be ¼ inch. Using the volume of a cylinder the approximate weight of the skin was calculated. (MatWeb)

2.5.3 Weight Establishment

The weight of the frame and the skin is the major influence on the weight of the vehicle. The skin will weigh about 113 lbs while the frame will weigh around 30 pounds. This brings the weight of this subsystem in at 133 pounds, more than any other subsystem. Equation 5 shows the equation used to calculate the weight of the skin and the frame. The volume of each component was calculated then multiplied by the density of the material.

Equation 5 $W=\rho V$

The development of lighter weight strong materials will greatly reduce the weight of this subsystem. These materials should be developed by the time the XTR-1 will be in production. However, this is not a major issue on whether the vehicle will fly or not.

2.6 Payload Handling

2.6.1 Location of Payload

The payload will be located on the top of the vehicle around the center of mass. The reason for this is so the XTR-1 can fly with or without the payload. Because the payload is located over the center of gravity the flight characteristics of the vehicle will not be affected when it is removed.

2.6.2 Payload Carrying Capabilities/Limitations

The payload is located centrally on the vehicle, which makes it ideal for sensors and other types of payloads. The payload bay can carry deadweight payload or payload that requires a little power. Also the cover that closes over the payload can be locked open so that payloads that need access to the outside can be used.

The XTR-1 is limited to carrying payloads less than 80 pounds. This is due to the stress on the frame. This is acceptable because the payload requirement is only 60 pounds. The payload is also limited by power requirements. The payload must require as little power as possible because this power will taken from the power source for the rest of the vehicle. Too much power taken and the vehicle will not fly.

2.7 Avionics

2.7.1 Computer System

The UAGV will have three major computers. These will be the Flight Computer, Communication Computer, and Navigation Computer. The Flight Computer will be responsible for such vehicle controls as movement, vehicle balance, and wing control. The navigation Computer will be responsible for anything that is related to navigation, such as receiving information from GPS/DGPS. For example, the Navigation Computer will tell where the vehicle is located. The Communication Computer will also be responsible for receiving and sending data and signals, such as images and K-Band to and from satellites and ground station. (Jane's Information)

2.7.2 Sensor System

The UAGV will maintain sensors to make it powerful in doing its job. Radar-altimeter will determine the vertical distance from the vehicle to the ground, and prevent the UAGV from crashing. (Radar) Mapping- radar will give images of the ground that the UAGV is flying over, and the entire environment surrounding it, even under bad conditions such as fog or fir smoke. (Mapping) IFF is an electronic package that must be on the UAGV. It will be part of the communication package, and is worth mentioning in this section, since it is neither signal nor data. (Jane's Avionics) The Acoustic Sensor will play a big role since it tells what kind of object is moving near the vehicle. For example, it will be able to tell whether an object is a tank or an airplane. (Acoustic) Terrain following, matching, and avoidance will take a part on the UAGV. Their primary job will be to avoid crashing and follow the UAGV's path on the ground. The system will receive the distance from vehicle to ground, using the radar- altimeter, and receive the height from vehicle to sea level, using the baro-altimeter. (Baro) The matching radar can then subtract the distance to the ground from the distance to sea level, and deliver the data to the avoidance radar, which will prevent the vehicle from crashing. Fiber Optic Gyroscope is a sensor that is available on today's market. Its primary job will be dealing with the rotation of the vehicle. Since the UAH Optics Department is researching this sensor to make it cheaper, it is worth mentioning here, as the UAGV will be available 25 years from now. The UAGV needs to have this sensor in order to maintain its balance in the air. (Lawrence) Sensors like Inertial Measurement Unit and Baro-altimeter will also be part of the UAGV. These two sensors will help the UAGV to determine air pressure, necessary flight speeds, temperature, and surrounding environment, and determine whether the UAGV will be able to function under such conditions. (Baro, IMU) These sensors, along with others, will be included in the vehicle.

2.7.3 Communications System

Since we want to deal with a secure communication, singles and data have to be functioned under Spread Spectrum and Encoding Inscription techniques. Both techniques are to provide intentional jamming by another source, in other word to protect sending and receiving signals and data from and to vehicle, satellites, and station. The communications that are going to be used on this UAGV are K-band, KU-band, C-band, UHF-VHF band, and HF band. The K-band KU-band and C-band are part of microwave singles. They are considered to be LOS. They have high atmospheric. They can support wider band, which is going to support faster data rate. They have only one disadvantage in which they have to have clear path to satellites. Their main function is going to be as receiving and sending data and signals from and to satellites, some of these bands are better in receiving and sending images than other band because of their different bandwidth that each may handle. They made point-to-point communication better than HF in some prospective. UHF-VHF are ideal for local communication in other word in same graphical area, therefore they do not have that high atmospheric LOS. HF band in which stands for high frequency bands is the primary method of BLOS. It communicates with out the need of satellite. UAGV is going to use it in case if there is lost of satellite communication and weak connection and this is an advantage for HF band over the microwave signal. (Jane's Information)

2.7.4 Weight Establishment

Weights vary from sensor to sensor, signal to signal, and data to data. According to Jane's weekly news, the estimation for total sensor weight is 15- 30 pounds, and the power required by the entire sensors and communications system is estimated to be around 185 Watts. (Jane's Avionics, Jane's Information)

2.8 Operations

2.8.1 Deployment

The XTR-1 will be ready for deployment in 2025. This is the target required in the CDD. Deployment of this vehicle will be critical on the future battlefield. An issue that could hinder the deployment of the vehicle is the development of the PDE. The PDE is currently being tested in developed by many people. The Navy is doing the necessary research on the use of heavy fuels with the PDE.

2.8.2 Mission Performance

The vehicle will perform all necessary aspects of a mission. The vehicle is capable of the required 30 km/hr for forward flight; it can hover, has VTOL capability, and is mobile on the ground. The vehicle will have a complete sensor and communications package allowing it to complete a mission quickly and effectively. This is important because the vehichle must avoid being detected which means it should not stay in one area for too long.

2.8.3 Maintenance

Maintenance on this vehicle will be easy for the most part. The materials used are strong and will not need to be fixed often. The Wankel engine is a 4-cycle engine, which soldiers can easily maintain. The one aspect of the vehicle that will have a degree of difficulty maintaining is the PDE. Soldiers will have to be trained to repair this type of engine since it is not currently in use and will be new to them.

2.9 Technical Summary

The XTR-1 is 7 feet long with a diameter of 3.5 feet. The wingspan of the vehicle is 3'4" on either side of the vehicle. There will be a tail fin to provide stability to the aircraft. The XTR-1 will be capable of carrying the required 60-pound payload. This payload will be located on the top of the vehicle over the center of gravity of the vehicle. The fuel tank will be located directly under the payload and will deliver fuel to both the PDE and the Wankel engine. The fan is located at the front of the vehicle behind a nose cone. The airflow from the fan will be directed into a duct where it will be compressed into a 6-inch duct. From there the flow will be forced through 12 two-inch thrust-vectoring ports. These ports will provide the lift for the VTOL capability and provide directional control during forward flight. The nose cone makes the vehicle more streamline and prevent the airflow from hitting a flat face. The wheels will be semispherical and made from ABS reinforced plastic. These wheels will be connected to the vehicle using movable struts. This allows the vehicle to move over rougher terrain without turning over or stopping. Figure 11 shows the cross section of the XTR-1. The Wankel engine powers the wheels and the vehicle will be front wheel drive.

The vehicle will have a complete sensor package. The vehicle is not considered fully autonomous because it will need human interface to change its mission. It will need a preplanned mission programmed into the vehicle in order for the vehicle to operate. Full autonomy is a long time away. (Corsetti) The sensors will be located all over the body of the vehicle. The highest concentration of sensors will be on the top of the vehicle towards the front. Theses sensors will be behind a windshield to reduce drag.

Table 6 shows a summary of the technical information of the XTR-1.

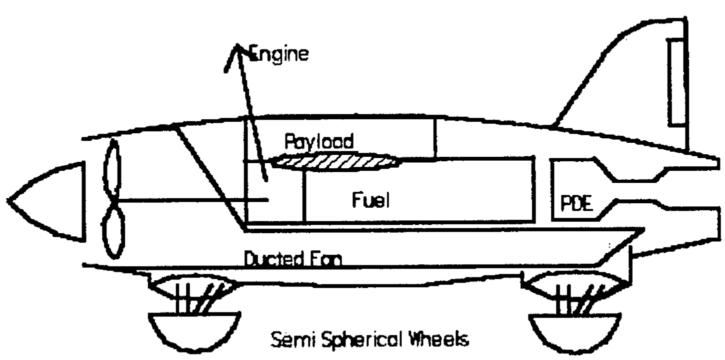


Figure 11: Cross Sectional View

Table 6: XTR-1 Technical Information

Comparison Criteria	XTR-1
Overall Specifications	
Air Configuration	Ducted Fans, Wings
Ground Configuration	Semi-spherical Wheels on movable struts
Payload Mass, kg (lb)	(27.2) 60
Gross Takeoff Weight. Kg (lb)	(218) 480
Energy Source for Air Transport	Wankel Engine (hover), PDE (Forward Flight)
Energy Source for Ground Transport	Wankel Engine
Hovering Power, Kw (hp)	83.5(112)
Cruise Power at 15 km/hr, Kw, (hp)	74.5 (100)
Total Energy for Mission Profile, KJ (BTU)	1.079×10^6 (1.023×10^6)
Basis of Autonomy	Computer
Primary BLOS Method	HF band
Primary Structural Material	Titanium, ABS plastic
Enabling Technology 1	PDE using heavy fuels
Enabling Technology 2	Muffler Technology for PDE
Frame Material	Titanium
Ground Package Material	Aluminum Beryllium, Wheels are ABS plastic

3.0 Implementation Issues

3.1 Programmatics Ground Rules and Assumptions

Programmatics is a discipline that uses quantitative methods to project and analyze information that is ever changing and not readily determinable. Persons working in this field must consider organizational functions, culture, and cost. Programmatics' personnel must be apt in and have a working knowledge of systems engineering, scheduling, costing, systems design, configuration control, quality assurance, manufacturing, operations and sustaining engineering, and logistics. Furthermore, this discipline has become very much electronically based. Computers are used to simplify many applications, such as costing and scheduling.

The Project Life Cycle is broken down into major costing cycles, Enabling Technologies, Manufacturing, Full Scale Development, Manufacturing, Operations and Sustaining Engineering, and Disposal. The Enabling Technologies' costing cycle is further broken down into phases and then, milestones. When scheduling and costing this project, it is assumed that all cycles and phases will act according to their prescribed schedule, cost, and output. If not, changes in the following cycles and phases will be inherent. Some flex with respect to each of these is given, but major alterations cannot be foreseen. In scheduling, it is also assumed that Congress, may at any time, cancel a project and therefore, special scheduling considerations have been made and noted in section 3.3. (Sanders)

3.2 Work Breakdown Structure

The work breakdown structure (WBS is located in Appendix G. The WBS lays out the steps required for the vehicle to be put into production. The WBS is an outline describing all of the work that must be completed, breaking it into categories. This gives the managers in charge of each department some direction in which to work. (Sanders)

3.3 Life Cycle Schedule

A fifty-year project life cycle was assumed for scheduling. The complete Life Cycle Schedule in Gantt chart forms available in Appendix G. A chart indicating other major milestones related to the project's development is located in Appendix G. Major scheduling milestones were planned to coincide with Presidential Elections. This would allow for the production of "results" at the same time that each new Presidential administration takes office. Therefore, allowing a better chance for survival. We feel producibility of tangible products will better secure the projects' funding.

The first step in this project is to conduct a yearlong feasibility study. At the midpoint of which, the SRR would be conducted. Assuming approval at that point, the SDR would be given in January of 2002. If approved, this would serve as the Authority To Proceed. Basic Research is scheduled for 2001 through 2005. Basic Research is conducted at a minimal cost compared to later phases and may very well overlap with following research phases. Assuming reasonable progress, the "Breadboard" could be established after this initial four years. The next phase is Applied Research, which requires increased funding and manpower, but is still minimal in comparison to latter phases. This phase is scheduled for 2005 through 2009. At the end of which, the "Brass board" could be established. From there, the Advanced Technology Development phase would begin, lasting from 2009 through 2017. Again, this would require increased manpower and funding from previous phases and could well overlap with the other phases. In January 2013, a flight demo is scheduled. In January 2017, a full-scale prototype should be well developed. After initial prototype development, the Demonstration and Validation phase is scheduled to last four years. Assuming producibility, Manufacturing and Full scale development is scheduled for 2021 through 2025. At the end of which, the CDR is given and a yearlong training program begins. Actual manufacturing is scheduled to last the four years following the CDR. The IOC is scheduled for January 2026. A twenty-year operational program is assumed lasting from 2025 through 2044. Followed by a five-year disposal program.

The development of technology necessary for successful completion of this project, also known as the "Technology Roadmap" is located in Appendix G. It is laid out in Gantt chart form and indicates necessary developments and expected man-hours. Aerodynamics' Technologies Development should encompass only the Advanced Technologies Development and Demonstration and Validation phases. This technology is dependent on the development of Mass Properties Technologies. Both phases were scheduled one phase earlier than indicated in the Life Cycle Schedule. This is simply a precautionary or flex measure. Necessary Aerodynamics' developments are near fully developed as is and will require no extensive Basic or Applied Research. The Propulsions' Technology development is expected to span the full life of the technologies' development. Basic Research, Applied Research, Advanced Technology Development, and Demonstration and Validation are all scheduled according to the Life Cycle Schedule. The Mass Properties' Technology development will include the first four phases of technology development as scheduled in the general life schedule. The Demonstration and Validation Phase of the Mass Properties' Development occurs as part of other technologies' development. Ground Robotics' development follows the same development schedule as Propulsion, but is dependent on Mass Properties at the Advanced Technologies Development phase. Sensors' and Communications' development follows the same schedule also. (Sanders)

3.4 Life Cycle Costs

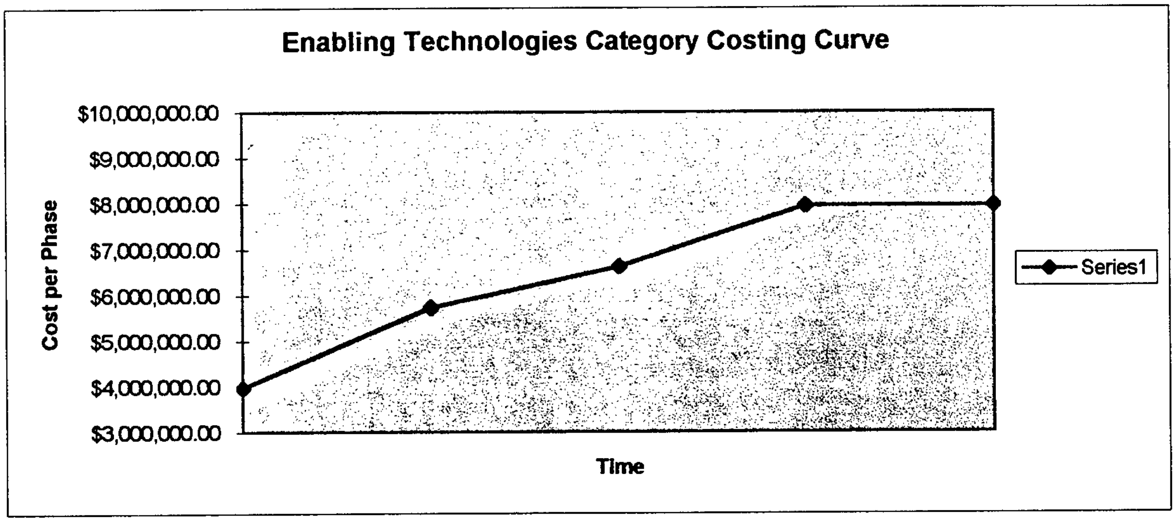
Total Life Cycle Cost for this project is estimated at $403,000,000. Table 7 breaks down the cost into its major components, Enabling Technology Development, Full Scale Development, Manufacturing, Operations and Sustaining Engineering, and Disposal. Man-hours for every part of this project can be broken down into one of these Costing Cycles. As table 3.4.1 indicates, the project's annual cost burden increases with the life cycle. The Enabling Technologies Costing Cycle accounts for $32,000,000 of the total cost, 8% of the total life cycle cost. When broken down, see Figure 12, this costing cycle also increases its' annual cost burden with time. Full Scale Development is estimated at $101,000,000. Manufacturing is expected to cost $133,000,000. Operations and Sustaining Engineering should cost approximately the same as Manufacturing at $133,000,000. While disposal is expected to cost $4,000,000. These cost were derived from developing a cost of Enabling Technologies, see Table 7. This was done by attributing expected man-hours to task and using that to develop an overall costing. From there, overall percentages of cost were assigned to each costing cycle based on generalized expectations of what proportional cost they would bare. The Enabling Technologies Costing Table shows the task, start date, finish date, duration, men assigned to each phase, full burden cost or total cost of worker plus benefits plus overhead, and Total Expected Cost. A Full Burden Cost derivation is shown below. (Sanders)

Full Burden Cost= $55,000 (average annual salary) x 200% (average cost of benefits & overhead)

= $110,000 per annum

Costing Cycle	Cost	% of Total Cost
Enabling Technologies	$ 32,242,269.23	8.0%
DDT&E (Full Scale Development)	$ 100,757,091.34	25.0%
Manufacturing	$ 132,999,360.57	33.0%
Operations & Sustaining Engineering	$ 132,999,360.57	33.0%
Disposal	$ 4,030,283.65	1.0%
Life Cycle Cost	**$403,028,365.38**	**100%**

Table 7: Life Cycle Costing



Category	Task	Total Man Hours	Costing	% of Total Cost
6.1	Basic Research	75168	$ 3,975,230.78	12.3%
6.2	Applied Research	108576	$ 5,742,000.00	17.8%
6.3a	Advanced Technologies Development I	125160	$ 6,619,038.45	20.5%
6.3b	Advanced Technologies Development II	150312	$ 7,949,192.30	24.7%
6.4	Demonstration & Validation	150456	$ 7,956,807.69	24.7%

Figure 12: Enabling Technologies Category Costing Comparison

3.5 Risk Analysis

3.5.1 Technical Performance

The technical performance of the vehicle presents some risk. The development of the PDE, while underway, may not be done by the there is some risk that the research may not be complete. The vehicle is complex and therefore carries a degree of risk.

3.5.2 Schedule

The primary scheduling risk associated with this project comes in the Enabling Technologies Costing Cycle or the first twenty years of the project. Scheduling technology developments is not an exact science. Simply allocating funds and manpower does ensure developments or, much less, breakthroughs in science. The phases of this cycle can and will very likely overlap and not be constrained by the indicated schedule. Hopefully, if our anticipations are correct, this schedule will serve as a baseline for when to reasonably expect results throughout this cycle. After this initial cycle, the remainder of the project's life such as manufacturing, operations, and disposal will likely follow the indicated schedule, barring discontinuance of the project at some point. The latter cycles can be controlled with a much higher consistency than can the technology developments. (Sanders)

3.5.3 Cost

The cost risk with this project can mainly be attributed to the ability of the technologies needed to be readily developed. If the technologies are not developed as expected, the initial development cost could be much greater than expected to compensate or the actual manufacturing cost could far supersede that which has been allocated. Something to remember is that the majority of the budgeted costing comes in the final cycles of the project, while only 8% comes in the initial twenty years and the primary cost risk is associated with the developments that take place in those initial twenty years. So if the projects' Life Cycle Cost is going to exceed expectations, it should be apparent prior to major spending. (Sanders)

3.6 Discussion of Application and Feasibility

From a scheduling and cost perspective, the technologies necessary for producibility of this project are realistic and achievable given the expected cost and time constraints. The greatest degree of uncertainty probably lies with the Propulsion Technologies. It requires the greatest costing, manpower, and scheduling burdens. With respect to cost effectiveness, we feel a cost on of the order of magnitude we propose, $403,000,000, over 50 years is reasonable and even favorable considering the requirements and expectations the government has set. (Sanders)

4.0 Company Capabilities

4.1 Company Overview

Extreme Engineering combined the skills of many team members to create a successful design. Each member of Extreme Engineering excelled in a different technical area. During Phase I of the design, team members worked with members of other teams in order to increase understanding of these technical areas and to develop a baseline design. The members of Extreme Engineering showed good sportsmanship and creative thinking as they worked and shared ideas with other teams. During Phase II of the design, team members further researched their technical areas, and combined their ideas with those of other Extreme Engineering members to create three more designs. This took teamwork, cooperation, and communication. During Phase III, Extreme Engineering showed dedication and hard work as they finalized the design.

Extreme Engineering showed communication skills in several ways. First, members of the team communicated technical ideas with each other, allowing each person on the team to have at least a basic understanding of the ideas and requirements that members of other disciplines were concerned with. This is evident in the way that all systems of the design are compatible with each other. Communication was also shown through presentations, as Extreme Engineering presented designs to the customer. All presentations were clear, detailed, and well communicated. Additionally, communication with mentors allowed each discipline to excel.

The members of Extreme Engineering have also demonstrated their ability to cooperatively solve problems. Members showed cooperation as they worked with the needs of all disciplines to create a design acceptable to everyone. Extreme Engineering also incorporated customer and mentor ideas into the design. Teamwork was a strong point in this team, as all members showed consideration for the needs of the team.

The ideas presented by Extreme Engineering showed creative thinking and the ability to find unique solutions to problems. This was shown in the designs presented by this group. Designs were unique and showed original thinking.

Extreme Engineering has shown teamwork, communication skills, and dedication in developing a UAGV to meet the needs of the customer. The members of the team have combined their talents and knowledge to develop an excellent vehicle design. By working to share ideas and skills, Extreme Engineering has developed the design presented in this paper.

Extreme Engineering consists of many brilliant, dedicated individuals. Their strengths will allow the team to plan and build the UAGV successfully. If Extreme Engineering is chosen, the following specialists are recommended to continue the project.

- Laura Filz - Project Office Manager
  Laura led the team through the design process. She was an excellent team leader, keeping meetings friendly yet focused, and was always considerate of the needs of both her team and the customer. Laura's outstanding leadership and dedication allowed the team to excel.

- Richard Sparkman - Programmatics and Marketing Team Leader
  Richard organized the team's programmatics and marketing. His careful planning in these areas ensured successful, cost- effective and time efficient completion of the project, and his great attitude was an asset to the team.

- Kris McDougal - Systems Integration Team Leader
  Kris was the team's Systems Integration Leader. He had an excellent understanding of all technical areas of the project. This allowed him to excel in coordinating the many parts into a single vehicle. The great amount of time and hard work he put into this project helped make the project successful.

- Kevin Buch- Aerodynamics Team Member
  Kevin planned the aerodynamics for the UAGV. Kevin is very talented in the area of aerodynamics. His creative ideas and unique solutions to problems are evident in all the proposed vehicle designs.

- Sebastian Kriner- Aerodynamics Team Member
  Sebastian was another of the team's aerodynamics experts. He showed cooperation and teamwork throughout the project, aiding in the design of an outstanding aerodynamic system.

- Tim Hardin- Propulsion and Drive Team Member
  Tim worked to design the propulsion and drive systems for the UAGV. A senior studying mechanical and aerospace engineering, Tim excels in these areas. His creative thinking and enthusiasm for this project were assets to the team.

- Shane Canerday- Propulsion and Drive Team Member/Programmatics
  Shane also worked on the propulsion and drive systems. His talent in design is evident in the vehicle design. His cheerful attitude and engineering talent were crucial to the design of a successful propulsion and drive system. Shane also stepped up to help Richard on his large task in Programmatics.

- Tim Hakimov- Mechanical Configuration Team Member
  Tim planned the vehicle's mechanical configuration. His expertise in the areas of mechanical drawing and basic design helped put together a workable design for the vehicle.

- Virgil White- Mechanical Configuration Team Member
  Virgil also worked on mechanical configuration. He is an outstanding designer,

and his understanding of mechanical systems was a definite asset to this team. Virgil helped keep team moral high.

- Jason Newton- Ground Robotics Team Member
  Jason designed the vehicle's ground robotics system. He worked hard to make sure this system was efficient, workable and original. His dedication to excellence can be seen in the vehicle's ground robotics system.

- William Thomas- Acoustics and Controls Team Member
  William aided in the design of the acoustics and controls system. He showed outstanding communication skills, teamwork, and cooperation as he worked with the team to design an outstanding acoustics and controls system.

- Pierrot Ivoula- Acoustics and Controls Team Member
  Pierrot also worked on the acoustics and controls system. Although he has been communicating with the team mainly through email and other Internet communication systems, he has shared many important ideas and designs with the team. He has been friendly and willing to work hard on this project. His excellent work can be seen in the vehicle's acoustics and controls system.

- Majed Batais- Sensors and Communications Team Leader
  Majed designed the vehicle's sensor and communication system. His outstanding research, dedicated analysis, and careful planning allowed for a complete and efficient sensor and communication system. Majed's seriousness about the project and dedication to its excellence helped the team to exceed expectations.

- Cyril Augier- Sensors and Communications Team Member
  Cyril also worked on the sensor and communication system. His good teamwork and communication skills allowed him to be a contributing member of this team, even from France.

- Angeline Nuar – Technical writing
  Angeline's diligence in producing quality reports has helped the team succeed. Angeline approached assignments with an enthusiastic attitude and was willing to help the team whenever she could. Her ability to convey the others ideas was very helpful and important to the project.

5.0 Summary and Conclusions

Extreme Engineering has designed a vehicle to fulfill the Army's needs. The vehicle will be a critical piece of equipment on the battlefield of the future. The XTR-1 design is a first level design and will require a more thorough design process before it can be implemented. However, from what has been calculated the XTR-1 looks to be an attractive solution to the need for a UAGV. For the vehicle to be successful the PDE engine must continue to be developed. Also, ways to make the engine quieter will have a great impact on the use of this engine in a reconnaissance role.

6.0 Recommendations

The power requirements for the vehicle would be greatly reduced if the VROC were lowered. However, this is not a major issue. The one issue that Extreme Engineering could not overcome was the issue of autonomy. Full autonomy of a vehicle is going to take many years to develop, if it ever develops. The vehicle design could be improved by the addition of lighter materials. This would require that research be done on new composites. This is not a major issue since materials are always under research. Also , after talking to the French students working on this project the vehicle may be improved by putting V-wings on the vehicle instead of a traditional tail. Also if the airfoil of the wing is increased to a NACA 4421, this will allow greater efficiency at lower speed and allow more space for fuel.

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Appendix A - Concept Description Document

1. General Description of Operational Capability
   1.1. Overall Mission Area
      1.1.1. The system shall be a versatile scout and pack animal for future force structures.
      1.1.2. The system shall be capable for use for area/target reconnoitering.
      1.1.3. The system shall be capable for use in terrain definition.
      1.1.4. The system shall be capable for use in situational awareness.
      1.1.5. The system shall be capable of both autonomous and semi-autonomous operation.
         1.1.5.1. The system shall be capable of human interface as required.
      1.1.6. The system shall be capable of executing both a preplanned and an alter mission profile.
      1.1.7. The system shall be capable of navigating and functioning without a payload.
   1.2. Operational Concept
      1.2.1. The system shall be capable of operation in a nap of the earth configuration.
      1.2.2. The system shall be capable of operation at a range of 15-30 km from the launch point.
         1.2.2.1. The system shall be capable of gathering information on threat activities at range.
         1.2.2.2. The system shall be capable of enhancing the RSTA/BDA.
         1.2.2.3. The system shall be capable of transmitting information via secure data links and C2 structures BLOS.
         1.2.2.4. The system shall be capable of using TF/TA hardware and software to define and navigate complex terrain.
         1.2.2.5. The system may encompass a degree of AI, ATR, and on-board decision making.
      1.2.3. Payload Requirements
         1.2.3.1. The system shall be capable of carrying a payload of 60lbs required gross weight, 120lbs desired gross weight.
         1.2.3.2. The system shall be capable of moving the payload to operational range in 30 minutes or less and be able to return from range in 30 minutes or less.
            1.2.3.2.1. The vehicle will have a minimum cruise speed of 30 km/hr and a desired speed of 100 km/hr.
      1.2.4. Mission Requirements
         1.2.4.1. The system shall be capable of landing in an unprepared area
            1.2.4.1.1. The vehicle must have vertical takeoff and landing capabilities.
         1.2.4.3. The system shall maximize survivability.
            1.2.4.3.1. The system shall be capable of avoiding sonic detection.
            1.2.4.3.2. The system shall have a near quiet acoustic signature.
            1.2.4.3.3. The system shall be designed for an operational altitude of 0 – 500 ft AGL.
            1.2.4.3.4. The system must have a 250 fpm VROC, 500 fpm desired.

1.2.4.4. The system must have a flight profile of hover to full flight.

2. System Capabilities
   2.1. The system shall be capable of operation at an altitude of 4000ft, 95 degrees Fahrenheit ambient temperature, and not using more than 95% intermediate rated power (IRP).
   2.2. Operational Performance
      2.2.1. The system shall possess essential performance, maintenance, and physical characteristics required to operate under adverse environmental conditions worldwide.
      2.2.2 The system shall possess essential performance, maintenance, and physical characteristics required to operate under adverse geographical conditions worldwide.
      2.2.3. The system shall be capable of operating from any unimproved land or sea borne facility surface day or night, including low illumination.
      2.2.4. The system shall be capable of operation under battlefield obscurants.
   2.3. The system shall possess the following electronic capabilities:
      2.3.1. Mission Planning System
         2.3.1.1. The system shall possess a point-and-click pre-mission planning system to simulate mission flight.
         2.3.1.2. The system shall possess data loading capabilities.
         2.3.1.3. The system shall be capable of coordination and reaction to immediate operational mission changes.
         2.3.1.4. The system shall be capable of processing self awareness and threat sensor inputs.
         2.3.1.5. The system shall be capable of enabling TF/TA from digital mapping information from satellite or other sources.
      2.3.2. Avionics
         2.3.2.1. Communications and navigation suite architecture shall be compatible with emerging JCDL and/or JAUGS.
         2.3.2.2. Payload must be "plug and play."
      2.3.3. Communications
         2.3.3.1. System communications shall be robust and have clear secure modes of operation
         2.3.3.2. Communications shall be simultaneously LOS and BLOS which can include satellite relay or other relay system compatibility.
         2.3.3.3. System must posses IFF and be compliant to all FCC/military communication regulations.
         2.3.3.4. System must be capable of communication with and sharing digital mapping/targeting information with other DoD RSTA platforms.
      2.3.4. Connectivity
         2.3.4.1. The system shall be interoperable with other DoD systems envisioned for the 2025 battlefield to the maximum extent possible and be compatible with service unique C41 systems.

Appendix B - White Paper

Alternate Concepts White Paper

IPT 1

Project Office:	Laura Filz
Programatics/Marketing	Richard Sparkman
Systems Integration:	Kris McDougal
Aerodynamics:	Kevin Buch; Sebastian Kriner
Propulsion/ Drive:	Tim Hardin; Shane Canerday
Mechanical Configuration:	Tim Hakimov; Virgil White
Ground Robotics:	Jason Newton
Acoustics/ Controls:	William Thomas; Pierrot Ivoula
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Abstract

This paper provides an overview of Phase II of the IPT 2001 project. It describes the specification that is being worked with and discusses the key challenges that will be faced in meeting these specifications. It discusses each of the four UAGV designs considered by Extreme Engineering, and the positive and negative attributes of each design. These attributes are incorporated into an evaluation matrix, which is used to select a final design. This design is the one that best meets the previously discussed specifications, and will be used for Phase III of the design process. Future plans for the chosen design are also discussed. Pictures of all three designs and the baseline design are included in the paper.

Résumé

Ce papier nous donne un apperçu de la phase II du projet IPT 2001. Il regroupe les scpécifications demandées et les problèmes techniques rencontrés puis résolus. Nous avons débattu pour chaqu`un des quatre modeles de UAGV defini par le groupe Xtreme, des points forts et faibles. Ces considerations sont incorporees dans un tableau d`evaluation, qui permettra de choisir le modele definitf. Ce modele sera le meilleur modele du point de vue des specifications demandees et sera utilise pour la troisieme phase de la conception. Les plans du modele choisi sont aussi debattus. Les representations des trois modeles et de la premiere specification sont fournis dans le document.

Technical Description

1.0 Overview of Phase 2

The Unmanned Air/Ground Vehicle (UAGV) sought by the U.S. Advanced Systems Directorate is envisioned to provide essential scouting and target recognition to the Brigade Commander. The customer and all participating teams endorsed a Concept Description Document (CDD) finalizing the customer requirements for this system on February 6, 2001. Phase 1 of the project produced one baseline concept that attempted to satisfy the project (CDD) using existing technology. Extreme Engineering at the University of Alabama in Huntsville has focused on synthesizing three alternative concepts. This White Paper provides a summary of the Baseline and our three alternative concepts. One of the concepts is selected for further development in Phase III.

1.1 Specification Summary

An unmanned air and ground vehicle (UAGV) will be designed by Extreme Engineering to meet specifications given by AMCOM. The UAGV will function reliably both in the air and on the ground. It will be designed to carry a payload of at least 60 pounds, and operate autonomously. The vehicle will be functional in any geographical area, and in any type of weather conditions.

The vehicle will move quickly and quietly, and have a hover to full flight profile. It may travel up to 15 kilometers from the launch point, and will fly at a speed of at least 30 kilometers per hour. It will take off and land vertically, and have a vertical rate of climb (VROC) of 250 feet per minute. It will be able to function up to 500 feet above the ground.

When completed, the vehicle shall be fully autonomous, with sensors and robotics to guide its travel. The sensors and robotics will function in all types of weather and lighting conditions. The vehicle will be capable of communication with other army vehicles, and with ground stations within and beyond the line of sight. It should have an extremely low signature, and be equipped with an identification of friend or foe (IFF) system, and be detected only by friendly sensors.

The vehicle will be efficiently designed, using both existing and future technologies. Its cost will be relatively low, and it will meet all specifications. The UAGV will be complete by the year 2019.

1.2 Key Challenges

There are challenges that must be faced in designing a vehicle to meet the given specifications. These challenges include designing a fully autonomous robotics and sensors system, as well as keeping the vehicle weight below 600 pounds. Existing vehicles are neither fully autonomous, nor as weight- efficient as this vehicle must be. New technology will be incorporated into the UAGV design to meet these challenges.

A fully autonomous vehicle will be challenging to design because no such "thinking" computer has yet been used with complete success. Autonomy has traditionally been a problem in unmanned vehicles. There are many sensors and decision- making programs that aid unmanned vehicles, but a vehicle that makes fully autonomous decisions, regardless of position and terrain will be more difficult to design. However, by combining existing sensors and computers with newer ideas, a fully autonomous UAGV should be feasible by the year 2019.

The weight of the vehicle is another challenge that must be addressed. Using traditional technologies, it is difficult to keep the necessary fuel, machinery, sensors, and payload to a weight under 600 pounds. Traditional engines and fuel are very heavy, as are the materials available for building the vehicle itself. Finding lighter, materials with strength equivalent to the strength of existing materials may allow the vehicle to be considerably lighter. By using more modern technologies and newer materials, the vehicle may weigh well under 600 pounds.

While the vehicle would be very difficult, and maybe even impossible, to build using existing technology, Extreme Engineering is considering newer ideas that will make the project feasible. These ideas will be discussed in greater detail in this paper. Extreme Engineering will design a vehicle that meets these challenges.

2.0 Description of Concepts

The designs were selected to meet the specification. Concept Design 1 (CD1-1) is a vehicle that uses one ducted fan and four wheels. Concept Design 2 (CD1-2) is a vehicle that utilizes only one ducted fan and four wheels. The last design, Concept Design 3 (CD1-3) is a vehicle that uses magnetic levitation device and ion thrust. It uses tracks as its means for mobility on the ground.

2.1 Concept 1-1 "CD1-1"

The first concept developed has one ducted fan to provide vertical lift. The ducted fan utilizes 4 thrust vectoring ports to provide the lift as well as giving the vehicle the capability to hover. The ducted fan will be powered by a 2-cycle Wankel rotary engine. (Moller) This engine is a diesel engine and will also provide the power for the ground mobility. The thrust vectoring also provides some stability for the vehicle keeping it from tipping over.

A pulse detonation engine will provide the forward flight movement of the vehicle. (Bussing, T.) This type of propulsion unit is very lightweight and will provide the forward flight velocity with no problem. The fuel for this unit is hydrazine. This propulsion unit will be located on the top of the vehicle in the rear.

This design will have four wheels using a suspension system that will allow the vehicle to move over rugged terrain. (Young) The wheels made out of rubber. The frame of the design will be made out of fiber reinforced plastic; the skin will be made out of the same. Figure 1 shows an illustration of the Design. The vehicle will be capable of carrying the required 60-pound payload. The payload will be carried on the top of the vehicle towards the back. The sensors will be carried towards the front of the vehicle and the fuel will be located at the center of gravity of the vehicle. This will help with the stability of the vehicle because the changing weight of the fuel will not affect the balance of the vehicle. The vehicle will fit within the constraints of a Hum-Vee trailer and will weigh approximately 350 pounds.

This concept will use a complete sensor package including Thermal Imaging Sensor System (TISS), Interferometric Synthetic Aperture Radar- Elevation (IFSARE), Differential Global Positioning System (DGPS), Global Positioning System (GPS), Automatic Target Recognition (ATR), K- Band Scanning Phased Array Antenna, and Unattended Ground Sensor (UGS). (Military, Starlink, Spacecom)

2.2 Concept 1-2 "CD1-2"

The second concept is an electrically powered vehicle with a single, centrally located ducted fan to provide lift. It combines existing aerospace propulsion systems with electricity from fuel cells to provide a hover to full flight profile. This concept uses a computer-regulated signal processing system with existing sensory equipment to provide a fully autonomous flight. In addition to the large ducted fan the vehicle will have 4 small fans to provide directional control and stability for the system. This vehicle will be lighter than the baseline.

The vehicle has four wheels with movable struts. (Young) This allows the vehicle to have versatility over different types of terrains. The vehicle will also be capable of rising up a couple of inches to aid the sensors. The wheels will be made of aluminum and rubber, to minimize weight. The frame and skin of the vehicle will be made out of carbon fiber. It will weigh approximately 550 pounds. This design is heavier than the first because the large tires add a lot of weight to the vehicle. It is shown in Figure 2. This concept will be capable of carrying the 60-pound payload, which will be carried on the back of the vehicle. The sensors will be carried on the front of the vehicle because this is where they will be the most useful.

This concept will use a complete sensor package including Thermal Imaging Sensor System (TISS), Interferometric Synthetic Aperture Radar- Elevation (IFSARE), Differential Global Positioning System (DGPS), Global Positioning System (GPS), Automatic Target Recognition (ATR), K- Band Scanning Phased Array Antenna, and Unattended Ground Sensor (UGS). (Military, Starlink, Spacecom)

2.3 Concept 1-3 "CD1-3"

This design will have three magnetic levitation devices, which use magnetic fields to make an object repel another object. (And, Bussing, Eidelmann, Hogan, Port, Wilson, Wu) There will be a gyroscope in each unit to stabilize it. These types of units have been under research for many years without any significant breakthrough.

The vehicle will utilize an ion drive propulsion system. This propulsion system will be scaled down to provide the proper amount of thrust. Right now this propulsion system is used on a very large scale and is being developed for space travel.

The ground mobility package will consist of two tracks located underneath the vehicle. The tracks will also be made of aluminum and rubber. Tracks were chosen to provide better mobility and stability over rocky terrain and sandy terrain. The downside of tracks is that they add a lot of weight to the vehicle. The body and frame will be made of aluminum, because of its low magnetic properties. This will prevent interference with the magnetic levitation device.

This concept will be capable of carrying the 60-pound payload. The payload will be located towards the back of the vehicle, while the sensors will be located towards the front of the vehicle. . This vehicle will use the same sensor package as concept 1-1. It will weigh approximately 300 pounds. This vehicle is significantly lighter than the other designs because its propulsion and lift systems are relatively light. It is shown in Figure 3.

This concept will use a complete sensor package including Thermal Imaging Sensor System (TISS), Interferometric Synthetic Aperture Radar- Elevation (IFSARE), Differential Global Positioning System (DGPS), Global Positioning System (GPS), Automatic Target Recognition (ATR), K- Band Scanning Phased Array Antenna, and Unattended Ground Sensor (UGS). (Military, Starlink, Spacecom)

2.4 Concept 1-4 "Baseline Design"

The baseline concept is a coaxial counter-rotating rotorcraft. It uses a diesel cycle engine. The frame is made out of titanium, and the skin is made of carbon fiber. It weighs 614 pounds. It has four wheels with a good suspension package. This design is capable of carrying the 60-pound payload. The payload will be carried underneath the vehicle. This design does not meet all specifications. It is shown in figure 4.

3.0 Selection of Final Concept

The final selected concept is concept design 1-1. This design was chosen after careful evaluation of all four designs. This design has some very attractive features such as a lightweight propulsion unit in the pulse detonation engine. Overall, the concept was better than the other three even though it lacked in some key areas. These areas included the cost, risk, and schedule of the vehicle. Table 1 shows the evaluation matrix and how the four concepts compare to one another. However, this design meets the specification more closely than the other three designs.

The reason CD1-1 was chosen as our selected design is because of the major drawbacks of the other designs. Originally the team was going to choose CD1-3 but after researching the magnetic levitation device and the ion drive system it was found that not enough information existed to produce a viable concept. The baseline design did not meet all of the specifications and important factors such as the weight of the swash plate and rotors were not taken into account. Concept 1-2 was not chosen because it was considered to conventional.

CD1-1 was chosen because of the forward thinking of the pulse detonation engine. This engine has been researched by a professor at UAH and is very appealing to the team. Another reason CD1-1 was chosen was because of the high efficiency of the ducted fans. These features made the first concept very attractive to the team.

4.0 Issues for Selected Concept

4.1 Development Issues

Many key technologies must be developed further in order for the vehicle to work properly. Developments must be made in the areas of materials construction, pulse detonation technology, and autonomy. All of these key technologies are already under study, and the studies should be complete well before the year 2019. The required technology is expected to be available before this vehicle is put into production because the bulk of the research has already been performed. The expected improvements on key technologies will result in a stronger, lighter, more efficient vehicle.

Materials development and construction is a key issue for the selected vehicle. With the use of lightweight materials the vehicle will weigh less and therefore require less power to lift it. There are currently many strong lightweight materials available. With the amount of money and research being put into lightweight materials it is not unreasonable to think that there will be an even lighter and stronger material by 2020. However, even if this material is not available the materials that are readily available today could still be used on the vehicle. This will allow the vehicle to be exceptionally light, and will allow systems to operate properly.

Additionally, improvements in the pulse detonation engine would be very beneficial to the project. The pulse detonation is already been researched a great deal, but advances in this technology will only add to its usefulness. Area of research that could make this engine better may be using different propellants. This technology will not have to encounter a significant breakthrough in order for it to be useful in the vehicle. It can be used as it is.

Systems to allow full autonomy of unmanned vehicles must also be developed more thoroughly. This vehicle must have the ability to travel without guidance and to make its own decisions. Currently, much technology exists in this area, but no current vehicle is entirely autonomous. Future systems, however, will include full decision- making ability. This will allow the vehicle to successfully fulfill its objectives. There is much research being done in this field and the technology is almost available.

The development of these key technologies is crucial to the full success of the proposed vehicle. Each of these technologies is being thoroughly researched, and many of them should be available within the next few years. This will allow them to be incorporated into the vehicle design in an effective, time- efficient manner. By incorporating future technologies into the design, a vehicle can be planned that will meet all of the given specifications.

4.2 Phase 3 Plan

During Phase Three of this project, the selected design will be improved, and its systems will be elaborated on. Development issues will be further studied, and, if possible, resolved, during this phase. Detailed designs and math models will be constructed for each subsystem of the vehicle. Accurate calculations will be made, and design work will be more detailed. Schedules, cost estimates, and related studies will also be completed during Phase III. Research will be conducted in order to complete an accurate, realistic design of the selected vehicle.

Development issues and future technologies will be thoroughly studied during Phase III of this design. Many technologies, that will be important to the proposed vehicle, are currently being developed by leading research groups. The new technologies will be studied in order to incorporate the latest technology into the design. The possibility of developing the required technologies specifically for this vehicle will also be considered. A detailed study of future technologies will be an important component of the Phase Three design.

Studying new technologies will also be important because it will help these designs to be understood well enough to be incorporated into the overall design in a numerically and dimensionally correct way. Sizes, weights, and important equations relating to the new technologies will be found. The design will thus include good data relating to new technology as well as to existing technology.

During Phase III, more exact numerical values will be obtained for size, weight, speed, power, and other measurements. Accurate math models for each subsystem will be written, and will be compiled to show that the overall design is feasible and will meet the given requirements. Precise designs of every system will allow these calculations to be made.

More detailed drawings will be made in order to show exactly where everything will be located in the vehicle. These designs will show how each subsystem fits into the design, as well as the numerical values associated with most parts of the design. New technologies will be incorporated into these designs

5.0 Illustrations

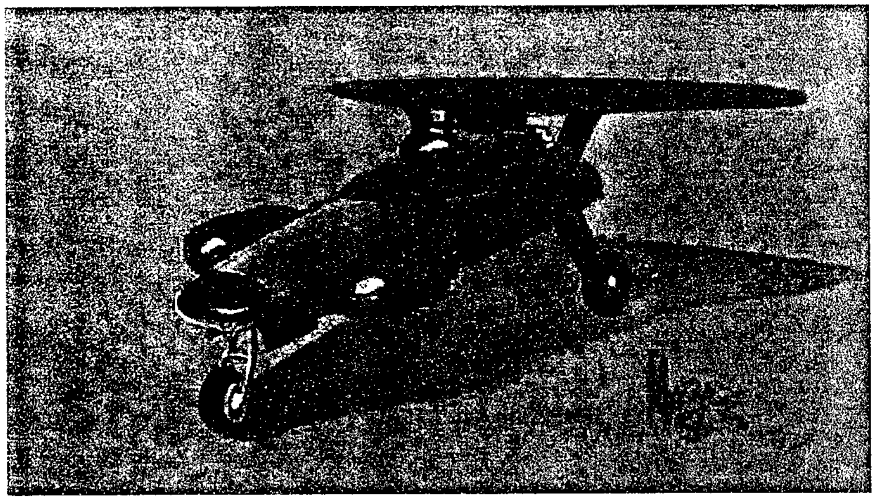

Figure 1. Concept 1-1 “CD 1-1”

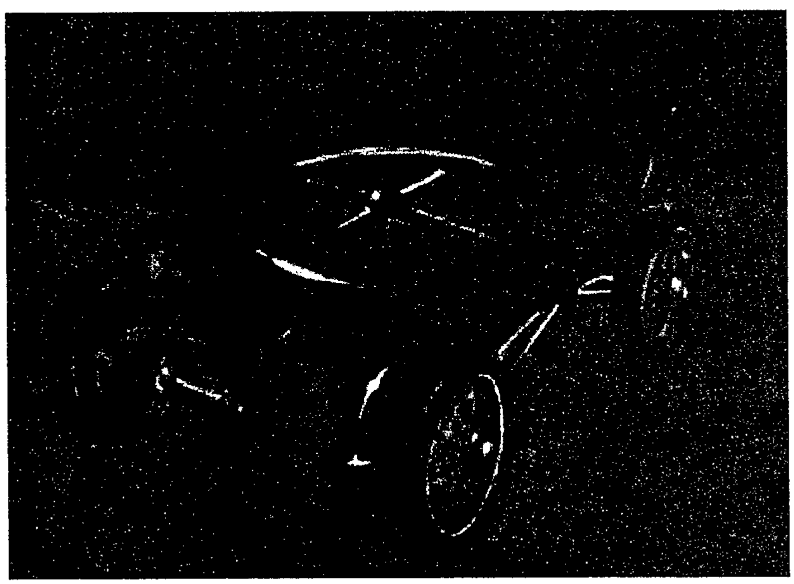

Figure 2. Concept 1-2 “CD1-2”

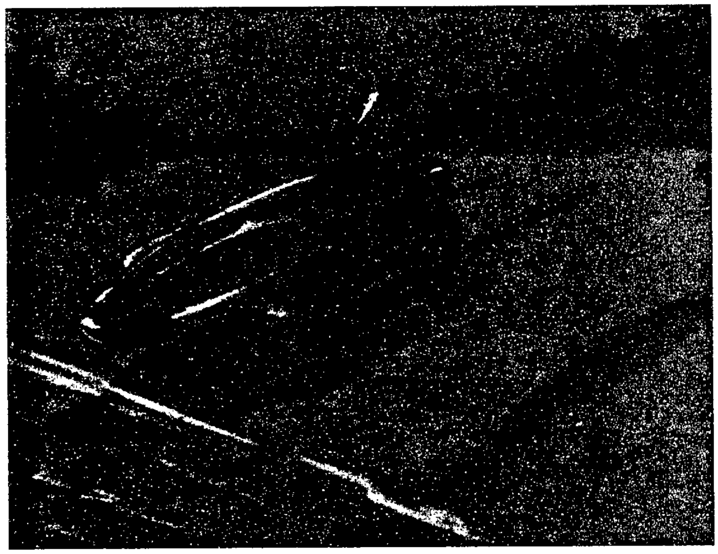

Figure 3. Concept 1-3 "CD1-3"

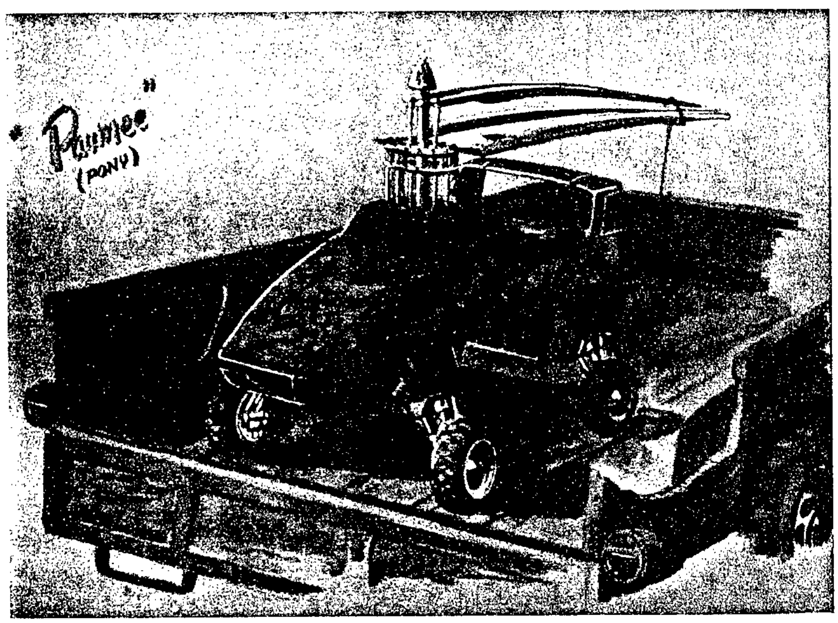

Figure 4. Concept 1-4 "Baseline Design"

Table 1. Concept Evaluation Matrix

This matrix is used to evaluate each of the concepts relative to each other. Each concept was compared to each other using the same characteristics. The factors looked at were weighted as to their importance to the project. A plus means that the concept meets the requirement and a minus means that the concept does not meat the requirement.

	Factor	Baseline	1-1	1-2	1-3
Range: 15 km From Launch Point	2	+	+	+	+
Cruise Speed of 30 km/hr	2	+	+	+	+
VROC of 250 ft/min	3	-	+	+	+
VTOL Capability	2	+	+	+	+
Payload: 60 lbs.	2	+	+	+	+
Operational Altitude of 0 to 500 ft AGL	2	+	+	+	+
Hover to Full Flight Profile	2	+	+	+	+
Autonomous or Semi-Autonomous	2	–	+	+	+
Near Quiet Acoustic Signature	2	–	+	–	+
BLOS Communications	3	-	+	+	+
Cost/Risk/Schedule	2	+	–	–	–
Potential Reliability (RAM)	2	+	+	+	–
Ground Mobility	2	+	+	+	+
Developmental Costs Below $20M	2	+	+	-	-
Totals	30	10	20	16	18

Table 2. Concepts Comparison

This table provides a side-by-side comparison of each design. It shows the same information for each vehicle.

Comparison Criteria	**Baseline**	**1-1**	**1-2**	**1-3**
Overall Specifications				
Air Configuration	Coaxial Rotor	1 Ducted Fans	1 Ducted Fan	Anti-Gravity
Ground Configuration	Wheels	Wheels	Wheels	Tracks
Payload Mass, kg (lb.)	27.2 (60)	27.2 (60)	27.2 (60)	27.2 (60)
Gross Takeoff Weight. Kg (lb.)	278.5 (614)	226.8 (500)	249.5 (550)	136.1 (300)
Energy Source for Air Transport	JP-8	Wankel Rotary Pulse Detonation	Electric Engine With Fuel Cell	Ion Drive
Energy Source for Ground Transport	JP-8	Wankel rotary gasoline	Electric Engine With Fuel Cell	Ion Drive
Hovering Power, kW (hp)	25.35 (34)	33.6 (135)	33.6 (136)	15 (20)
Cruise Power, kW, (hp)	67.86 (91)	22.5 (90)	22.5 (89)	22.5 (89)
Total Energy for Mission Profile, kJ (BTU)	5.611E5 (5.318E5)	1.145E6 (1.086E6)	1.145E6 (1.085E6)	1.145E6 (1.085E6)
Basis of Autonomy	None	Computer	Computer	Computer
Primary BLOS Method	None	K- Band	K- Band	K- Band
Primary Structural Material	Carbon Fiber	Fiber Reinforced Plastic	Carbon Fiber	Aluminum
Propulsion	Existing	Existing	Fuel Cells	Ion Drive
Aero	Existing	Existing	Existing	Anti-Gravity
Materials	Existing	Lighter Weight	Lighter Weight	Lighter Weight

(McCormick)

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Young, Suzy. 2001. Interviewed by Jason Newton. Huntsville, AL. 15 February.

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Young, Suzy. 2001. Interviewed by Jason Newton. Huntsville, AL. 15 February.

Word List

Word	Comments
AGL	Above Ground Level
AIAA	American Institute of Aeronautics and Astronautics
AMCOM	United States Army Aviation and Missile Command
BLOS	Beyond Line of Sight
CAD	Computer aided design
CM	Communication
Concept Description Document	Document that details the customer's technical specifications for the UA/UGV
CST	Central Standard Time
Customer	John Fulda and Jim Winkeler
Dry Weight	
EE	Electrical Engineering
EH	English
EM	Engineering Management
EST	Editorial Support Team
ESTACA	Ecole Superieure des Techniques Aeronautiques et de Construction
FLOT	Forward Line of Troops
Ft	Feet
IPT	Integrated Product Team
IRP	Intermediate Power Rating
JAUGS	Joint Architecture for Unmanned Ground systems
JCDL	Joint Command Data Link
Joint Vision 2020	TBD
Km	Kilometer
Lbs.	Pounds
MAE	Mechanical and Aerospace Engineering
MKT	Marketing
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
Nm	Nautical miles (~2025 yds)
Payload	Item carried by the system having a specified weight
Phase 1	Baseline review, conducted on conventional configuration using current and experimental technology, assess technologies clarify the Concept Description Document
Phase 2	Alternative concepts review, development and evaluation of four prototype designs to meet customer specifications. Select a preferred design.
Phase 3	Final Evaluation, detailed design specifications of selected design concept
RFP	Request for Proposal
RMA	Revolution of Military Affairs
Style Guide	Document that specifies the mechanics of writing

	documents required for the project
TBD	To be determined (not know at this time)
TBE	Teledyne Brown Engineering
TF/TA	Terrain following/terrain avoidance
UAH	The University of Alabama in Huntsville
UAVG	Unmanned Air Ground Vehicle
UAV	Unmanned Air Vehicle
UGV	Unmanned Ground Vehicle
US	United States
VROC	Vertical rate of climb
VTOL	Vertical takeoff and landing

Appendix C - France Travel Team

The following will go to France if our team is selected. The Table also represents the order of preference of team member if the team is not selected by additional slots are available. First member must be willing to present summary of team results. If you are proposing taking a friend or family member, please include.

NAME AS IT APPEARS ON PASSPORT	NATIONALITY	PASSPORT EXPIRATION DATE
Timur Hakimov (Student)	US	Current
Virgil White (Student)	Uzbekistan	2003
Jason Newton (Student)	US	pending
Felicia Smith	US	pending
Jennifer Leigh Kreps McDougal	US	pending
Kris McDougal (Student)	US	pending

Each student will have $75 dollars for transportation and $200 for food. The students will be housed by French students.

Appendix D - Team Member Resumes

Cyril Augier

221rue du Fbg St Honore
75008 Paris
Phone (33) 6 68 43 41 82
cyrilaugier@hotmail.com

Key Words — **Mechanical Engineering, Automotive Engineering, French, Systems Control, Matlab/Simulink-d-Space,**

Education

ESTACA Levallois-Perret, France
Five year program in Mechanical/Automotive Engineering
Expected graduation date: Jun 2002
Relevant Coursework: systems controls, automotive stability and control, engine design and control, suspension, structure modelization
TOEFL 000 score: 280
Work Sample:
http://mortonweb.uah.edu/ipt2001/AugierC_work.pdf

Technical Skills

Operating Systems: Windows 95, 98, NT
Computer Language: C++
CAD / FEM Systems: CATIA, ADAMS, Nastran, Matlab/Simulink-d-Space

Work Experience

Aug - Sep 2000 Cartier, Inc. New York, NY
After sale service agent
Took care of clients and of their repairs
Managed special orders and parts for quick service

Nov – Dec 1999 Le Parisien Paris, France
Team Manager
Managed launching of the Sunday edition of a local newspaper
Managed an "on the street" selling team of 12 people
Directed all the team leaders (15 people), who were all in charge of a selling team

August 1999 Jaguar Cars Paris, France
Spare Parts Dealer, Spare Parts Department
Sold spare parts to professionals and individuals
Managed the stock for the workshop and the dealership

References

Available on Request

Majed Batais

4515 Bonnell Drive, Apt. 1-F
Huntsville, AL 35816
Phone (256) 527-7002
Email bataism@email.uah.edu

Key Words
Electrical Engineering, Matlab, FORTRAN, C, I-DEAS, Workbench, Altera Max+PLUS, VHDL

Education
The University of Alabama in Huntsville Huntsville, AL
Bachelor of Science, Electrical Engineering
Expected graduation date: May 2001
Relevant Coursework: logic design using VHDL, analog and digital circuit simulation, data communication, software maintenance, analytical methods for continuous and multivariable and discrete time systems, computer networking
Work Sample: http://mortonweb.uah.edu/ipt2001/BataisM_work.pdf

Technical Skills
Operating Systems: Windows 95, 98, 2000, and NT
Computer Languages: FORTRAN, C, Assembly
CAD Systems: I-DEAS, Matlab
Circuit Simulation Systems: Workbench and Altera Max+PLUS
Major Software Packages: MS Office 2000
Web Development: FrontPage 98 and 2000

Work Experience
May 1997– Aug 2000 The University of Alabama in Huntsville Huntsville, AL
Computer Lab Assistant
Assisted students in solving software installation and maintenance problems.
Simulated and created wiring circuits using electronics workbench, Max+PLUS software, and analog/digital trainer.

Kevin R. Buch

Permanent Address
6243 Rime Village Dr. 206
Huntsville, AL 35806
Phone (256) 971-1493
Email buchk@email.uah.edu

Key Words

Mechanical Engineering, Aerospace Engineering, German

Education

The University of Alabama in Huntsville Huntsville, AL
Bachelor of Science, Mechanical/Aerospace Engineering
Expected graduation date: August 2001
Minor: None
GPA.: 3.56/4.0
Relevant Coursework: thermodynamics, fluid mechanics, dynamics, basic circuits, introduction to engineering design, aerodynamics, aerospace structures, propulsion
Honors and Affiliations: UAH Engineering Dean's List, Pi Tau Sigma Mechanical Engineering Honor Society

Technical Skills

Operating Systems: Windows 95, 98, NT
Computer Languages: FORTRAN, Microsoft Excel
CAD / FEM Systems: AutoCAD 11
Major Software Packages: MS Office 2000

Work Experience

Jun 1999 – Aug 1999 Marshall Space Fight Center Huntsville, AL
Summer Faculty Fellowship accompanying Student
Performed Thermal and Optical analysis of a laser lightcraft concept.

Jun 2000 – Aug 2000 U.S. Space and Rocket Center Huntsville, AL
Space Academy Conselor
Supervised campers and taught them space history.

Sept 2000 – Present University of Alabama in Huntsville Huntsville, AL
Research Assistant, Department of Mechanical/Aerospace Engineering
Prepared equipment for use in the Vacuum Test Facility in the Solar lab.
Working on design on Solar Sails in cooperation with Teledyne Brown Engineering.

Refrences

Available Upon Request

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Permanent Address
5013 County Rd. 61
Florence, AL 35634
Phone (256) 760-4986

Key Words — **Mechanical Engineering, Solid Edge, I-DEAS, C++, Structural Analysis, Thermal Analysis**

Education

The University of Alabama in Huntsville — Huntsville, AL
Bachelor of Science, Mechanical Engineering
Expected graduation date: May 2001
Relevant Coursework: thermodynamics, fluid mechanics, material science, electrical circuits, mechanics of materials, dynamics, statics, aerospace structures, heat and mass transfer, kinematics, machine design, engineering design
Work Sample: http://mortonweb.uah.edu/ipt2001/CanderdayS_work.pdf

Technical Skills

Operating Systems: Windows 95, 98, 2000, NT, ME
Computer Languages: C++, Visual Basic
CAD / CAM Systems: I-DEAS, Solid Edge

Work Experience

Oct 1999 – Jan 2000 — Bosch Aerospace — Huntsville, AL
Engineering Assistant
Researched carbon fibers for use by military as a heat dissipation system.
Studied wind tunnel design and development.

Sep 1997 – Apr 1998 — Eliza Coffee Memorial Hospital
Florence, AL
Storeroom Clerk
Delivered supplies throughout the hospital.
Entered received supplies into database.

References — Available on Request

Laura M. Filz

103 Chris Hoover Circle
Harvest, AL 35749
Phone (256) 830-1968
Email lmfilz@aol.com

Key Words — **Mechanical Engineering, Aerospace Engineering, MathCAD, Solid Edge**

Education

The University of Alabama in Huntsville — Huntsville, AL

Bachelor of Science, Mechanical Engineering

Expected graduation date: May 2001

- Minor: Mathematics
- GPA: 3.00/4.0
- Relevant Coursework: thermodynamics, materials science, fluid mechanics, dynamics, design, aerodynamics, aircraft stability and control, mechanics of materials
- Work Sample: http://mortonweb.uah.edu/ipt2001/FilzL_work.pdf
- Honors and Affiliations: UAH Academic Excellence Scholarship, American Helicopter Society, Team Leader for senior design class

Technical Skills

- Operating Systems: Windows 95, 98, and DOS
- CAD / FEM Systems: Unigraphics Solid Edge
- Major Software Packages: MS Office 2000 (including Access), Matlab, MathCAD, Lotus Suite

Work Experience

June 1994 – Present — Filz Renovations — Harvest, AL

Remodeling/Repair Assistant

- Supervise two employees.
- Accomplish site set and completion of contract in a set time requirement.

Dec 2000 – Present — The University of Alabama in Huntsville — Huntsville, AL

Research Assistant, Department of Mechanical/Aerospace Engineering

- Responsible for administrative duties relative to AMCOM project.
- Attend meetings with the customer.
- Ensure that all students have the material they need for the class.

References — Available upon request

Timur M. Hakimov

1503 Sparkman Drive, Apt. T-157
Huntsville, AL 35816
Phone (256) 837-7603
E-mail timur64@hotmail.com

Key Words

Mechanical Engineering, I-DEAS, C, Basic, Unix, Russian, Uzbek

Education

The University of Alabama in Huntsville — Huntsville, AL
Bachelor of Science, Mechanical Engineering
Expected graduation date: May 2001

- Relevant Coursework: thermodynamics, fluid mechanics, heat and mass transfer, material science, aerospace structures, basic circuits
- Work Sample: http://mortonweb.uah.edu/ipt2001/HakimovT_work.pdf
- Honors and Affiliations: Scholar of the UMID Foundation of the President of the Republic of Uzbekistan to support education of talented youth abroad

Technical Skills

- Operating Systems: Windows 95, 98, 2000, NT, Unix, and DOS
- Computer Languages: C, Basic
- CAD/FEM Systems: I-DEAS
- Major Software Packages: MS Office 2000

Work Experience

Jun 2000 – Aug 2000 State committee for Science and Technology of the Republic of Uzbekistan — Namangan
Research Assistant, Design Department

- Calculated thermal analysis on heating awning made from ceramics and filled with pereclas (a powder that helps to stand temperatures up to 1000 °C).
- Helped to perform capability studies of the equipment

Jun 1999 – Aug 1999 "UzAutoRoad" Business Concern — Uzbekistan
Research Assistant, Architecture and Design Department

- Drew graphs and schemes of a new road from the capital to one of the biggest cities of the republic.
- Helped develop a database that was used to calculate the number of traffic lights, traffic signs, and bus stops that needed to be installed on the road.

Timothy W. Hardin

135 Alton Lynch Cir.
Huntsville, AL 35757
Phone (256) 722-2707
Tanis1977@yahoo.com

Key Words **Mechanical Engineering, Thermal Analysis, AutoCAD, I-DEAS, FORTRAN**

Education

The University of Alabama in Huntsville — Huntsville, AL

Bachelor of Science, Mechanical/Aerospace Engineering

Expected graduation date: December 2001

- Relevant Coursework: thermodynamics, materials science, fluid mechanics, dynamics, basic circuits, design, manufacturing processes
- Work Sample: http://mortonweb.uah.edu/ipt2001/HardinT_work.pdf
- Affiliations: Junior ROTC, Society for Creative Anachronism

Technical Skills

- Operating Systems: Windows 95, 98, NT, ME
- Computer Languages: FORTRAN
- CAD / FEM Systems: I-DEAS, AutoCAD 12 & 14
- Major Software Packages: MS Office 2000

Work Experience

Aug 2000 – Present The University of Alabama in Huntsville — Huntsville, AL

Attendant, University Center Cyber Café

- Monitor use of campus facilities.
- Assist student use of campus facilities.
- Operate cash register.
- Lock up at night.

Aug 1999 – Feb 2000 Alabama Science in Motion Program — Huntsville, AL

Research & Lab Assistant

- Maintained and set up chemistry lab and equipment for a program designed to bring college level chemistry to high schools.
- Did office work (answered phones, typed, prepared instructions for labs, etc.)
- Researched various topics about teaching chemistry.

Refrences Available upon request

School Address
18 boulevard Pereire
Paris, 75017
Phone : (33) 1 42 27 48 32
E-mailpivoula@caramail.com

Permanent Address
55 rue Poivre
Bras_Panon,97412
Réunion Island

Pierrot Ivoula

Key Words

Mechanical Engineering, Aeronautical Engineering, Servo Control, Databases, Java, CATIA, ADAMS, Matlab, Simulink, Nastran, Patran, Spanish

Education

ESTACA Levallois-Perret, France
Five-year program in Aeronautical Engineering
Expected graduation date: Jun 2002
Minor: Spanish
Relevant Coursework: servo-control, materials science, fluid mechanics, dynamics, basic circuits, aerodynamics, aerospace structures, aircraft stability and control, propulsion
Work Sample: http://mortonweb.uah.edu/ipt2001/IvoulaP_work.pdf

Technical Skills

- Operating Systems: Windows 2000, NT, Unix
- Computer Languages: Basic, C, Java
- CAD / FEM Systems: CATIA 4.19, Nastran, Patran
- Major Software Packages: MS Office 2000 (including Access)
- Graduate school specialized in transport (equivalent to MSc)

Work Experience

Aug 2000 Air-France Industries Réunion, France
Aircraft Maintenance Department
Analyzed and streamlined the department organization.
Assisted technical staff in maintaining the aircraft (B747, A340, DC10-30) landing gear, engine, and wings.

Jul 2000 SNECMA-moteurs Gennevilliers, France
R&D Division
Worked in department that studied fans for engines CFM56 and GE90
- Focused on one stage of the production cycle aimed at changing the structure of steels.
- Attended engine tests at SNECMA, Villaroche.

Jul 1999 T.I.P.E (Travail d'Initiative Personnelle Encadré)
Gave presentation on Michelin tires and aircraft measuring speed equipment to a physicist and an engineering teacher.

References

Available upon request

School Address
7 rue Victor Hugo
92300 Levallois-Perret, France
Phone (33) 6 63 85 72 19
E-mail skriner@estaca.fr

Permanent Address
7 rue du Chevreuil
60200 Compiegne, France
Phone (33) 3 44 20 83 75

Sebastien Kriner

Key Words

Mechanical Engineering, Aeronautical Engineering, Thermo Fluid Engineering, Nastran, CATIA, FORTRAN, FLUENT

Education

ESTACA Levallois-Perret, France
Five-year program in Mechanical/Aerospace Engineering
Expected graduation date: Jun 2002
Relevant Coursework: thermodynamics, fluid mechanics, dynamics, aerodynamics, aerospace structures, propulsion
Work Sample: http://mortonweb.uah.edu/ipt2001/KrinerS_work.pdf
Honors and Affiliations: President of Mechanic's Student Offrice of Pierre et Marie Curie University

Technical Skills

- Operating Systems: Windows 95, 98, 2000, NT, UNIX, and DOS
- Computer Languages: FORTRAN, Turbo Pascal
- CAD / FEM Systems: Nastran, CATIA, FLUENT
- Major Software Packages: MS Office 2000

Work Experience

Jun - Aug 2000 Alstom Industries La Courneuve, France
Co-op Research Engineer
Developed a new oil less regulation system for Steam Turbine.

Jun -Aug 1998 Société National des chemins de Fer Francais Paris, France
Assistant in Information Department

Jun - Aug 1997 Credit Lyonnais Bank Paris, France
Cashier

References

Available upon request

Kristopher J. McDougal

School Address
416 Julia St., Apt. 207
Huntsville, AL 35816
Phone (256) 534-2101
Email kjmcd3301@cs.com

Permanent Address
1978 County Road 170
Killen, AL 35645
Phone (256) 757-5391

Key Words **Mechanical Engineering, CAD/CAM, HVAC, Leadership, Matlab**

Education

The University of Alabama in Huntsville — Huntsville, AL

Bachelor of Science, Mechanical Engineering

Expected graduation date: May 2001

- GPA: 3.18/4.0
- Relevant Coursework: engineering design, machine design, AutoCAD, fluid dynamics, thermodynamics, engineering graphics, manufacturing processes, analysis of engineering systems, measurement and instrumentation, nature and property of materials
- Work Sample: http://mortonweb.uah.edu/ipt2001/McdougalK_work.pdf

Northwest-Shoals Community College — Muscle Shoals, AL

General Studies

- Honors and Affiliations: Phi Theta Kappa Academic Honor Society, Leaders of the Future Ambassador, Runner-up Mr. Shoals Community College

Technical Skills

- Operating Systems: SUN Microsystems, Windows 95, 98, NT
- Programming Languages: Matlab, FORTRAN
- Software Applications: MS Office Suite (including Access), Total CAD 2D/3D

Work Experience

Sep 1998 - Mar 1999 — SCI Systems, Inc — Huntsville, AL

Material Handler / Shipping and Receiving.

Gained knowledge of each part and component and its function.
Utilized COPICS, tracking and inventory software.
Assembled and tested state-of-the-art satellite systems.

May 1991- Aug 1998 — McGee Heating and Air — Killen, AL

System Installer

Installing and troubleshooting heating and cooling systems.
Handling basic service of units.
Installing gas equipment.
Designing and building duct systems.
Assessing homes for system size and layout of supply and return duct.

References

Available on Request

Jason M. Newton

1161 Highway 99
Anderson, AL 35610
Phone (256) 247-0737
Email newtonj@email.uah.edu

Key Words

Mechanical Engineering, Automobile Engineering, C, I-DEAS

Education

The University of Alabama in Huntsville   Huntsville, AL

Bachelor of Science, Mechanical Engineering

Expected graduation date: Dec 2001

Relevant Coursework: thermodynamics, materials science, fluid mechanics, dynamics, basic circuits, design, statics, kinematics and machine design
Work Sample: http://mortonweb.uah.edu/ipt2001/NewtonJ_work.pdf
Honors and Affiliations: Society of Automotive Engineers

Technical Skills

- Operating Systems: Windows 95, 98, NT
- Computer Languages: FORTRAN, C, Pascal
- CAD Systems: I-DEAS
- Major Software Packages: MS Office 97

Work Experience

Oct 2000 - Present   Joe Wheeler State Park   Rogersville, AL
Dining Room Server
Responsible for care of customers and cash register.

Jun 2000 - Aug 2000 Shaw Constructors   Decatur, AL
Electrician Helper
Installed electrical conduit and wiring for instrumentation.

May 1998 - Jun 2000 Joe Wheeler State Park   Rogersville, AL
Assistant Banquet Supervisor
Responsible for crew supervision and room set-up.
Stand-in for banquet manager when needed.

Apr 1997 - May 1998 Wal-Mart   Athens, AL
Sporting Goods Associate
Responsible for customer service, stocking, and gun sales.

May 1991 - Aug 1996 Joe Wheeler State Park   Rogersville, AL
Banquet Manager
Responsible for recruiting employees, scheduling, room set-up.
Overseer of banquet functions.

References

Available upon request

Angeline Nuar

3227 Westheimer, Apt. 4
Huntsville, AL 35805
Phone (256) 534-6861
Email nuara@email.uah.edu

Key Words

Mechanical Engineering, Aerospace Engineering, Basic, FORTRAN, Microsoft Office

Education

The University of Alabama in Huntsville — Huntsville, AL

Bachelor of Science, Mechanical/Aerospace Engineering

Expected graduation date: Dec 2001

- GPA: 3.0/4.0
- Relevant Coursework: fluid mechanics, materials science, thermodynamics, numerical methods, instrumentation, engineering design
- Work Sample: http://mortonweb.uah.edu/ipt2001/NuarA_work.pdf
- Honors and Affiliations: ASME, CSF, Cross Country Team, SEDS, ASME Student Engineer of the Year Award, 1998 Gold Scholar-Athlete Award

Technical Skills

- Operating Systems: Windows 95, 98
- Computer Languages: FORTRAN, Basic
- Major Software Packages: MS Office

Work Experience

May 1998 – Present U.S. Space and Rocket Center — Huntsville, AL

Space Camp Counselor, Space Academy Counselor

- Organize, supervise, and support teams of trainees.
- Lead teams through various space-related activities.
- Teach space science and space history.

Jan 1998 – Dec 1998 Teledyne Brown — Huntsville, AL

Co-op Engineer

- Wrote programs predicting behavior of re-entry vehicles.
- Coordinated various reports, schedules, and calendars.

References

Available upon request

Richie Sparkman

Address

104 Seneca Springs Dr.
Trinity, Alabama 35673
Phone: (256) 308-0180
Email: Tideguy77@aol.com

Key Words

Mechanical Engineering, Autocad, Microstation, Community Planning, Microsoft Project, HVAC, Municipal, CNC, Ergonomics, Machine Shop, Manufacturing Engineer, Project Management, Outage Planning, Maintenance Engineer, Multi-Skilled Helper, High Volume Assembly, Paper Mill, Chemical Plant

Education

The University of Alabama in Huntsville — Huntsville, AL

Bachelor of Science, Mechanical Engineering
Expected Graduation Date: May 2001

- Relevant Courses: CAD/CAM, Ergonomics, Design, Heat Transfer, Thermodynamics, Fluid Mechanics, Strength of Materials, Material Science, Instrumentation, Systems Analysis, Probability and Statistics, Circuits, Kinematics, Dynamics, Machine Design

Technical Skills

- Extensive experience in all phases of community planning, development, and government
- Skilled in Fortran, Lotus, Irma, Microsoft Office, Microsoft Project, Microstation and Autocad 14

Work Experience

Dec 2000- Present Reisz Engineering — Huntsville, AL

Asst. Engineer

- Design and Development of Commercial and Industrial HVAC and Thermal Systems

Oct 2000- Present Town of Trinity — Trinity, AL

City Council Place #3

- Govern municipality in which I live
- Council Representative to Trinity Planning Commission (Planning Commissioner)
- Council liaison to town engineer and planners

May 2000- Aug 2000 Copeland Corp. — Hartselle, AL

Machine Shop Co-op

- assumed role of manufacturing engineer
- Daily oversight of production and maintenance on East Crank Line
- CNC experience
- Member of Ergonomics Team

June 1997- Jan 2000 Champion Intl. Paper — Courtland, AL

Mechanical Engineering Co-op

- Managed small to large scope projects ($10,000-$400,000)
- Assisted Superintendents, Planners, and Foremen in daily maintenance activities and outage planning
- Maintenance Engineer on #30 Paper Machine

Oct 1995- June 1997 BE& K (@ Nova Chemicals' Site) — Decatur, AL

Multi-Skilled Helper

- Assisted BE&K craftsmen and Nova maintenance team in project work, shutdowns, and daily maintenance

William Thomas

27 quater rue des meuniers
75012 Paris, France
Phone: +33 6 61 57 42 49

Key Words

Mechanical Engineering, Automotive Engineering, Servo Control, Noise & Vibration, CATIA, Nastran, Patran, ADAMS, C++, Matlab/Simulink

Education

ESTACA Levallois-Perret, France

Five-year program in Mechanical/Automotive Engineering Expected graduation date: Jun 2002

- Minor: Spanish
- Relevant Courses: thermodynamics, materials science, fluid mechanics, dynamics, design, aerodynamics, FEM, servo control, brake system, signal processing, sensors
- Work Sample: http://mortonweb.uah.edu/ipt2001/ThomasW_work.pdf
- Honors and Affiliations: Creation of an association called "Talon-Pointe" at ESTACA, which permits me to drive a sports car on a clay track.

Technical Skills

- Operating Systems: Windows 95, 98, NT
- Computer Language: C++
- CAD / FEM Systems: CATIA, Nastran & Patran, ADAMS, Matlab/simulink
- Major Software Packages: MS Office 2000 (including Access)

Work Experience

Jun - Aug 2000 SAAB/SMART Paris, France

Driver

- Drove during the Paris Motor Show.

Jun – Aug 1999 L'Acrotere Paris, France

Organization Assistant

- Organized the head office of an old building rehabilitation company.
- Improved the computer network.

Jun - Aug 1997 Dassault-Aviation Argenteuil, France

Spare Parts Assistant

- Assisted in checking out the entry and exit of spare parts.

References

Available on Request

Virgil Joe White

School Address
301 Sparkman Drive
Huntsville, AL 35899
Phone (256) 890-6120
Email namboat2@mindspring.com

Permanent Address
8005 Tommy Hill Road
Anderson, AL 35610
Phone (256) 232-8201

Key Words

Mechanical Engineering, Thermal Analysis, CAD (Solid Edge and Ideas), Basic Fortran, Excel, Lotus 1-2-3, Stylus, Computer Ordering

Education

The University of Alabama in Huntsville — Huntsville, AL
Bachelor of Science, Mechanical Engineering
Expected graduation date: Aug 2001

- Relevant Coursework: thermodynamics, material science, fluid mechanics, dynamics, basic circuits, design, heat and mass transfer

Technical Skills

- Operating Systems: Windows 95, 98, NT
- Computer Languages: Basic Fortran
- CAD: Solid Edge, Ideas
- Major Software Packages: MS Office

Work Experience

June2000– Present The Kroger Company Store #887 — Huntsville, AL
Assistant Grocery Manager

- Order merchandise and predict item sales
- Send and receive orders and deliveries
- Supervise and train grocery stock crew
- Audit inventory and maintain computer ordering system
- Ensure proper customer relations

Jan 1991 – June2000 The Kroger Company Store#508 — Huntsville, AL
Grocery Stock Clerk

- Ordered and stocked merchandise
- Audited inventory and unloaded deliveries

June 1991 – Jan1994 The Kroger Company Store#856 — Athens, AL
Part time produce clerk, cashier, courtesy clerk

- Operated checkout register and bagged groceries
- Weighed, priced, and displayed produce

Appendix E – Sample Calculations

The calculations are provided in the hard copy of the paper. The documents were unreadable when scanned in.

General design computational procedures:

Of main importance are evaluation of center of gravity position and of thrust-minus-drag, and Lift/Drag for general performances.

1. Center of Pressure evaluation
   The size of the wing can be deduced from rough estimates of the realistic wing loading and the size of the fuselage is generally coming from volume constraints, but the balance of the mass require quotation from the start of the project definition. So a progressive approach by three procedures (each being more complex and more accurate that the preceding one) seems necessary an have to be used successively.

   The first is an old but efficient rule of determination of approximate subsonic center of pressure on the drawing table. It relies on the assumption that the repartition of the lift on different elements of the aircraft is elliptic or slightly distorted from elliptic distribution as given by figure 1 versus the aspect ratio, sweep angle and taper ratio. And we can assure that wing + fuselage characteristics are obtained from wing alone plus interaction. Conventionally Kw is the factor of wing lift increment when fuselage-body is present, Kb is the percentage of lift transferred to the body.

   The aerodynamic center can be built by assuming that its local position for a slice in span is on a 25% position on current chord.

   The second level of estimation of the position of the aerodynamic center is based on the use of software named NASTRAN but we need more details about the exact geometry of the aircraft.

   The third level of codes to be used in preliminary design is the level of 3D complete viscous code as FLUENT 3D. In fact , that using needs mesh definition, checking of the quality and correct mesh refinement as locally required.

2. Lift & Drag evaluations

   For each wing, we can know the graphic between Lift and Drag coefficients. As the estimation of center of pressure position, we use the method of wing + fuselage.
   If we didn't have the characteristics of Lift & Drag for the whole aircraft (wing + fuselage + tail), we must make measure during Wind tunnel test.

3. Wing PlanForm Selection

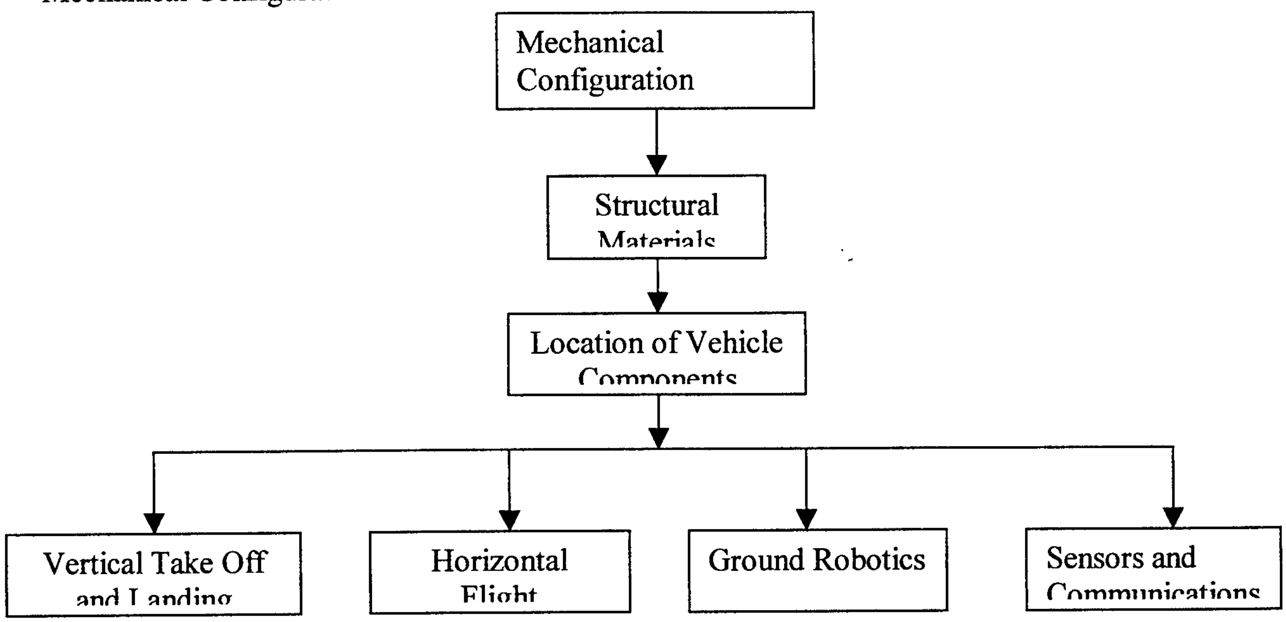
   Before the design layout can be started, the wing geometry must be selected , including parameters such as aspect ratio, sweep, taper ratio, dihedral, and thickness. While all these parameters will be numerically optimized at some later date, that optimization will proceed from a baseline aircraft arrangement and that baseline must include some initial guess as to these parameters.
   The "reference", or "trapezoidal" wing is the basic wing geometry used to begin the layout. Note that the reference wing is fictitious, and extends through the fuselage to the aircraft centerline.

There are two key sweep angles. To reduce drag it is common to sweep the leading edge behind the mach cone but it's for supersonic flight. The sweep of the quarter chord line is the sweep most related to subsonic flight.

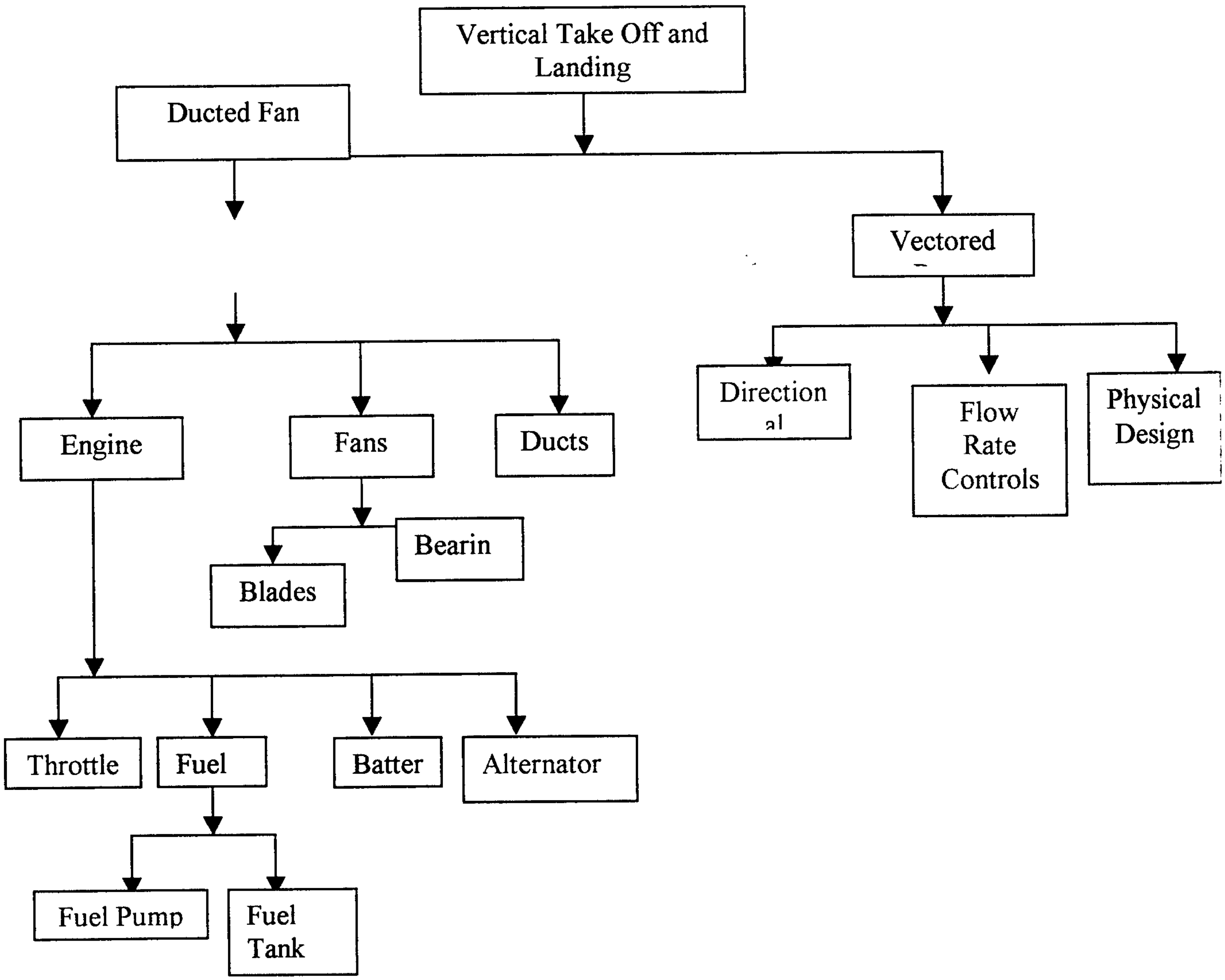
The mean aerodynamic chord is the chord "c" of an airfoil, located at some distance "y" from the centerline.
The entire wing has its mean aerodynamic center at approximately the same percent location of the mean aerodynamic chord as that of the airfoil alone. In subsonic flow, this is at the quarter chord point on the mean aerodynamic chord.
The mean aerodynamic chord and the resulting aerodynamic center point is issued to properly locate the wing.

Appendix F – Flow Charts

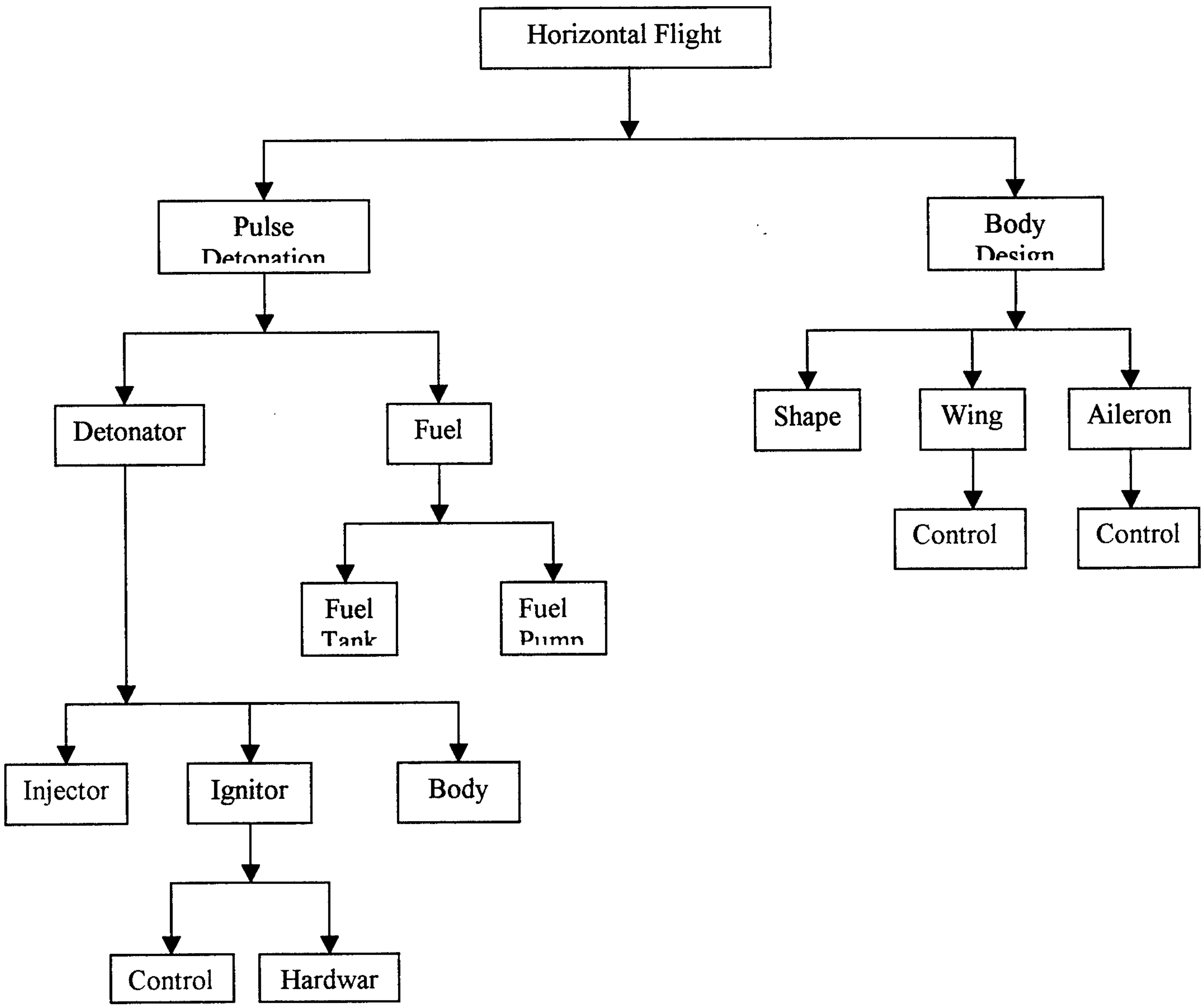
Mechanical Configuration



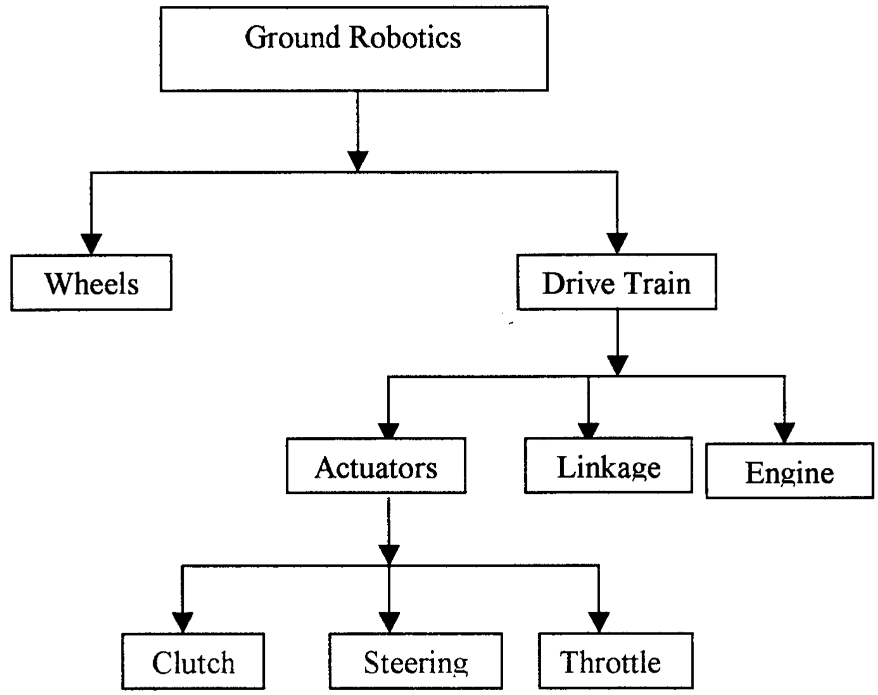
Vertical Take Off and Landing



Horizontal Flight



Ground Robotics



Appendix G – Cost Charts

The costing charts are also located in the hard copy because they were unreadable when scanned in.