CARLETON UNIVERSITY

Department of Mechanical and Aerospace Engineering

Aerospace Engineering Project

# GEOSURV II UNINHABITED AERIAL VEHICLE

FINAL REPORT

April 2009

Page intentionally left blank

## CONTENTS

Page intentionally left blank

GEOSURV II UNINHABITED AERIAL VEHICLE

FORMAL REPORT

# PART A

# INTEGRATION


**<u>Group Members</u>**

André Couture

Eric Burghardt

**<u>Lead Engineer</u>**

Michael Martin


April 2009

Page intentionally left blank

# ABSTRACT

This report provides an overview of the UAV Project at Carleton University. The project team is designing an Unmanned Aerial Vehicle called the GeoSurv II to perform geophysical surveys. A Prototype has been built and the meaning of “Prototype”, as it was interpreted by this year’s team, is briefly defined. The system requirements for the GeoSurv II are also given since these remain the ultimate goal for the aircraft. A typical mission profile is shown, which includes a catapult launch, transit to the survey area, the survey itself and a return to the recovery area with a parafoil-based recovery. An overview of the design of the UAV is provided and the major dimensions are shown to be a 16 ft wingspan, 14 ft length and 3 ft height.

The remainder of the report highlights the major aspects of the work performed by the Integration group of the 2008 – 2009 UAV project team. This includes a description of its role within the team. More specific attention is paid to three aspects of Integration’s role this year: the creation of a new approval process for designs, the methods used for configuration control and the scheduling work that was performed. It is noted as part of configuration control that the Prototype is currently estimated to weigh 193 lbs, which is 43  lbs heavier that the desired maximum weight. Also important is the need for 25  lbs in ballasts to maintain a positive static margin. This is mostly due to some equipment that would be on the GeoSurv II not being present on the Prototype. Scheduling this year was done using Excel and an overview of the method used is provided. The report provides some conclusions on the work performed this year as well as some recommendations for future teams.

# Table of Contents

## List of Figures



## Nomenclature

| | |
|---|---|
| AER | aerodynamics and propulsion |
| AVI | avionics and flight testing |
| DR | design report |
| FS | fuselage station |
| GCS | ground control station |
| HP | horsepower |
| INT | Integration |
| KEAS | knots equivalent airspeed |
| knots | Nautical miles per hour |
| lbs | Pounds weight |
| ODA | obstacle detection and avoidance |
| OML | outer mould line |
| Pro/E | Professional Engineer CAD program |
| SAF | system safety and certification |
| SGL | Sander Geophysics Limited |
| SRD | systems requirements document |
| STR | structures and mechanical systems |
| UAV | unmanned aerial vehicle |
| WL | waterline |
| WS | wing station |

## 1. PROJECT INTRODUCTION

The 2008-2009 academic year was the fifth year of the Carleton University GeoSurv II project. This project brings together fourth year engineering students to accomplish a multi-year goal of designing and building a composite-construction Unmanned Aerial Vehicle (UAV) that can perform geophysical surveys autonomously. Sander Geophysics Ltd. (SGL) in Ottawa, Ontario currently flies these types of missions all over the world using conventional aircraft like the Cessna Caravan. Flying surveys in this aircraft requires a crew of four people including two pilots, a geophysicist and an aircraft maintenance engineer. In contrast the GeoSurv II is designed to be operated by a crew of two, an aircraft maintenance engineer and a geophysicist. The autonomous nature of the UAV system means that a conventional pilot is not required. The UAV uses a supervisory control style where the operator tells the aircraft where to go and what to do but the autopilot makes all of the necessary decisions along the way including obstacle detection and avoidance. The reduction in crew is just one of the many advantages of the GeoSurv II system. Other advantages include being able to fly lower and slower than conventional aircraft, not requiring a pilot, and with an entirely composite airframe, the magnetic signature of the GeoSurv II is minimized and therefore produces less noise in the sensor data.

Sander Geophysics Ltd. and Carleton University have partnered to develop the GeoSurv II and all required systems. This year the focus has been on the manufacturing of a prototype. The prototype configuration will use landing gear in place of a launch and recovery system. The prototype will be radio-controlled (RC) and flown similar to small RC planes. The system designed to eventually control the UAV autonomously will be onboard taking data points. As well this year an air data probe was designed and manufactured for more accurate in-flight data. As the scope of the UAV requires a large team of students, the team is divided into five specialized groups. The groups that make up the GeoSurv II project team are:

- Integration (INT)
- Aerodynamics and Propulsion (AER)
- Avionics and Flight Testing (AVI)
- Structure and Mechanical Systems (STR)
- Airworthiness and Certification (ACE)

The remaining sections of this report will outline the work accomplished by the 2008-2009 UAV team with the remainder of Section A providing an overall view of the aircraft as it exists currently and the work completed by the Integration group.

## 2. DESCRIPTION OF THE GEOSURV II PROTOTYPE

The 2008/9 year differed from previous years in that almost all of the team’s efforts in analysis and design were dedicated to the GeoSurv II Prototype as opposed to the GeoSurv II itself. The definition of the Prototype was not completely explicit from the beginning of the year, but a few aspects were clear. Namely, the Prototype:

1. will not be performing a catapult launch or parafoil recovery but will use conventional landing gear,
2. will not meet the maximum weight requirement of 150 lbs,
3. will be radio-controlled for initial flight testing rather than autonomous,
4. will not contain any system permitting autonomous obstacle avoidance or terrain-following,
5. will not carry mission sensors such as magnetometers,
6. will be designed to prove the flight characteristics of the platform and will therefore be as true to the GeoSurv II as the pre-existing design work and manufactured parts allow.

Given the above considerations, the design of some aspects of the aircraft was simplified and no further consideration was given to the catapult launch or parafoil recovery methods. Furthermore, the avionics design was restricted to what was required for successful radio-controlled flight, with no consideration given to autonomous flight features. An additional requirement to gather flight performance data prompted some new design work on an air data boom by the AER group.

For a point-by-point analysis of the elements of the System Requirements Document (SRD) that do not apply to the Prototype, please refer to revision F of the SRD.

## 3. SYSTEM REQUIREMENTS

The requirements for the UAV system were developed as a collaborative effort between the Carleton University UAV fourth year project team and Sander Geophysics Ltd. The system requirements for the GeoSurv II system are outlined in a System Requirements Document (SRD) which is managed by the UAV Project Team. This is a living document, and updates can be made as the project progresses and requirements change.

This section summarizes the major requirements of the GeoSurv II system, the typical mission profile, as well as the changes made to the SRD during the 2008-2009 academic year.

### 3.1 Summary of Major Requirements for GeoSurv II

SGL requires that a crew of two persons be capable of deploying and operating the GeoSurv II system. The reduction in crew size from that of a standard manned aircraft directly corresponds to the weight requirements of the GeoSurv II system. The maximum take-off weight of the system is 150 lbs, chosen because it reflects the maximum weight that can be safely lifted by two individuals.

To ensure transportability, the aircraft must be composed of modular components. No component may have a length greater than eight feet so that transportation to and from survey sites is possible in a standard pick-up truck. The complete UAV system must also fit inside a standard Air Canada cargo container for transport around the world. The UAV must be able to perform the surveys at speeds between 60 and 100 knots, while maintaining an altitude of 33 feet above the draped surface of the earth. A minimum climb and descent gradient of 10% is needed to ensure the flight path is smooth relative to the terrain. Due to the sensitivity of the magnetometers in the wingtips, the wings must have a natural frequency of greater than 2 Hz.

The UAV is to have a minimum flight endurance of 4 hours at 60 KEAS, and 2 hours at 100 KEAS. The UAV must also be able to maintain a constant flight speed within +/- 3 KEAS, with a stall speed no greater than 45 KEAS. The system must also be able to achieve a rate of climb of 400 feet per minute. GeoSurv II must be able to meet these performance characteristics at altitudes of up to 8000 feet above sea level.

GeoSurv II must be able to carry out autonomous operation throughout all phases of flight during a mission so that supervision by the operators in minimized. Therefore, an Obstacle Detection and Avoidance (ODA) system will be required. This system will be used to adjust the flight path of the aircraft to avoid any unforeseen obstacles in the preprogrammed flight path, while still continuing the mission. The aircraft must also be able to send and receive data from the ground control station (GCS) at regular, changeable time intervals. Furthermore, GeoSurv II must also carry sufficient avionics and sensor packages for normal aircraft operations and certification.

Please see Section 2 for information on the distinction between the GeoSurv II and its Prototype.

## 3.2 Typical Mission Profile

The typical magnetometer survey mission for the GeoSurv II system will begin with compensation manoeuvres to calibrate the magnetometers at an altitude of 6000-8000 feet above ground level. Once complete, the UAV will transit to the survey site and fly a grid-like pattern over the area at 60 KEAS. Once the survey is complete, the UAV will return to the launch and recovery area. See Figure A-1 for a summary of the typical mission profile.

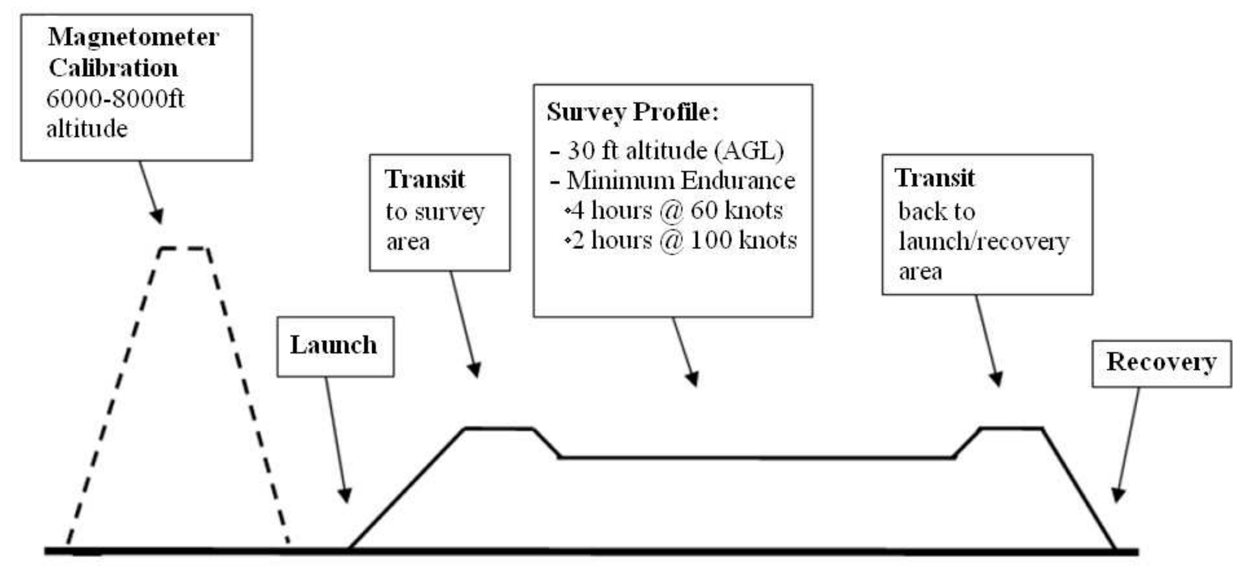


**Figure A - 1: Typical mission profile for GeoSurv II**

## 3.3 Changes to the SRD

This year, a complete item-by-item review of the SRD was undertaken in order to identify items that the Prototype might not be expected to meet. In most cases, the exception was justified using a brief explanatory note. Please see Revision F of the SRD for more detailed information.

# 4. DESIGN OF THE GEOSURV II PROTOTYPE

This project year did not see any major configuration changes to the UAV, as the outer mould line was frozen in the previous year. The major milestone set for the year was to complete manufacturing of the prototype. With the goal in mind some designs were completed by team members to ensure parts fit to the components that were built last year.

The overall shape of the GeoSurv II prototype has not changed and it remains a pusher configuration with twin booms leading to a U-tail. The engine is a two-stroke, 30 HP, dual piston, boxer engine with a 36 inch diameter propeller. The airframe is designed to be dis-assembled for transportation into six major components; fuselage, port wing, starboard wing, port boom, starboard boom, and tail. Figure A-2 illustrates the assembly for the current GeoSurv II prototype configuration. The air data boom is shown on the nose of the fuselage.

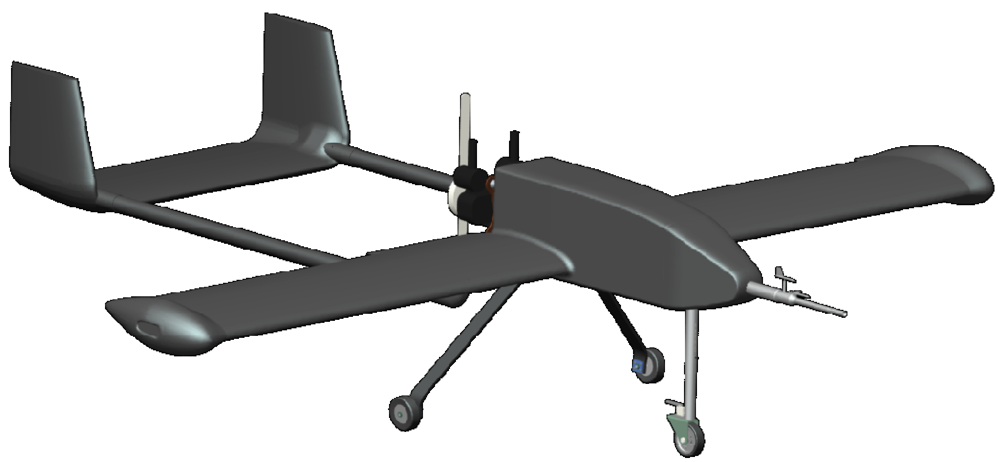

**Figure A - 2: 3D model of the GeoSurv II prototype.**

The fuselage has a foam core sandwich construction and is divided into five sections: nose cone, upper bay, parafoil bay, lower bay and spar carry through. Each of the areas is easily accessed through hatches for onsite repair or replacement. The wing tips have large fairings that contain magnetometers. These magnetometers are the sensors that are able to detect the minute changes in earth's magnetic field and allow the geophysicists to determine possible locations for oil, water or precious metal deposits.

The airfoil on the wing is LS 0417 and incorporates a negative three degree incidence angle to reduce drag and improve stability. The flight speed for surveying does not require any sweep of the wing, nor twist. The empennage of the GeoSurv II prototype has a NACA 0012 airfoil, with a split elevator. Two cylindrical booms run from the main wing to the inlet on the tail and contain all of the necessary wiring for servos, lights and antennas. The tail is constructed of a foam core wrapped in a carbon fibre skin. All of the control surfaces use a direct linkage method to translate the motion from the servos.

To clarify locations on the aircraft a set of datum planes were determined in the early project years. All components of the UAV are located in 3D space utilizing this coordinate system. The datum standards are shown in the following figures. Fuselage Station 0 (FS 0) is located 36 inches in front of the main bulkhead, Water Line 0 (WL 0) is located 36 inches below the fuselage baseplate and Wing Station 0 (WS 0) is located along the line of symmetry of the aircraft with the positive direction being to the starboard side.

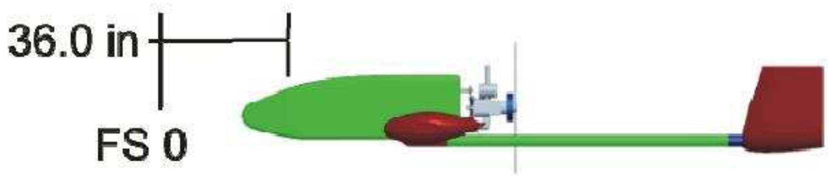


**Figure A - 3: Location of FS 0**

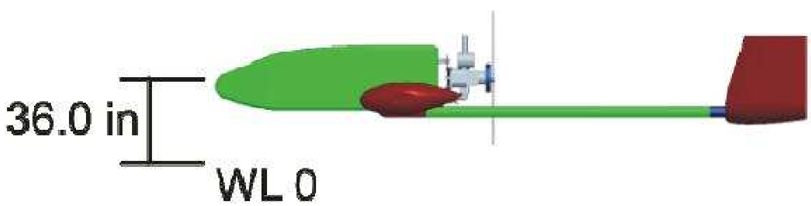


**Figure A - 4: Location of WL 0**

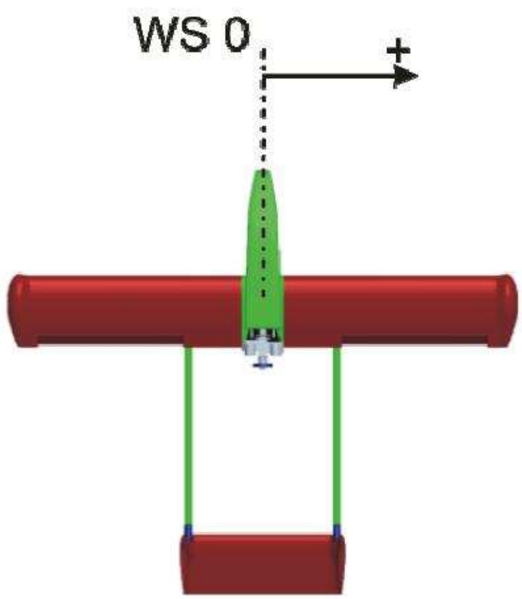


**Figure A - 5: Location of WS 0**

The GeoSurv II prototype can be seen in Figure A-5, the UAV is 14 feet long with a 16 foot wingspan and a 3 foot propeller. When the landing gear is attached the bottom of the fuselage will be approximately 26 inches off the ground.

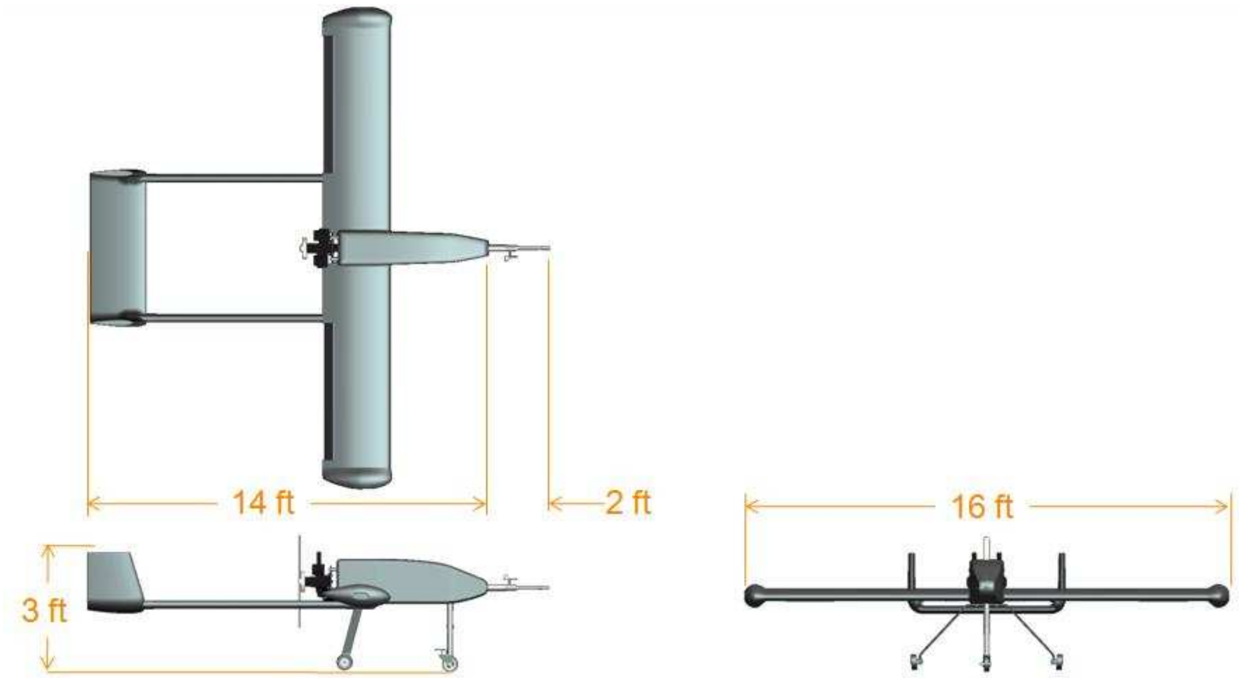


**Figure A - 6: Major dimensions of the GeoSurv II prototype**

The current configuration of the aircraft has an approximate take-off weight of 193 lbs. The weight exceeds the requirement set forth in the SRD. For a crew of two people to successfully operate the, eventual, GeoSurv II weight must be an important consideration. For the prototype the excess take-off weight will be okay, but ongoing efforts in weight reduction for the GeoSurv II will be needed.

## 5. ROLE OF INTEGRATION

The role of the Integration team on the project is analogous to oil for an internal combustion engine. The engine can operate without oil for a time, but then it will seize and cease to function as a unit. Integration is the oil of the UAV team. The Integration team helps to seamlessly ensure the group is firing on all cylinders. Several tools, described in this section, are used to ensure the group functions seamlessly. The tools are as follows:

- Scheduling (discussed in a later section)
- Team communications
- Part and file management
- Planning and running major events
- Minute taking at weekly team meetings
- Design Report archiving and numbering
- Monthly progress reports
- Compiling and editing major documents

The Integration group for the 2008 – 2009 GeoSurv II project consists of three team members:

- Mike Martin (Lead engineer)
- Andre Couture (Weights, Pro/E Model and Approval packages)
- Eric Burghardt (Scheduling and DR Registry)

Although the group members have assigned tasks, the majority of the tasks were completed as a team.

## 5.1 Team Communication

Communication is vital to the success of the project. The individual groups need to be working with the same information. There are multiple ways Integration communicates with the team.

### 5.1.1 Memoranda System

Memos are important documents for the UAV team. They are used for vital communication to the entire team. Since, the team changes year-to-year a method has been devised to ensure memos are kept for future years. The Integration team created a Google groups account. All memos are posted to this account, and automatically emailed to the entire UAV team. This ensures the information will be available in subsequent years.

### 5.1.2 Website

Information pertinent to completing work is housed in an internal website. This website is accessible from any internet connect using the password given to team members. The website also contains an archive of the previous project year websites. Previous year sites contain their Design Report (DR) registry and final reports for current team members to access relevant information. The layout of the internal website can be seen in Figure A-7**.**

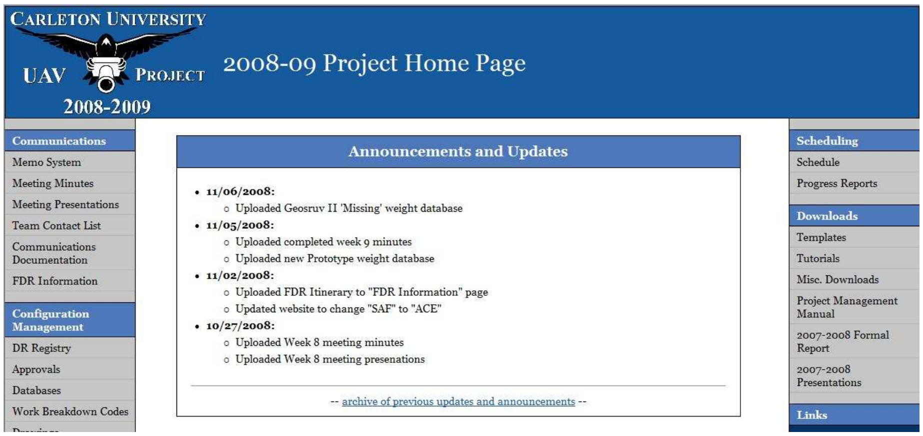


**Figure A - 7: Snapshot of the internal website main page.**

The website is host to the most recent versions of many documents, including: Systems Requirements Document (SRD), DR Registry, Safety and Certification documentation, schedule, meeting minutes, and meeting presentations.

### 5.1.3 Group/Team Meetings

Each week, a meeting is held for the entire UAV team to update progress, present new designs, and revisit goals. This allows the entire team to provide input into new designs; as well changes are suggested to ensure a design will meet its specified requirements. Each individual group meets on a weekly basis to assign tasks and coordinate efforts.

### 5.1.4 Meeting Minutes

In the weekly team meetings Integration records meeting minutes, after posting the minutes on the internal website. The minutes record several key pieces of information. First, important deadlines are recorded. Second, action items to specific groups are identified and recorded. Third, general information is recorded; this can consist of award deadlines, etc. The meeting minutes are typed out in a format of general items first, and then items for each group are presented in the order of the meeting presentations.

### 5.1.5 Meeting Presentations

For the weekly team meetings groups tend to produce a Power Point presentation. It is the responsibility of the Integration group to collect all the presentations and post them on the internal website.

## 5.2 Design Reports

Design Reports (DRs) are important documents produced by team members. DRs contain the work done by group members as well as relevant designs and procedures. Year-to-year the DRs inform the new team of work accomplished, future work, and current standing. The new group will need relevant DRs to their area of assignment and then can proceed.

### 5.2.1 DR Request Procedure

A team member from Integration will take responsibility for the DR registry of the project year. The DR registry is an Excel database containing all the DRs from the current team year. As such, for a team member to write a DR a number must be requested from Integration. Integration will assign a number according to the conventions established in DR 32-03 Rev. B. The team member shall update the DR registry then post it online for the team to view.

## 5.3 Progress Reports

A progress report is to be written by each of the five groups every month. The progress report, to be submitted at the end of the month, must contain a summary of work completed, problems encountered, hours worked, and future work. The five reports will then be summarized by INT into a concise report, which is then sent to Sander Geophysics Ltd. The individual reports, as well as the summary, are posted on the website and viewable by the team.

## 5.4 Design Reviews

There are two design reviews, one per term. Each term, Integration has many responsibilities surrounding the event. A DR must be written to inform the team of the dates, deadlines, and procedures concerning the design review, see DR 92-01 and DR102-04. After the DR is written and deadlines are prescribed, the Integration team must collect the presentation from each group. The presentations are to be converted to .pdf file format and posted online for the team to review before the design review.

Integration is responsible for the entire day of the design review. The room needs to be set-up as well the presentations need to be on the correct computer or drive and ready to go. During the day Integration should time the presenters and single when their time limit is up, and move on to the next presenters to ensure the schedule is maintained.

# 6. APPROVAL PACKAGES

A large number of parts were built in the 2008-2009 year, and the design documentation for those parts required approval from the Lead Engineers. A document called an "Approval

Package" was already loosely defined but no true process existed for approvals. The previous procedure involved printing out the documentation that formed the Approval Package and circulating to all the Lead Engineers (LEs). This method was inefficient due to the long delays incurred by the requirement to transfer the hard copy document from one person to the next. A new, electronic process was suggested by INT and improved by the LEs and is briefly presented next. A more thorough presentation of the procedure can be found in DR102-01.

## 6.1 New Procedure

The new procedure consisted of a transfer from INT to a Lead Engineer of the responsibility for circulation, review and gathering of feedback on Approval Packages. This LE was dubbed the "Lead Engineer in Charge". Typically, the LE in Charge would be one of the LE of the group that the designer belongs to. The steps involved in creating and reviewing an approval package were described in DR102-01 and a summary was provided on the website's "Approvals" page as a quick reference. The summary of the procedure is as follows:

<u>Instructions for Designers:</u>

1. Prepare approval package and request AP number from INT.
2. Ensure that a Lead Engineer (LE) has been selected as being in charge of the package's approval.
3. E-mail the package to INT or save it to \Integration\07_Approval Packages and notify INT. The LE in Charge should be identified in the package or should be specified to INT.

<u>Instructions for LEs:</u>

1. The LE in Charge of the approval package shepherds the package once INT has uploaded it and notified him.
2. Other LEs provide their comments to the LE in charge using the Comment and Approval sheet or through e-mail.
3. The LE in Charge works with the designer to address concerns.
4. Once design is acceptable to all LEs, the LE in charge notifies INT and the designer. The signature sheet can then be filled out at the next LE meeting.

## 6.2 Results

This procedure proved more efficient in communicating feedback to designers promptly. However, the finalization of approvals through the signature sheet was not sufficiently enforced due to the entire team's focus on completing the aircraft. This year was also exceptional in that many designs were modified during manufacturing and the Approval Packages weren’t always updated promptly, making it difficult for the LEs to approve the package since the design had changed from the documentation presented to them before manufacturing had started.

## 6.3 The Role of Integration in the Approval Package Procedure

Not included in the above description was the work performed by INT to keep track of Approval Packages. A table was created on the website’s “Approvals” page and updated as new information was available for Approval Packages. Colour codes were used to help the team quickly see the status of Approval Packages, as shown in Figure A - 8.

| Package No. | Date AP# Requested | Author | Grp | Package Title | Files | LE in Charge | Status |
|---|---|---|---|---|---|---|---|
| AP103-01 | Jan 16 2009 | S. Clifford | AER | Air Data Boom | - Combined PDF (includes 4 files)<br>- Sign-Off Sheet<br>- Summary<br>- DR93-02<br>- DR93-09 | | Approved |
| AP103-02 | Feb 04 2009 | G. Blouin | AER | NLG Length Change | - Approval Summary (.doc)<br>- DR103-01 (.doc) | Prof. Etele | Approval Pending |
| AP107-07 | Feb 9th 2009 | D. Boyle | STR | Flaperon Hinge | -<br>-<br>- | Prof. Straznicky | Package not yet available |

**Figure A - 8: Sample of Approval Package Tracking Matrix**

## 7. CONFIGURATION MANAGEMENT

Configuration management describes the activities surrounding the maintenance of important configuration data so that the current and future UAV Project teams can benefit from having easy access to it. This year, this was done through 3 major activities:

1. Maintaining the Aerodynamics database
2. Maintaining the Weight and Balance database
3. Ensuring all 3D model files and drawings are available for next year.

### 7.1 Aerodynamics Database

The previous version of the Aerodynamics database was mostly used without modification. The AER group was asked to provide updates on the major coefficients that they determined during wind tunnel testing. The main user of this information is the AER group and more specifically, the member creating the dynamic simulation of GeoSurv II. Furthermore, some errors remaining from last year's work on the database were noticed and corrected.

### 7.2 Weight and Balance Database

INT focused on assessing the weight and balance, i.e. C.G. position, of the prototype and did not consider most of the components that were expected to be found only on the GeoSurv II. For example, the absence of the obstacle avoidance system in the nose of the aircraft as well as the addition of the air data boom were both reflected in the database. For a more detailed account of modifications made to the database, refer to DR102-05. The prototype database was created from the previous year's GeoSurv II database as described in DR92-02.

### 7.2.1 Prototype Weight

The aircraft's weight, with all available measurements as of the last week of March 2009 and previously-determined estimates, was 193 lbs. This is 43 lbs over the desired GeoSurv II weight of 150 lbs. The weight calculation also only includes enough fuel for a test flight (1.5 L) and 25 lbs ballasts to maintain a positive static margin of approximately 9%. It is therefore essential that weight reduction efforts continue to be a priority. Although most components that were already manufactured may be difficult to lighten, it should be a priority of designers to identify weight-saving opportunities in their designs and make recommendations to future designers and manufacturers of GeoSurv II components.

The weight of the Prototype is broken down as shown in Figure A - 9.

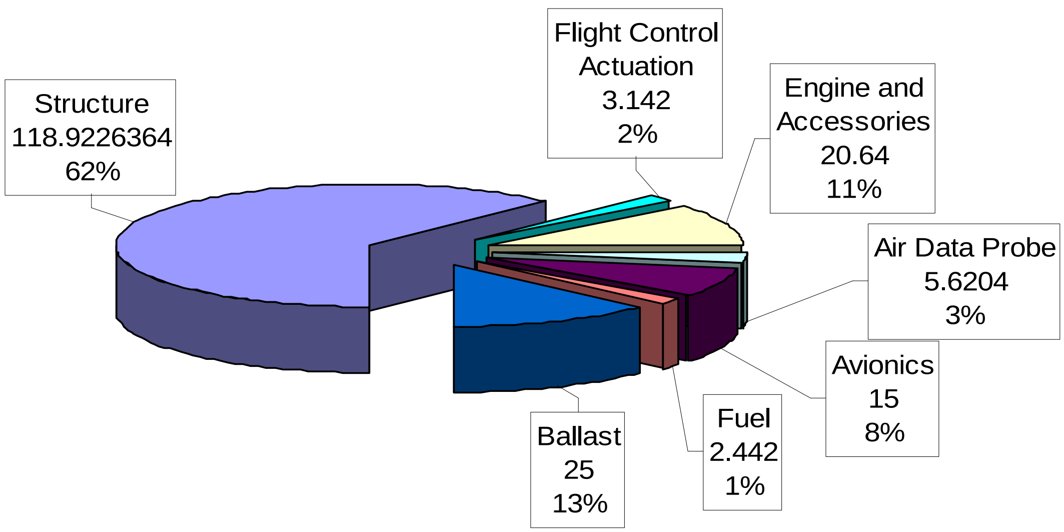


**Figure A - 9: Prototype weight breakdown (weights in lbs)**

### 7.2.2 Prototype Centre of Gravity Position

Some changes were also made to the section of the database dedicated to determining the position of the aircraft C.G. In addition to updating a large number of component C.G. positions, a change in the formatting and in the determined values was made. First, a column was added to show the Static Margin, and second, the C.G. position and Static Margin were determined for three major cases:

1. Test Quantity of fuel (1.5L) and no ballasts.
2. Test Quantity of fuel (1.5L) and ballasts.
3. No Fuel, no ballasts.

These were the most pertinent cases as the required weight of ballasts could be determined from the output values 1 and 2 above, while the output value 3 provided an indication of the aircraft's C.G. position when empty, which could be used to assess balance on the landing gear. It is important to note that the test quantity of fuel would not provide the endurance set in the SRD, but would be used for short test flights only.

The C.G. positions are summarized in Table A - 1. Note that Static Margin does not really apply for Case 3 because the aircraft would not fly in this configuration. The C.G. position is important for balance on the ground, however.

**Table A - 1: C.G. positions for three most pertinent cases**

| Case | Description | C.G. Position | Static Margin |
|---|---|---|---|
| 1 | Test Quantity of fuel (1.5L) and no ballasts | 70.94 in. | -5.70% |
| 2 | Test Quantity of fuel (1.5L) and ballasts | 66.93 in. | 9.13% |
| 3 | No Fuel, no ballasts | 70.95 in. | *(N/A)* |

To help the group members provide C.G. positions for their components, a grid was created to clarify the positions of the reference planes presented in Section 4.

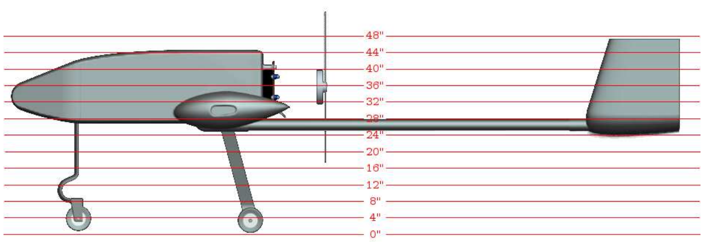


**Figure A - 10: Positions with respect to WL0 reference plane**

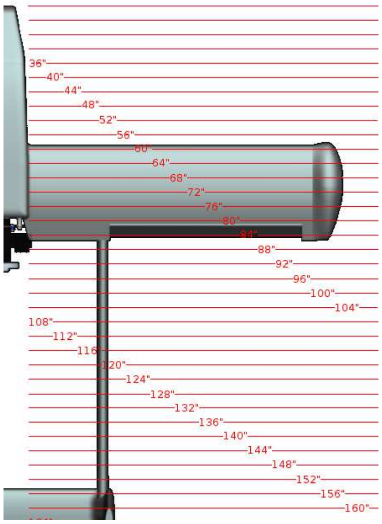


**Figure A - 11: Positions with respect to FS0 reference plane**

# 8. SCHEDULING

Maintaining a useful, accurate, schedule is important. This role typically falls to a single member of the Integration team. The schedule was moved to Microsoft Excel this year, instead of Microsoft Projects as in former years. This section will detail the purpose, preparation, and maintenance of the schedule.

## 8.1 Purpose of Scheduling

The purpose of a schedule is to decide, as a group, on a common goal. Then the common goal can be broken down into several manageable chunks for an individual to attain. Once this goal has been established and individuals understand their commitment, the schedule acts as a mirror. It allows us to reflect on progress and see the problem areas to make changes.

## 8.2 Creation of the Schedule

The schedule, this year, was completed using Excel. As Excel is a commonly used tool, the team would have easier access to updates. Scheduling in a large company would likely be in Excel as it can query internal databases and reduce large quantities of information in a few short computations. For the UAV project, both Microsoft Projects and Microsoft Excel are equally useful.

Using Excel the schedule was broken down into the five major teams. The schedule was further broken down into workgroups within the team. For example, the structures team was broken down into six workgroups, including: Fuselage, Wings, Empennage, Controls, Landing Gear, and Analysis. Within these teams milestones were created and updated. For a detailed explanation of the schedule see DR92-03.

## 8.3 Schedule Maintenance

Schedule maintenance is a critical role of integration. Creation of the schedule is just the beginning of schedule related work. On a weekly basis integration prepared a PowerPoint presentation outlining the milestones completed, due, and overdue. The update was presented during the weekly team meeting. This allowed immediate feedback on overdue milestones and showed the progress week to week. One metric presented every week was Percent Complete graph. A chart was created in Excel, showing the percent completion of milestones for a each term. The chart had a running three week view showing the progress. Another metric presented to the team on a weekly basis was Slips. If a due date of a milestone changed, then it was counted as a slip. The amount of weeks of change was the size of the slip. The number of slips and average slip size was shown to the team throughout the first term. This gives a good indication of teams who routinely complete work on time and those who tend to delay. At the start of the first term the schedule should be re-visited and all teams milestones re-forecast. Once complete the average slip size per group can be compared giving actual time-frames for completion. The details of this method are outlined in DR92-03.

## 9. CONCLUSIONS

A few important conclusions can be reached with respect to the work performed by this year's Integration group, as outlined in this section.

- The GeoSurv II Prototype weight remains too high. A weight of 193 lbs was estimated while not considering the obstacle avoidance system, parafoil system, mission sensors and full fuel load means that even the 200 lbs limit may be surpassed by the current aircraft.
- Ballasts will be required for the first flight of the Prototype.
- The SRD was updated to reflect some of the specific points where the Prototype does not meet the GeoSurv II requirements.
- The website was used successfully to maintain up-to-date information for the team, including the newly-developed Approval Package documentation and procedure.
- The schedule and associated weekly updates presented to the team with regards to completed, overdue and upcoming milestones helped maintain a continuous view of the team's progress and identify specific sticking points.

## 10. RECOMMENDATIONS

As next year is expected to be the last project year working on the GeoSurv II, some recommendations on remaining work can be made to the next Integration group.

- Identifying weight-savings opportunities and estimating the improvements that would be achieved would benefit our partner, SGL.
- Setting up a process to track the aircraft configuration prior to each flight and ensuring that a thorough and correct equipment list and assessment of the C.G. position is made is likely the best method of ensuring safe test flights.
- For any manufacturing activities, a system for obtaining weekly feedback (even if no new weight has been measured) on component weights would improve the accuracy of the data analysed by INT.
- Improving the feedback process between designers and LEs who have provided comments on their designs in the Approval Package reviewing procedure would improve its efficiency further.
- Using Excel instead of MS Projects helps reduce the learning curve at the beginning of the year, though some students may find that learning to use MS Projects could benefit them in the future. The INT Lead Engineer, Project Manager and INT students may want to consider both alternatives at the beginning of the project year and weigh their benefits.

- Very little work was done on cost estimation and assessment in the 2008/9 project year; updating the estimation performed in previous years may be desired.

- Improving the DR Template to use Styles and Formatting to automatically number section headers and other similar changes would benefit the entire team.

- Creating a complete 3D assembly of the aircraft may be required. The 2008/9 INT group did not perform a full update but only added the air data boom and new nose landing gear to the 2007/8 model.

- Ensuring that all team members use the project drive as the main storage space for their work helps ensure continuity of data between project years and even between team members in the same year. Providing clear instructions to non-M&AE students (e.g. ELEC and SYSC students that may be working in the Avionics group) on how to obtain access to the M&AE network should be provided and insisted upon.

## 11. REFERENCES

"Systems Requirement Document", GeoSurv II, Carleton University, Ottawa, Canada, Rev. E, Mar. 31, 2008.

## 12. DESIGN REPORTS

| | |
|---|---|
| **DR92-01**<br>E. Burghardt and A. Couture | Instructions for FDR |
| **DR92-02**<br>André Couture | GeoSurv II Prototype Weight Database |
| **DR92-03**<br>Eric Burghardt | Project Scheduling |
| **DR102-01**<br>André Couture | Design Approval Procedure |
| **DR102-02**<br>Eric Burghardt | Estimated Cost/Budget |
| **DR102-03**<br>André Couture | Airworthiness Standards: Weight Considerations |
| **DR102-04**<br>E. Burghardt and A. Couture | Instructions for WDR |
| **DR102-05**<br>André Couture | Prototype Weight and Balance: End of 2008-2009 |