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SYSTEMS REPORT ON REMOTE CONTROLLED (RC) PLANE

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1. Project Overview

1.1. Team Members

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1.2. Project Scope

The system of interest for this Systems Engineering analysis is a remote controlled (RC) plane and the transmitter to control the movement of the RC plane. The term *RC Plane system* will be used in this paper when discussing both the RC plane and the transmitter controller. In this report, all of the components, functionalities, operational scenarios and details will be defined. Concepts and principles discussed in the Systems Engineering course will be applied to describe RC plane from a systems point of view.

2. Operational Concept

2.1. Project Concept

The motivation for this project is to analyze and apply systems engineering concepts to a technology or concept of choice. Our team has decided to analyze the remote-controlled airplane from a systems engineering point of view.

Remotely-controlled airplanes have a variety of uses which includes recreational activity, education of heavier-than-air flight principles, and serves as applications in the national defense field, to name a few. In the latter sense, human operators flying a plane through transmitted signals allows them to utilize the benefits of air travel without risking the safety of the operator.

The transmitter controller and the RC plane interact by sending and receiving signals to and from each other by which the controller determines the airplane's altitude, speed, and direction. The system's essential functions are to accept inputs from the transmitter operated by a user and convert the inputs into signals that will then be transmitted to the airplane. The airplane will then receive the airborne signals that will play the primary role in manipulating the airplane control features, which include the elevator, rudder, and throttle. This project will examine the relationship and interaction between the operator, who controls the system, the transmitter and the airplane.

2.2. Systems Definition

Our defined system is comprised of two subsystems which are the transmitter (controller) and the airplane. External systems that interact with the two subsystems include the operator and the operational environment, such as the weather conditions and the terrain surrounding the airplane. The user interface for the system is the control panel of the transmitter through which the user can provide inputs to the system that determines the movement of the plane.
Controls are processed in both the transmitter and the airplane. Microcontrollers are used for most of the output functions. For example, the operator's request to increase the airplane's throttle will be requested using the transmitter interface in which the transmitter's microcontroller will interpret the signal and transmit it to the airplane. On the contrary, the airplane's microcontroller support several functions such as the ability to receive information, interpret the information, and to actively sense and react to fail-safe mode in an occurrence of a failure mode, such engine overheating or electrical short in the circuit.

Physical inputs from the user are converted into signals usable by the airplane component of the system through an appropriate formatting mechanism. These physical inputs from the user, which can be an activated switch or the movement of a joystick, will cause certain electrical contacts in the controller to touch, thereby completing a circuit. The completed circuit is connected to a specific pin of an integrated circuit (IC) that is part of the microcontroller that will generate a pattern of electrical impulses that describe the user's input. These generated electrical pulses will be transmitted in the form of radio waves at a particular frequency.

Meanwhile, the RC plane is constantly monitoring any incoming radio waves at the same frequency the transmitter is operating under. Once the RC plane receives the radio wave signals, it converts the radio waves into electrical pulses and is sent to the IC chip that is installed on the RC plane to decode the electrical pulse pattern. Once decoded, this will activate a motor as defined by the pulse pattern and provide movement. The outputs delivered by the microcontroller aboard the airplane are formatted into actual changes in such things as throttle valve position and elevator and rudder angles.

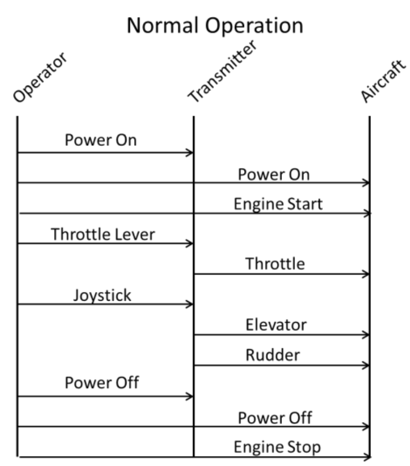
The user finds these outputs to be useful and can make changes to her inputs based on her satisfaction with the observed effects of previous inputs. For instance, if an input that signals the controller to pulse the elevator motor such that the elevator angle tips up, causing the plane to descend, the operator may input the opposite signal to repeat the cycle in order to incite corrective (climbing) output action.

2.3. Operating Scenarios

There are eight operating scenarios defined in this project. These scenarios describe the interaction between the operator, the transmitter, and the aircraft. The operating scenarios include normal operation, maintenance required to recharge the batteries of the airplane or transmitter, an electrical shorting of a circuit, the engine overheating, transmitter failure, midflight malfunction, and alignment correction of the airplane.

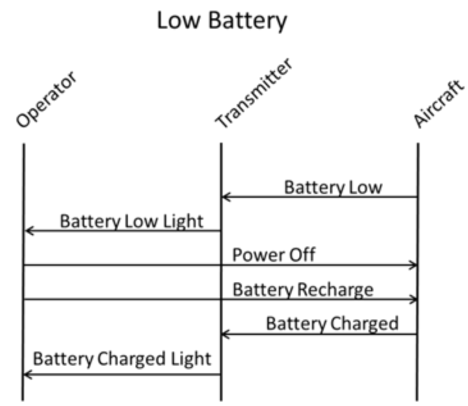
2.3.1. Normal operation.

The operator flips the transmitter switch into the “on” position and flips the power switch of the plane to the “on” position. The operator flips a second switch on the plane to initiate the engine. The operator uses the transmitter to send signals to the plane to control the plane’s throttle, the elevator, and the rudder. As a result, the plane will adjust its speed for take-off or in while in flight, the roll, the pitch and the yaw angle accordingly. To end the operation mode, the operator will use the transmitter to land the RC plane. Once the RC plane has landed, the operator turns off the plane’s engine and power and the transmitter’s power.



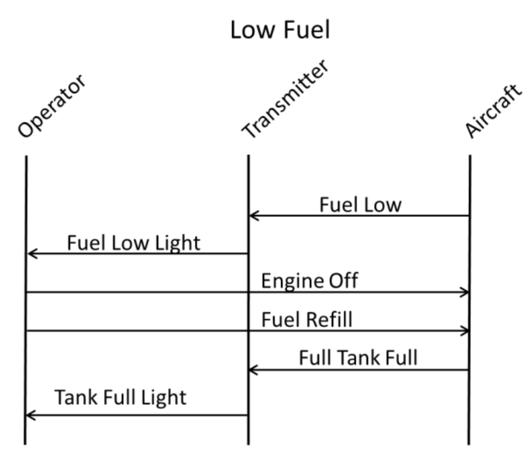
2.3.2. Maintenance required: recharge battery.

The plane’s sensors detect that the battery level is low. It sends these signals to the transmitter indicating low battery on the plane. The operator will end the operation mode and removes the battery pack from the plane and recharges the battery. Once the batteries are fully charged, the operator will install the charged batteries into the plane and the plane will send signals to the transmitter indicating that the battery is fully charged.



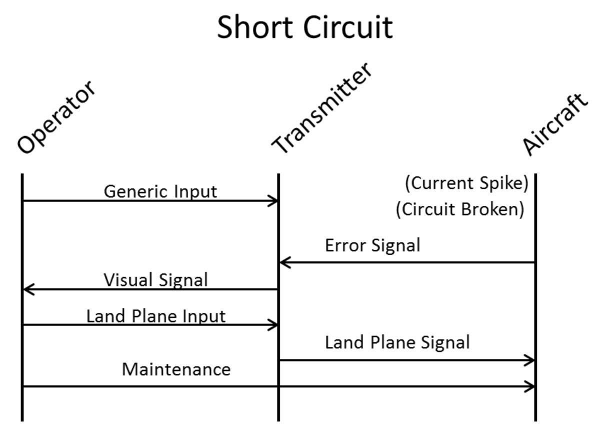
2.3.3. Maintenance required: refuel plane.

The plane's sensors detect that the plane's fuel tank is low. It sends these signals to the transmitter indicating the plane's fuel tank needs to be refilled. The operator will end the operation mode and provides more fuel into the plane's fuel tank. Once the fuel tank is filled, the plane will send signals to the transmitter indicating that the tank is full.



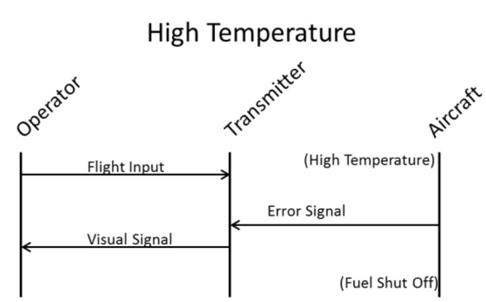
2.3.4. Short circuit in airplane.

A short circuit occurs in the plane's electronics, causing a current spike. This spike is detected and the power to the component being affected by the current spike is shut off. A signal is sent to the transmitter, notifying the operator of this error so that the operator will attempt to safely land the plane and provide maintenance to the plane.



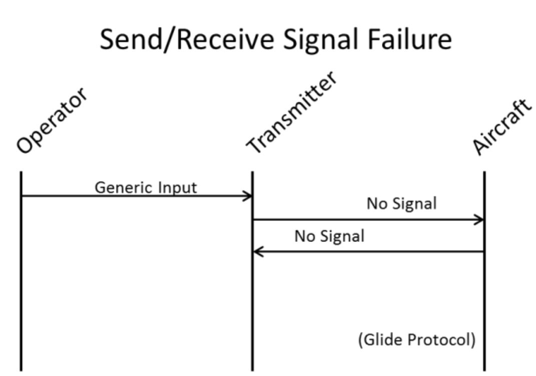
2.3.5. Engine overheated.

A temperature sensor on the RC plane's motor detects that the temperature is dangerously high. The plane will send a signal to the transmitter addressing this issue. If the plane remains in operation mode and the temperature continues to increase, the fuel will shut off to prevent overheating.



2.3.6. Transmitter failed to send/receive signals.

The remote control unit is unable to send or receive signals from the airplane for an extended period of time. The plane, in response, initiates a glide protocol that assumes flat ground ahead and will prepare all adjustable flaps into the best static position to maximize the chance of landing safely without input from an operator.

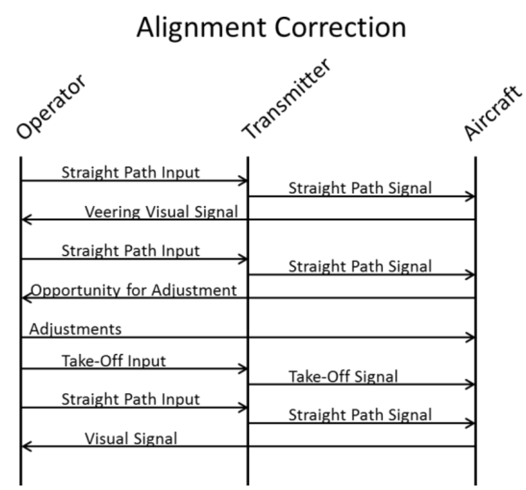


2.3.7.Mid-flight malfunction.

If the plane experiences any sort of mid-flight malfunction that would cause it to crash, the impact shall be detected as beyond operational magnitude and the fuel shall be shut off and the motor shall discontinue operation. This scenario presents no interaction between transmitter and airplane; the airplane relies on its own internal programming for this scenario to play out.

2.3.8. Alignment correction.

The controller tells the plane to keep a straight path, yet it always veers to one side. The operator will land the plane and switch the power off. The operator will adjust the alignment settings of the wings and/or tail fins to correct this drift. If the plane still does not fly straight under normal operation, repeat the above steps until straight flight is achieved.



2.4. External Systems Diagram

The external systems diagram demonstrates the interaction between the interaction between the transmitter (A0) and the RC plane (A1) in which both subsystems are controlled by the operator (A2). The operator handles inputs to the transmitter to control the movement of the plane as well as handles all maintenance requests by the subsystems.

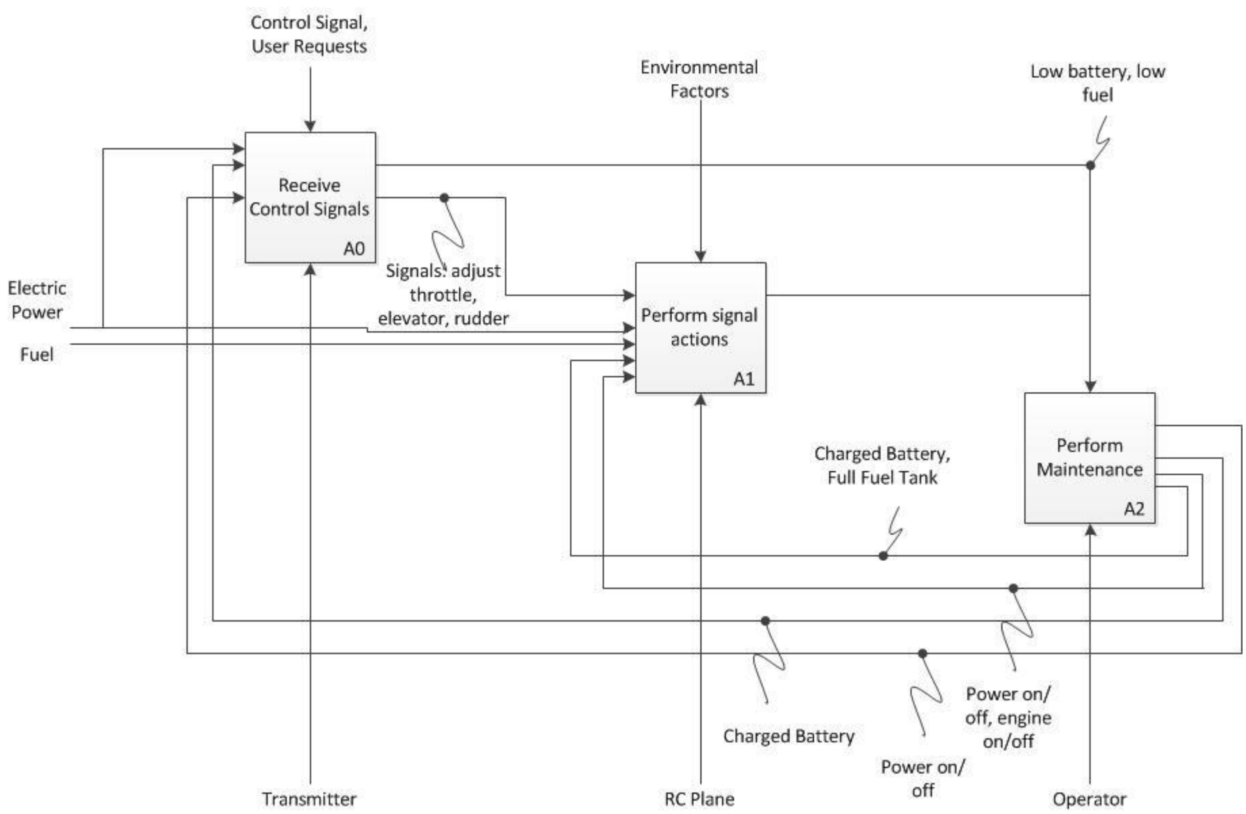


Figure 1: External Systems Diagram for the overall RC Plane system.

3. Requirements

3.1. Input/Output Requirements

3.1.1. Input Requirements

3.1.1.1. The airplane shall accept signals from the transmitter.
3.1.1.2. The transmitter shall accept signals from the airplane.
3.1.1.3. The airplane shall accept fuel.
3.1.1.4. The airplane shall accept electrical power.
3.1.1.5. The transmitter shall accept electrical power.
3.1.1.6. The airplane shall accept conditions from the surrounding environment.
3.1.1.7. The system shall accept maintenance from the operator.

3.1.2. Output Requirements

3.1.2.1. The airplane shall provide signals to transmitter.
3.1.2.2. The transmitter shall provide signals to airplane.

3.1.2.3. The airplane shall provide feedback to the transmitter that the airplane's batteries are low.
3.1.2.4. The airplane shall provide feedback to the transmitter that the airplane's fuel tank is low.
3.1.2.5. The airplane shall provide flight.
3.1.2.6. The airplane shall provide in-flight maneuverability.

3.2. Technology and System Wide Requirements for Development

3.2.1. Technology Requirements

3.2.1.1. The airplane and transmitter systems shall strictly adhere to all federal, state, and local government regulations.
3.2.1.2. The fuselage shall be made of fiberglass composite.
3.2.1.3. The airplane system shall have a range of no less than one half mile direct line of sight.
3.2.1.4. The airplane system shall be able to sustain flight at 30 mph and have a maximum speed of 60 mph.
3.2.1.5. The transmitter system shall be a 4-channel system.
3.2.1.6. The transmitter system shall operate at 2.4 GHz.
3.2.1.7. The transmitter system shall have a separation between channels of 72 MHz.
3.2.1.8. The transmitter system shall transmit a frequency modulated signal.
3.2.1.9. The battery of the transmitter system shall have an operational life of no less than 48 hours. Design goal is 60 hours.
3.2.1.10. The transmitter system shall operate using four AA batteries.
3.2.1.11. The battery of the airplane system shall have an operational life of no less than 2 hours. Design goal is 3 hours.
3.2.1.12. The airplane system shall operate using a 1200 mAh 8.4V NiMH rechargeable battery.
3.2.1.13. The airplane system shall be a 2-stroke engine.
3.2.1.14. The airplane's fuel tank shall have a nominal capacity of 20 ounces.
3.2.1.15. The airplane's engine shall be 0.50 cubic inch displacement.
3.2.1.16. The airplane system shall operate using 15% nitromethane fuel.
3.2.1.17. The airplane system shall have a 54-inch wingspan.
3.2.1.18. The airplane system shall have a 50-inch fuselage length.

3.3. Qualification Requirements

3.3.1. Verification

3.3.1.1. The system shall require Inspection to verify the following requirements:
3.2.1.1. - 3.2.1.2. - 3.2.1.5. - 3.2.1.11. - 3.2.1.12. - 3.2.1.16. - 3.2.1.17. - 3.2.1.18.
3.3.1.2. The system shall require Instrumentation to verify the following requirements:
3.3.1.3. The system shall require Demonstration to verify the following requirements:
3.1.1 All Input Requirements
3.1.2 All Output Requirements

3.3.2. Validation

3.3.2.1. The system validation shall address every scenario in the operational concept using demonstration and inspection.

3.3.3. Acceptance

3.3.3.1. The system acceptance test shall demonstrate all functional inputs and outputs.

4. Functional Architecture

4.1. First Level Decomposition

The first level decomposition divides our overall system into seven functionalities. The control interface component, the pulse generator component, the signal transmitter component, the signal receiving component and the electrical power component describe the functionalities of the first subsystem: the transmitter. In summary the transmitter will provide an interface for the user to input signals. Another component will interpret the user's input as a pattern of electrical pulses and convert that pattern into radio signal waves. Those radio waves will then be transmitted to the RC Plane for further action. In addition, the transmitter contains a component that will accept input electrical energy to power the transmitter device.

In the RC plane subsystem, the signal transmitter component, the electrical power component, the mechanical power component, the signal receiving component and the moving component make up the functionalities of the RC plane subsystem. The RC plane will receive and convert the incoming signals into electrical pulses, defined by the transmitter, and will activate a motor to change that would cause the RC plane to change directions or speed.

By creating a first level decomposition functional architecture, some of the same functionalities occur in both the transmitter and the RC plane. For example, both subsystems are able to provide and accept signals and both subsystems are able to provide electrical power through a battery source. In the first level decomposition figure, a shaded gray box will indicate the functionalities shared by both subsystems.

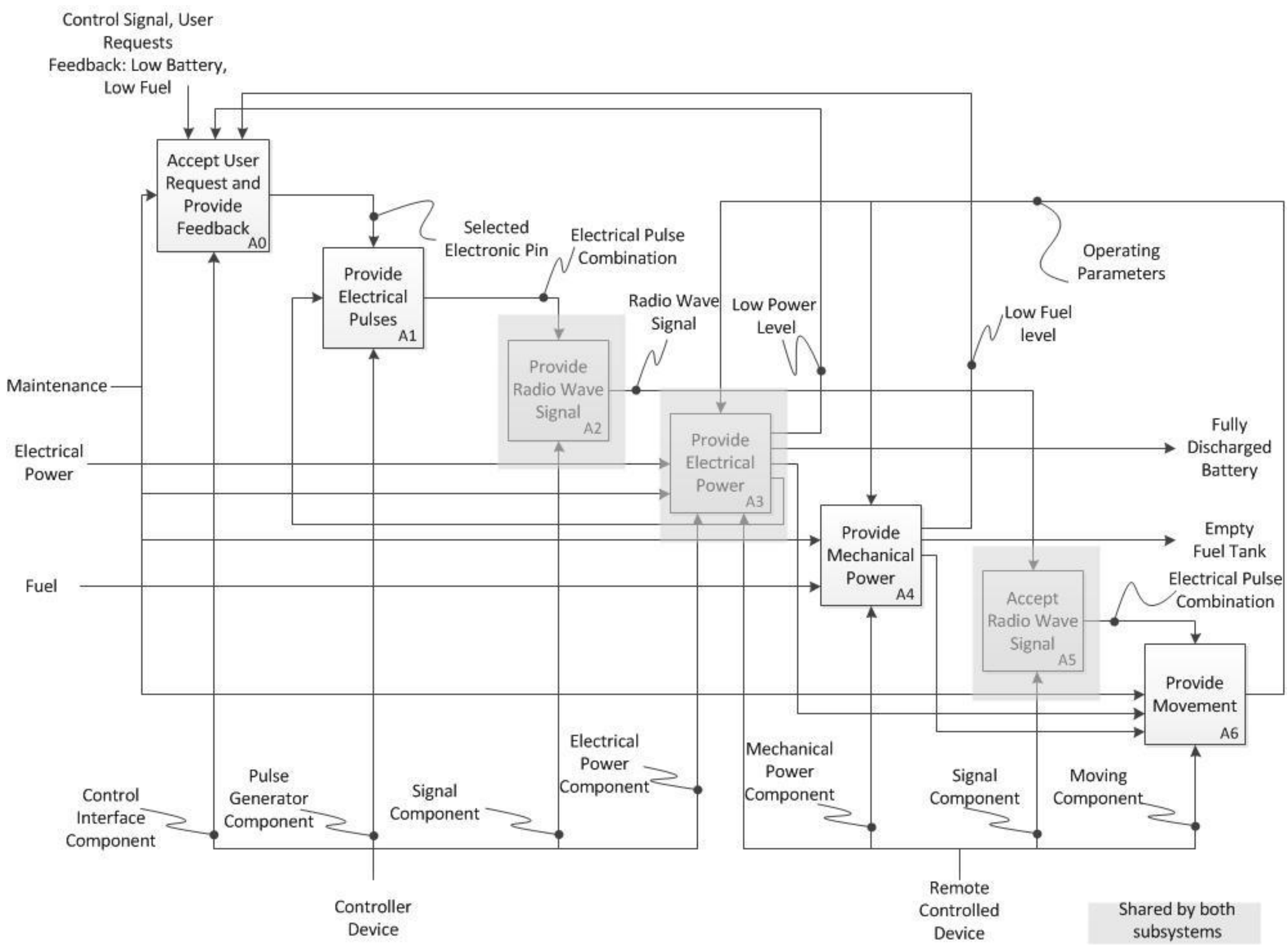


Figure 2: First Level Decomposition Functional Architecture.

4.2. Second Level Decomposition

The second level decomposition describes the first level decomposition, but puts focus on the principal functionality of the overall system. The intent is to illustrate the process by which the user presses a button, and in turn the transmitter will generate a set of electrical pulses to be sent to the plane via radio wave signals. The radio wave signals is received by the plane in which it initiates a motor to create a movement. (A Materials-Energy-Flow decomposition in the Appendix on page 23 shows the effect of throttle control on the propulsion system sub-subsystem.) The figure also illustrates the functions that are shared by both subsystems by highlighting the individual block diagrams in gray, A2 and A3. In other words, both the transmitter and receiver shall receive and transmit signals.

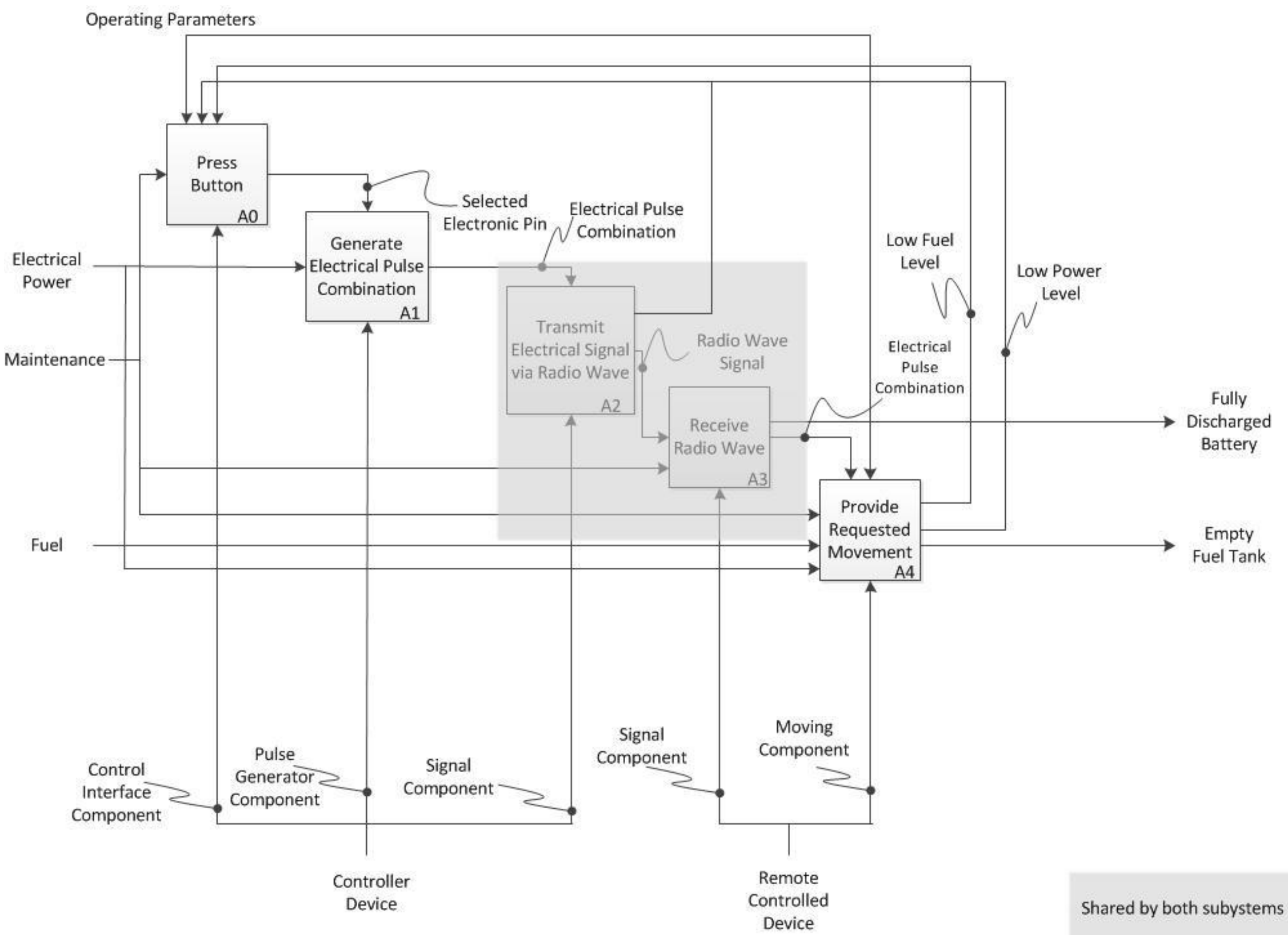


Figure 3: Second Level Decomposition Functional Architecture.

5. Physical Architecture

The physical architecture is derived from the first and second level decomposition functional architectures. The physical architecture lists all the components that are comprised within the transmitter and RC plane. This is a generic list such that it can be utilized for a similar RC system, such as a RC car. However, minor modifications would need to be made in the moving component list. In addition, a generic list can allow for various types of models to be listed as possible implementations when constructing an RC plane in the later stages of the design phase. For example when considering the user interface component, one can consider creating a controller with different types of buttons or mostly touch screen.

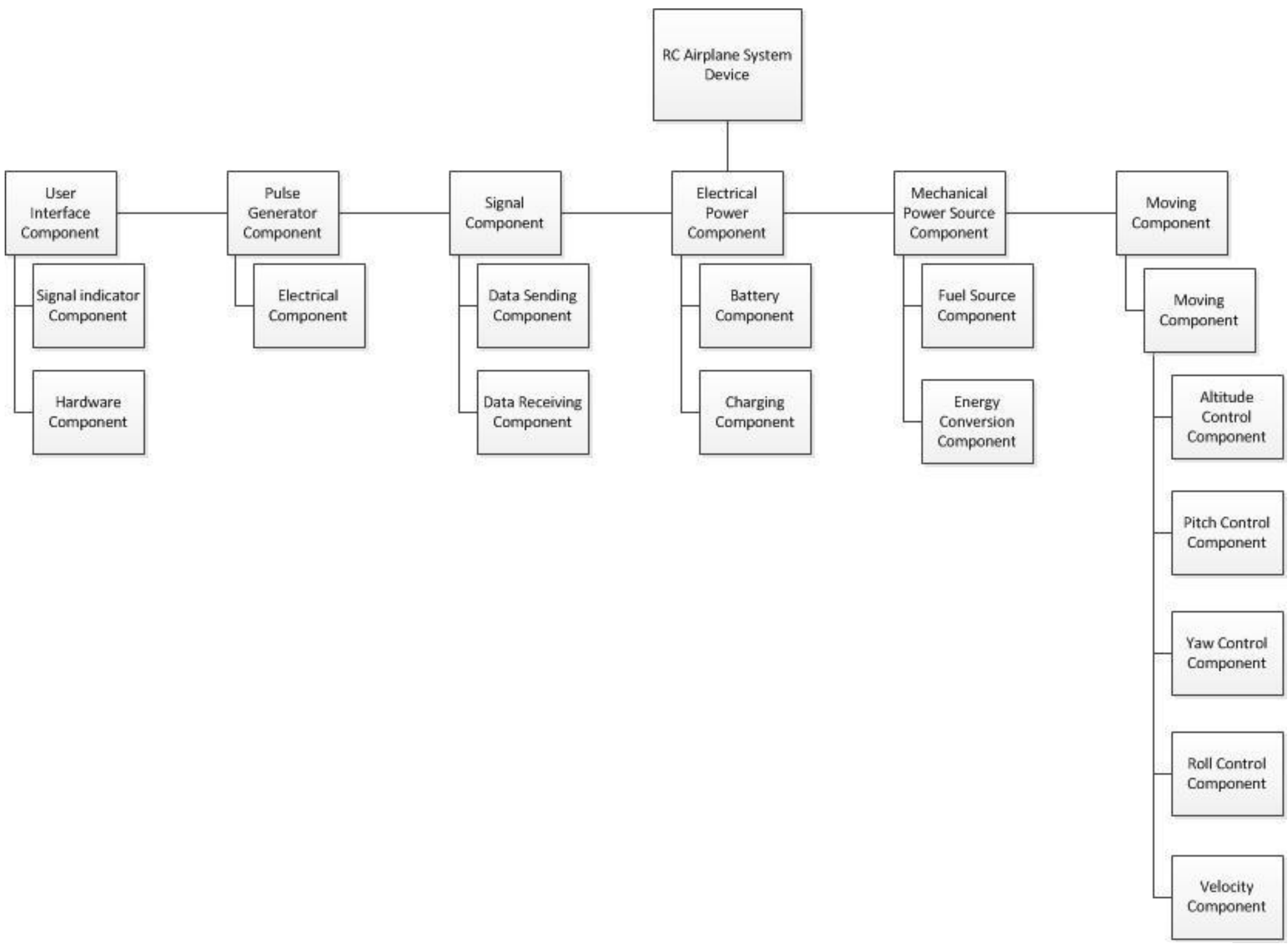


Figure 4: Generic Physical Architecture.

6. Derived Requirements

5.1 (Signal Transmitting) Transmitter

5.1.1 Transmitter shall receive physical operator input for throttle.
5.1.2 Transmitter shall receive physical operator input for elevator and rudder control.
5.1.3 Transmitter shall format physical inputs for use in processing.
5.1.4 Transmitter shall convert formatted signals into radio wave signals.
5.1.5 Transmitter shall receive stored electrical energy (battery).
5.1.6 Transmitter shall receive radio wave signal from airplane.
5.1.7 Transmitter shall display visual signals to operator.

5.2 (Signal Receiving) Airplane

5.2.1 Plane shall accept signals from transmitter.
5.2.2 Plane shall accept fuel.
5.2.3 Plane shall accept stored electrical energy.
5.2.4 Plane shall format received signals for use in processing.
5.2.5 Plane shall convert formatted signal into electrical signals.
5.2.6 Plane shall receive fuel level signal.
5.2.7 Plane shall receive battery level signal.
5.2.7 Plane shall provide mechanical power.

7. State Transition Diagram

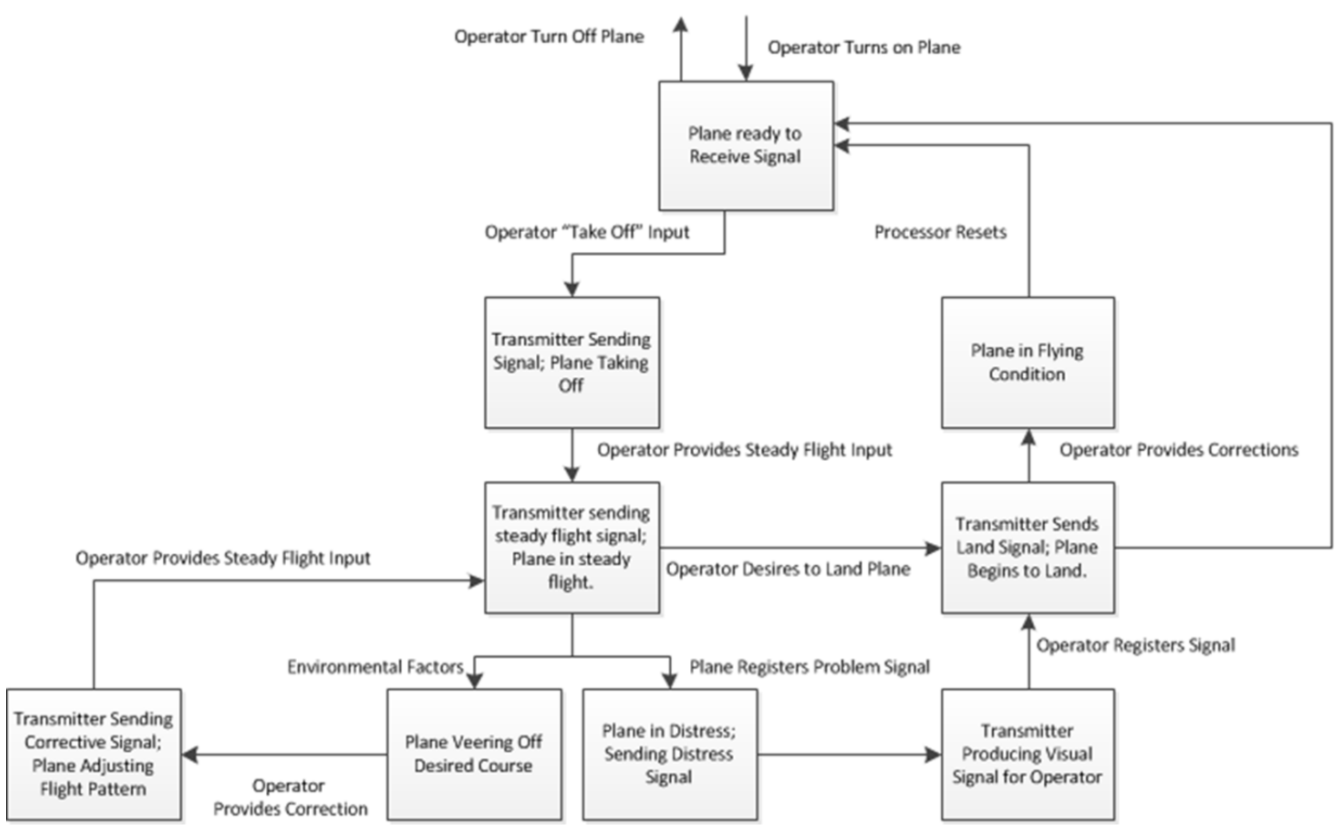


Figure 5: State Transition Diagram.

The RC plane interfaces are the locations at which the system interacts with another system. Most of the system interactions are between the airplane and the environment, the transmitter and the user, and the airplane and the user. Additionally, there are several different interactions between the airplane and the transmitter, but since we are viewing them together as one system these signals are not considered interfaces.

In normal operation, the environment interacts with the airplane in the form of wind, updrafts, rain, etc. In addition, the user and transmitter both interact with each other. The user uses controls on the transmitter to adjust the plane's thrust, elevator, and rudder. The transmitter sends signals in the form of LED's to indicate the planes fuel and battery charge statuses.

Also, there are interactions between the airplane and the user. The user sees the airplane's movements and how his or her interactions with the transmitter affect it, so the plane is sending a visual signal. Additionally, the user performs maintenance on the plane and inputs fuel and battery charge.

A summary of the system interfaces has been tabulated below:

Table 1: Systems Interface Table.

Component	Signals	Interface Type	Logical Function	Physical Function	Physical Interface Type	Usage
Accept User Requests & Provide Feedback	Throttle Elevator Rudder	Input	Control airplane's movements	Provide data for control signals	Throttle lever Joystick	Normal operation mode
Accept User Requests & Provide Feedback	Low fuel LED Low battery LED	Output	Alert user to perform maintenance	LED's emit light to alert user	LED	As needed
Provide/Accept Radio Wave Signal	Control Signals: Throttle Elevator Rudder	Airplane: input Transmitter: output	Accept operating parameters	Receive operation details from transmitter	FM receiver	Continuous
Provide/Accept Radio Wave Signal	Feedback Signals: Low fuel Low power	Airplane: output Transmitter: input	Provide status updates	Send feedback of fuel and battery levels	FM transmitter	As needed
Provide Electrical Power	Electric current	Input	Accepts electrical power	Battery recharges from external charger	Electrical socket connection	As needed
Provide Mechanical Power	Nitromethane fuel	Input	Accepts fuel	Fuel refilled from source	Tank input port	As needed
Provide Movement		Input/Output	Provides movement	Airplane rotor provides thrust, wings generate lift from air	Rotor Wings	Normal operation mode

9. Integration

Our system will be integrated using the bottom-up technique. Each individual part - such as motor, fuselage, etc. - will be tested separately. Then, as each sub-assembly is completed, it will be as tested as well. This will be continued until we reach the fully-assembled top-level system. This method ensures that problems with components or subsystems can be worked out before they present a .risk to the system as a whole.

10. Risk

For our project, we will be performing risk assessment, analysis, and planning. These three steps are crucial to the completion of an on-time and on-budget project. For our system, our main risk factors concern the hardware involved.

10.1. Risk Assessment

10.1.1. Frequency modulated transmitter receiver systems are fairly common, and can be purchased off the shelf.
10.1.2. Electrical and mechanical power sources are extremely common and can be purchased off the shelf.
10.1.3. The main airplane components - fuselage, wings, etc. - will have to be designed in a CAD program, but existing solutions we can use as a basis do exist.
10.1.4. A small amount of microprocessor programming will be needed to translate sent/received signals to proper outputs.
10.1.5. The system will need a custom printed circuit board for both the transmitter and receiver.
10.1.6. System integration will involve many small pieces fitting together just right, involving skilled and time-intensive labor.

10.2. Risk Analysis

For our project, we analyzed the risks involved using the models provided in class. Below is a table summarizing out results:

Table 2: Risk Analysis Table.

Factor	Score	Reasoning
PMhw	0.3	Most hardware will be slightly redesigned versions of existing solutions
PMsw	0.3	There is sample code available for translating received RF signals to motor control signals
PChw	0.3	The hardware is fairly simple, founded on basic aerodynamic principles
PCsw	0.1	The coding is extremely basic
P_D	0.3	Most design will be done in house, but some parts will come from outside vendors
Ct	0.3	Technical factors could have some consequence to design
Cc	0.1	Budget is outside the scope of this project, therefore low consequence
Cs	0.1	Schedule is outside the scope of this project, therefore low consequence

From this, we are able to calculate the risk factor for our project (all factors weighted equally):

$$Pf = (PMhw + PMsw + PChw + PCsw + P_D) * {}^{1}\!/_{5} = 0.26$$
$$Cf = (Ct + Cc + Cs) * {}^{1}\!/_{3} = 0.167$$
$$Risk\ Factor = Pf + Cf - Pf * Cf = 0.383$$

A risk factor of 0.383 implies that this is a relatively low-risk project.

10.3. Risk Plan

Because this project is essentially a revamping or redesign of existing solutions, there is low risk involved. Additionally, many of the components – engine, motor, electrical hardware, etc. – will be purchased off the shelf. This essentially eliminates the risk involved in these major components, assuming the vendors chosen are reliable. Cost and staying under budget can be major a risk but this is outside the scope of our project, so we assumed it to be low risk. Similarly, scheduling and time management can often be of high risk in system integration projects. Assuming good leadership and management allowed us to put this as a low risk item.

Though not listed in the table above, the major risk for our project is system integration. Individually, no one subsystem has a great risk involved because there is nothing completely new or revolutionary about or project. However, there are many parts involved coming from different vendors and manufacturers, so making sure that these parts connect and work together correctly will be difficult.

11. Qualification

11.1. System Qualification Plan

The system qualification plan will ensure that the overall RC plane system correctly works to provide the expected outputs for a given input(s). The RC plane system uses the following qualification methods to confirm that the subsystems are functioning as required:

(i) ***Inspection***
Inspection test will require the user's examination to confirm that the requirements are met as outlined in requirements section.

(ii) ***Demonstration***
Demonstration tests are similar to the inspection test. In fact, demonstrating that both subsystems are working properly will require inspection from the user and other audiences.

(iii) ***Instrumented Test***
Instrumented tests will produce more accurate results. Tools such as measurement tools, speedometer, etc., will be used to verify that both subsystems have met the minimum requirements.

(iv) ***Analysis and Simulation***

To further validate the inspection, demonstration, and instrumental tests, analysis and simulation experiments should be conducted. This will also serve as another way to see if the results from the previous tests are similar as well as complete a full qualification plan.

11.2. Qualification Matrix

The qualification matrix below relates the each of the system requirements with the operating scenarios and qualification requirements. Since our project is dealing with two subsystems, the transmitter controller and the RC plane, an extra column has been added to indicate if the requirement applies to the transmitter (T), the RC Plane (P), or both (PT).

Table 3: Qualification Matrix.

Operating Scenarios											Method			
Normal Operation	Recharge Battery	Refuel Plane	Short Circuit in Plane	Engine Overheated	Transmitter failed to send/receive signals	Mid-flight malfunction	Alignment Correction	Transmitter (T) or RC Plane (P)?	The RC plane system shall		Inspection	Demonstration	Instrumentation Test	Analysis/Simulation
									Req.	Description				
x								P	3.1.1.1	…accept signals from the transmitter.	x	x		x
x								T	3.1.1.2	…accept signals from the airplane.	x	x		x
		x						P	3.1.1.3	…accept fuel.		x		x
	x					x		P	3.1.1.4	…accept electrical power.		x		x
	x					x		T	3.1.1.5	...accept electrical power.	x	x		x
x					x	x	x	P	3.1.1.6	…accept conditions from the surrounding environment.		x		x
	x	x	x	x	x	x	x	PT	3.1.1.7	…accept maintenance from the operator.		x		x
x								P	3.1.2.1	…provide signals to transmitter.		x		x
x								T	3.1.2.2	…provide signals to airplane.		x		x
	x							P	3.1.2.3	…provide feedback to the transmitter that the airplane's batteries are low.		x		x
		x						P	3.1.2.4	…provide feedback to the transmitter that the airplane's fuel tank is low.		x		x
x							x	P	3.1.2.5	…provide flight.		x		x
x							x	P	3.1.2.6	…provide in-flight maneuverability.		x		x

x								PT	3.2.1.1	…shall strictly adhere to all federal, state, and local government regulations.				
x		x						P	3.2.1.2	… fuselage shall be made of fiberglass composite.				
x								P	3.2.1.3	… have a range of no less than one half mile direct line of sight.			x	
x								P	3.2.1.4	… be able to sustain flight at 30 mph and have a maximum speed of 60 mph.			x	
x								T	3.2.1.5	**…be a 4-channel system.**				
x								T	3.2.1.6	… operate at 2.4 GHz.			x	
x								T	3.2.1.7	**…have a separation between channels of 72 MHz.**			x	
x								T	3.2.1.8	**…transmit a frequency modulated signal.**				
x								T	3.2.1.9	… **battery shall have an operational life of no less than 48 hours. Design goal is 60 hours.**				
x								T	3.2.1.10	… **operate using four AA batteries.**				
x								P	3.2.1.11	… **have an operational life of no less than 2 hours. Design goal is 3 hours.**	x		x	
x								P	3.2.1.12	… **operate using a 1200 mAh 8.4V NiMH rechargeable battery.**	x			
x				x				P	3.2.1.13	… **be a 2-stroke engine.**				
x		x						P	3.2.1.14	… **fuel tank shall have a nominal capacity of 20 ounces.**			x	
x		x						P	3.2.1.15	**…engine shall be 0.50 cubic inch displacement.**				
x		x						P	3.2.1.16	… **operate using 15% nitro methane fuel.**	x			
x							x	P	3.2.1.17	… **have a 54-inch wingspan.**	x		x	
x		x						P	3.2.1.18	**…have a 50-inch fuselage length.**	x		x	

11.3. Testing Equipment and Resources

The table below lists and describes the system requirements that can be tested using instrumental tools. It also provides the list of the tools required for testing and the approximate time the test will take for each listed requirement.

Table 4: Testing Equipment and Resources Table.

Requirement ID	Description	Equipment	Resources
3.2.1.3	The airplane system shall have a range of no less than one half mile direct line of sight.	• Laser range-finder • Airplane and transmitter systems	• Tester • Open field • One day
3.2.1.4	The airplane system shall be able to sustain flight at 30 mph and have a maximum speed of 60 mph.	• Radar speed gun • Airplane and transmitter systems	• Tester • Open field • One day
3.2.1.6.	The transmitter system shall	• RF Receiver	• Tester

	operate at 2.4 GHz.	• Spectrum analyzer • Transmitter system	• One hour
3.2.1.7	The transmitter system shall have a separation between channels of 72 MHz.	• RF Receiver • Spectrum analyzer • Transmitter system	• Tester • One hour
3.2.1.9	The battery of the transmitter system shall have an operational life of no less than 48 hours. Design goal is 60 hours.	• Transmitter system • 4 AA batteries	• Tester • Three days
3.2.1.11	The battery of the airplane system shall have an operational life of no less than 2 hours. Design goal is 3 hours.	• Airplane system • NiMH battery	• Tester • Three hours
3.2.1.14	The airplane's fuel tank shall have a nominal capacity of 20 ounces.	• Airplane system • Graduated cylinder	• Tester • One hour
3.2.1.17	The airplane system shall have a 54-inch wingspan	• Airplane system • Measuring tape	• Tester • One half hour
3.2.1.18	The airplane system shall have a 50-inch fuselage length	• Airplane system • Measuring tape	• Tester • One half hour

12. Conclusion

It has been demonstrated that a systems approach to analyzing how the RC plane functions sheds light on how the system works and what is required to design such a complex system. Applying concepts and modeling tools obtained from the Systems Engineering course has allowed our team to divide and analyze our system in a top-down approach and, in some cases, a bottom-up approach. By using these applied concepts and tools, the tables and figures in this paper can be used to redesign and fully test the RC plane system.

13. References

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Appendix: Materials-Energy-Flow Decomposition of the Airplane Propulsion System