Department of Aerospace Engineering Sciences
Senior Projects – ASEN 4018

Stable Handling Aerial Radio-controlled Cargo-testbed
SHARC

Project Definition Document (PDD)

Document History

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Approval

Title	Name	Signature	Date
Customer			
Advisor #1			
Advisor #2			
CC			

Project Definition Document

Aerospace Senior Projects (ASEN 4018 & 4028)

1.0 Information

1.1 Project Title

Stable Handling Aerial Radio-controlled Cargo-testbed (SHARC).

1.2 Project Customers

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2.0 Background and Context

Sierra Nevada Corporation (SNC) is currently developing a tactical unmanned aerial system (UAS) nicknamed Spartan. The UAS consists of the Spartan air vehicle, a ground control station, and a variety of sensor payloads (Figure 1 and Figure 2). Sensor payloads are nearing completion and are awaiting successful flight tests from the Spartan vehicle. However, Spartan is still in development and will require a large logistical footprint for flight testing. The objective of this payload demonstrator project is to provide a low cost, easy to operate, and reliable unmanned aerial vehicle (UAV) to test the Spartan related sensor payloads prior to their integration with the Spartan vehicle.

Since there currently is not a UAV on the market compatible with SNC's payload module, this project provides a team of undergraduate engineering students with the opportunity to create a unique design solution to a specific customer need. Having an industry customer will provide the team with an opportunity to work in an academic setting while being held accountable to an industry professional standard.

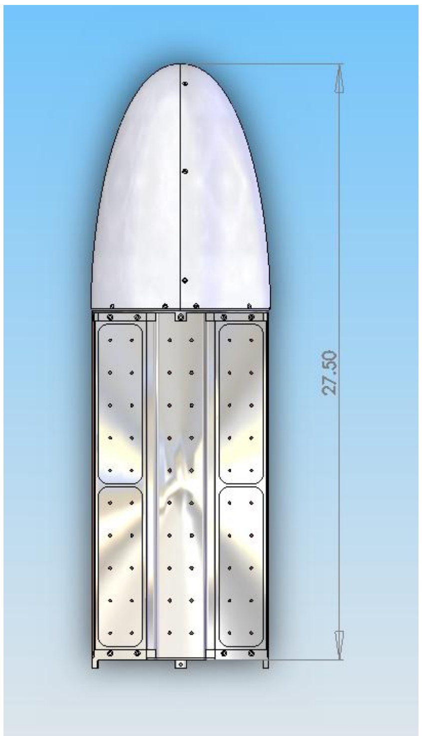

Figure 1: SNC Payload Schematic (Top View) [Inches]

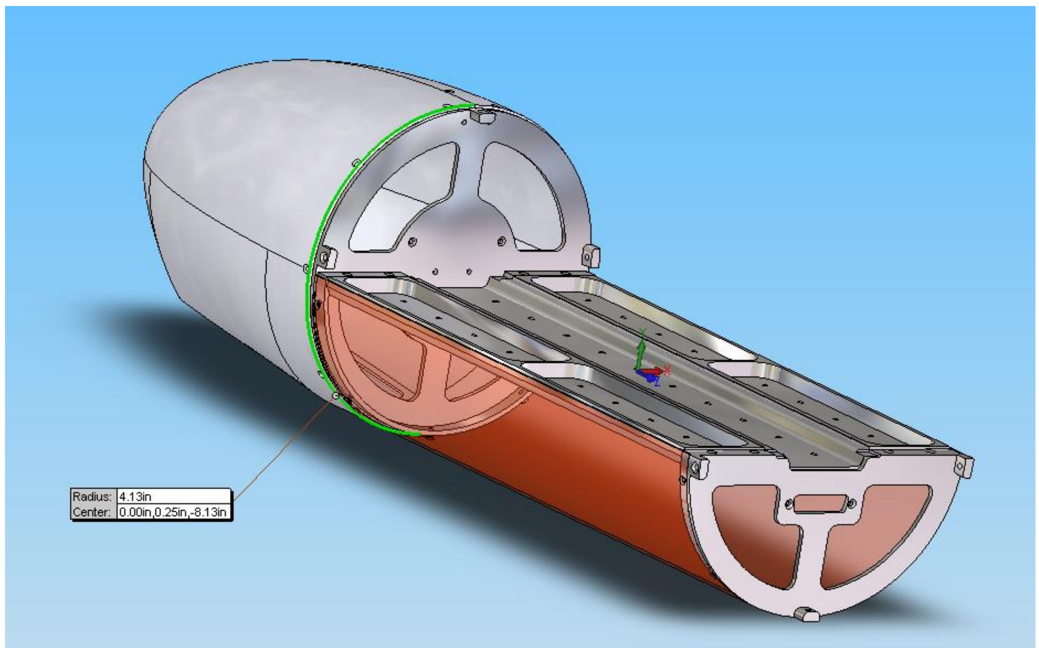

Figure 2: SNC Payload Schematic (Isometric View). [Inches]

3.0 Goal

SNC desires a stable aerial platform to implement multiple experimental payloads. Due to the unique nature of the customer's payloads, they require a specific aircraft design to meet specific mission operations. The overall goal is to successfully design, build, test, and verify an aircraft that mechanically interfaces with the 15-pound payload module from SNC. Radio-controlled flight will consist of takeoff, cruise, data collection and landing of the aircraft. The aircraft will be named the Stable Handling Aerial Radio-controlled Cargo-testbed (SHARC).

4.0 Objectives

The objective of this project is to design, build, test, and verify a UAS on which the SNC Spartan sensor payloads can be integrated for successful flight testing. The UAS will consist of the SHARC aircraft as well as sufficient ground support hardware. This hardware includes equipment to charge batteries, start engine(s), control, and fuel the aircraft for successful flight testing. Due to variation in payload configurations, equipment may be needed to check the center of gravity of the aircraft add ballast to adjust the c.g. In addition, the support equipment will be compact and able to be transported in any mid-size sedan along with the aircraft itself. Downloading the data acquired during flight can be done later in an office environment.

The customer requires this UAV, named SHARC, to be a radio-controlled aircraft that can be flown in Boulder County's RC park[1]. Therefore, restrictions must be placed on the size of the aircraft. The objective is to construct an aircraft that is approximately 6 feet in length and span to meet the minimum requirement provided by the customer that it not exceed 7 feet in any dimension. Furthermore, the nose section of the aircraft must be the appropriate size such that the 8.25 inch diameter payload shown in Figure 2 can be successfully integrated. These payloads are expected to weigh a minimum of 15 pounds and therefore, the aircraft must be designed to carry this weight with a stretch goal of supporting a 25 pound payload. This payload weight is included in the maximum gross takeoff weight (MGTW) which cannot exceed 70 pounds. The objective MGTW is 55 pounds.

A successful UAV will also meet the minimum endurance, speed, and operating altitude requirements given by the customer. The goal is to achieve a flight endurance of 60 minutes; however, a 20 minute endurance is sufficient for customer minimum requirements. Furthermore, the design of the aircraft will also be driven by the goal of achieving a stall speed of 30 knots and a dash speed of 90 knots. However, the minimum requirements of a stall speed less than 45 knots and a dash speed of at least 60 knots are objectives to be met. Finally, the operating density altitude must be at least 6,000 feet with an ultimate goal of 10,000 feet.

At a minimum, success of this project would be defined by the ability of the aircraft to takeoff, fly, and land by its own power and be recoverable. Furthermore, the aircraft must be able to support the customer provided payload, remain in flight for a sufficient amount of time to acquire, log, and store data that can be recovered after landing. Also, in order to meet the course requirements and verify the design of the aircraft, a test payload must be built and successfully tested to gather airspeed, altitude, and acceleration data. This test payload will be augmented from a SNC provided payload in the same shape and weight for similarity of integration and verification.

This project will be accomplished through integration of several subsystems on the aircraft including aerodynamics, structures and materials, electronics and controls, propulsion, and manufacturing. On the systems level, the aircraft must use a conventional internal combustion engine(s), a conventional propeller(s), and be able to power the test payloads. It must also be designed to be setup and operated by two trained people and transported in any mid-sized sedan. Successful completion of this project will result in a transportable, easy to operate, low cost vehicle that the customer can rely on to test their payloads before integration with the Spartan UAS vehicle.

5.0 Functional Block Diagram

Figure 3 contains a functional block diagram of the SHARC UAS. It contains the payload and air vehicle as the two main subsystems. Notice that the payload included in the block diagram is designed to verify the SHARC requirements. SNC payloads will be wired for compatible interfaces, but will contain different sensors and subsytems.

[1] Boulder County's RC Field 40°5'6.91"N 105°13'57.71"W. Dimensions (est.): 25' x 450'

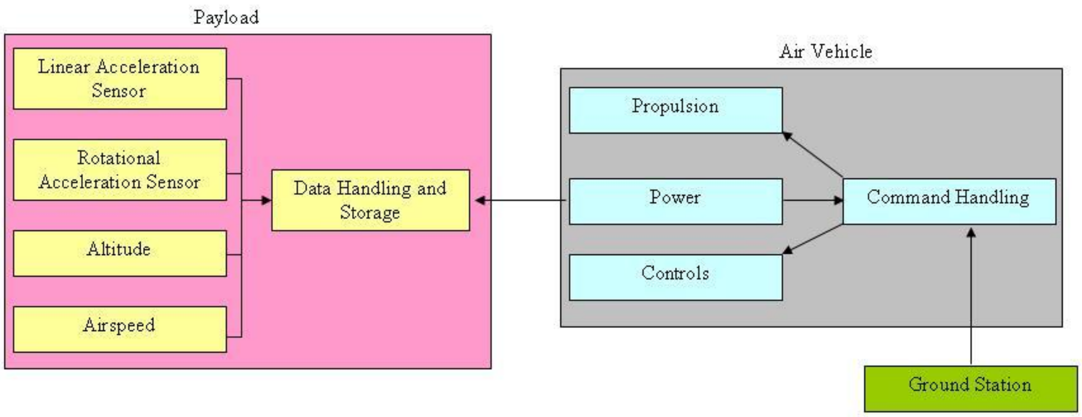

Figure 3: SHARC Functional Block Diagram

Linear and rotational acceleration sensors will be implemented to verify the UAV's handling and stability. Altitude and airspeed sensors will be able to verify the operating altitude, stall speed, and dash speed. Commands originating from the ground reach the UAV through the command handling subsystem which passes them off to the propulsion and controls subsystem. The controls subsystem contains the electronics and mechanical actuators to move all of the control surfaces. Engine, throttle control, fuel tanks, and fuel lines are all contained in the propulsion subsystem. Power is provided to the command handling system and the payload through the power subsystem.

6.0 Mission Profile:

Figure 4 represent the expected mission profile for SHARC

1. Startup/Warmup
2. Taxi
3. Takeoff
4. Climb
5. Cruise
6. Loiter
7. Descend
8. Land/Taxi

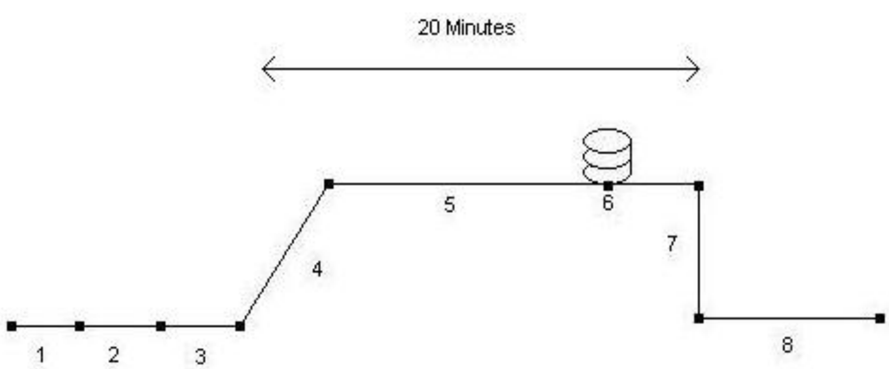

Figure 4: SHARC Mission Profile

7.0 System Operational Timeline (Concept of Operations)

Figure 5 contains a diagram of the concept of operations (ConOps) for the SHARC project.

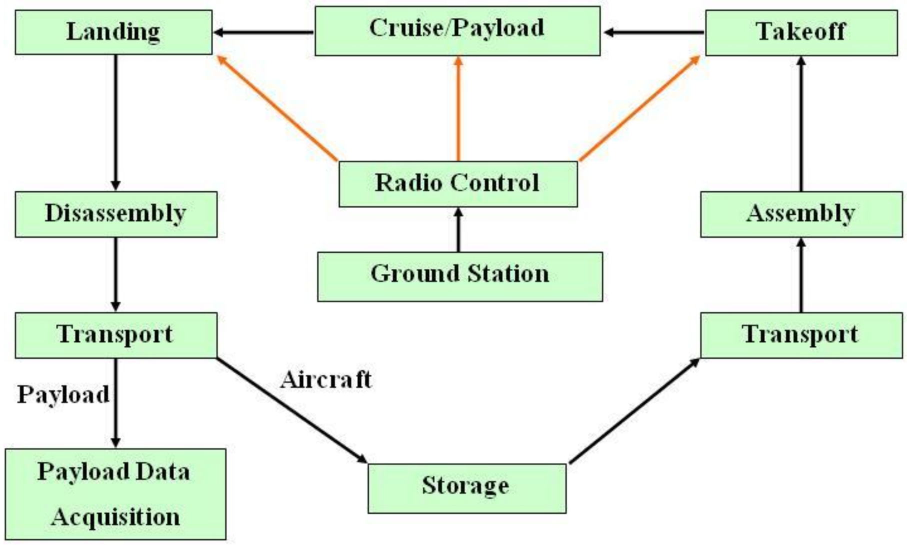

Figure 5: SHARC ConOps Diagram

There are five main areas of operation for this UAV which imply many project level requirements:

7.1 Storage

7.1.1 Driver for minimal size and easy assembly/disassembly.

7.1.2 Materials selection for long life and durability.

7.2 Transport

7.2.1 Size requirements for broken down aircraft and payload to fit in a typical ground vehicle.

7.2.2 Desirable to transport in same container as storage.

7.2.3 Supporting equipment should fit in the ground vehicle.

- 7.3.2.1 Ground stations.
- 7.3.2.2 Engine supporting equipment.
  - 7.2.3.2.1 Fuel.
  - 7.2.3.2.2 Engine starter and ignition source.
- 7.3.2.3 Flight supporting equipment.
  - 7.2.3.3.1 RC controller.
  - 7.2.3.3.2 Ballast.

7.2.3.3.3 Mobile power supply.

7.2.3.3.4 Battery charger.

7.3 Assembly/Disassembly

7.3.1 Simple assembly and disassembly

7.1.3.1 Aircraft should break down into a minimum number of parts and use a minimum number of fasteners and tools to assemble.

7.1.3.2 Procedures for assembly and disassembly should be simple and documented in a set of instructions.

7.4 Flight

7.4.1 Takeoff and landing shall be conducted from typical RC aerodromes.

7.4.2 Cruise duration, altitude, and speed should be sufficient for payload and/or aircraft testing.

7.5 Payload Data Acquisition

7.5.1 Payload should be easy to remove from UAV.

7.5.2 UAV verification package should contain sufficient instruments to verify UAV design requirements.

7.2.5.1 Measure, record, and analyze altitude and airspeed.

7.2.5.2 Measure, record, and analyze linear and rotational acceleration in all three axes.

7.2.5.3 Easy access to data is desirable.

8.0 Project Requirements

All the parent requirements for this section originated from the Request for Proposal[2] (Appendix A) for a UAV Testbed document by Sierra Nevada Corporation (SNC).

8.1 UAV for Payload Testbed

8.1.1 This vehicle must be able to carry a payload for testing.

8.1.2 This requirement provides the costumer with a working UAV to test their payload.

8.1.3 The method of verification is demonstration of a working vehicle.

[2] Bertman, Michael. Request for Proposal for an Unmanned Aerial Vehicle Payload Testbed. Sierra Nevada Corporation. Littleton, 2007.

8.2 Budget

8.2.1 This vehicle must comply with budget offered by SNC.

8.2.2 Verification of budget is documentation.

8.3 Assembly and Operation

8.3.1 The vehicle must be able to be assembled and operated by no more than two people.

8.3.2 This requirement allows for ease of operation. In addition, this requirement enables the customer to save money by reducing the manpower needed to operate tests.

8.3.3 A method of verification is demonstration of assembling and operating the vehicle with two people following completion of aircraft flight test and checkout.

8.4 Ground Operations

8.4.1 The UAV will have sufficient support from ground operations.

8.4.2 Supporting equipment will consist of one radio controller to be operated by a SHARC team member. This person will exhibit average RC pilot skills.

9.0 Top Level System Requirements

All the top level system requirements for this section originated from the Request for Proposal for a UAV Testbed document by Sierra Nevada Corporation (SNC)(2) (Appendix A).

9.1 Radio-Controlled

9.1.1 The vehicle needs to be flown as a conventional radio-controlled (RC) aircraft.

9.1.2 The purpose of this requirement is to operate the aircraft at any RC flying park. This will allow more testing/operating usability.

9.1.3 From Parent Requirement 7.1 UAV for Payload Testbed.

9.1.4 Method of verification is demonstration of flying the aircraft.

9.2 Vehicle Size

9.2.1 The vehicle must not exceed 7 feet in any dimension. The goal is to make the aircraft not exceed 6 feet in any dimension.

9.2.2 This enables the vehicle to be fully insured by the customer.

9.2.3 The size of the aircraft will be verified by inspection.

9.3 Weight

9.3.1 The total weight of the aircraft, including the payload, must not exceed 70 lbs. The goal for the total weight is to not exceed 55 lbs.

9.3.2 This requirement is in place to meet requirement 7.2, referring to the assembly and operation of the aircraft by no more than two people.

9.3.3 This requirement will be verified by weight inspection.

9.4 Payload Location

9.4.1 The payload must be located on the nose of the aircraft.

9.4.2 This requirement was given by the customer to enable proper use of the payload contents.

9.4.3 This requirement will be verified by inspection.

9.5 Flight Endurance

9.5.1 The aircraft must achieve a flight endurance of at least 20 minutes. A flight endurance of 60 minutes is the ultimate goal.

9.5.2 This requirement is driven by the needs of the payload being tested. The aircraft must remain in flight for a sufficient amount of time to allow all testing to be completed.

9.5.3 The endurance will be verified through recorded flight testing.

9.6 Stall Speed

9.6.1 The stall speed of this aircraft cannot exceed 45 knots. The goal is to have a stall speed of 30 knots.

9.6.2 From Parent Requirement 7.1 UAV for Payload Testbed.

9.6.3 Stall speed is verified through flight testing and recording.

9.7 Dash Speed

9.7.1 The aircraft must achieve a dash speed of at least 60 knots. The goal is to achieve a speed of 90 knots.

9.7.2 From Parent Requirement 7.1 UAV for Payload Testbed.

9.7.3 Dash speed will be verified through flight testing and recording.

9.8 Operating Altitude

9.8.1 The operating altitude must be the equivalent of at least 6,000 feet density altitude. The objective operating altitude is 10,000 feet.

9.8.2 From Parent Requirement 7.1 UAV for Payload Testbed.

9.8.3 Operating altitude will be verified through flight testing and recording.

9.9 Power

9.9.1 Provide required power to payload section.

9.9.2 TBD through customer interaction by September 24st, 2007.

10.0 Minimum Requirements for Success

10.1 SNC Payload Integration

10.1.1 The payload will be mechanically integrated into the UAV. The payload will receive power provided by the aircraft.

10.2 Takeoff Capability

10.2.1 The UAV will be able to takeoff from a standard RC field runway under its own power (25' x 450').

10.3 Flight Characteristics

10.3.1 The aircraft will climb and obtain a steady level flight after achieving cruise altitude.

10.4 Landing

10.4.1 The UAV will land with minimal/repairable damage in order to accomplish subsequent flights. Upon landing, data from the payload section will be recoverable.

11.0 Deliverables

11.1 Intellectual Property

11.1.1 SNC will have all rights regarding the design and design reports associated with the SHARC UAS. This includes all design process reports, notes, and CAD designs (i.e. PDR, CDR, and FFR).

11.2 Physical Property

11.2.1 The SHARC UAS will become the property of SNC and will be turned over to them upon the completion of the project. This will include the physical air vehicle, ground support equipment, and molds used to construct SHARC.

12.0 Technical Risk

12.1 Incomplete Milestones

12.1.1 Components or tasks not completed by deadlines will push the dependent component or task behind schedule.

12.1.2 To mitigate this risk, future components will be reprioritized in order to meet next milestone. This includes augmenting the schedule to allocate more hours to the project.

12.2 Budget

12.2.1 A specific system of the project exceeds allotted funding.

12.2.2 A risk mitigation budget of 20% will be included in the Bill of Expected Materials (BOEM) submitted to SNC. This budget allotment will be implemented to bring the project back up to an operating phase.

12.2.3 SNC does not express desire to fund the SHARC project.

12.2.4 Under the circumstances that funding is not provided through SNC, a grant request will be submitted to EEF and other outside funding resources (UROP, UCEC, SoFo). Outside funding will invalidate all intellectual and physical property rights given to SNC.

12.3 Design

12.3.1 The project experiences a design flaw or a specific component does not meet expected strengths or performances.

12.3.2 Prevention of this risk shall be done by performing early and frequent testing and verification of components before integration to ensure they meet design expectations to catch flaws early.

12.3.3 Solving this will require the team to reanalyze the problem and reengineer to create a physical solution. Review the affects caused to the schedule and augment due dates for problem mitigation.

12.4 Group

12.4.1 The team experiences a member shortage or a lack of expertise in any area.

12.4.2 This will be solved by assessing the current schedule and determine if components are meeting deadlines under the current situation. If a component becomes behind schedule, reevaluate resources provided to the team and reorganized such that milestones are still accomplished with as little delay as possible.

12.5 Requirements

12.5.1 The team does not meet one or more of the project's requirements.

12.5.2 Careful analysis of the problem will help create possible physical solutions. Further review for the overall schedule and augment due dates for problem mitigation.

12.5.3 Throughout the course of this project SNC desires to change any requirement previously mentioned.

12.5.4 In the event of a requirement change, a proper formal agreement and document will be compiled to appropriately review and engineer desired components.

13.0 Anticipated Engineering Expertise

Technical Area	**How Applied / Indicate Team Member Responsible**
Aerodynamics	Apply aerodynamic theory as major design driver. Eli, Kim, Luke, T.J.
Structures/Materials	Ensure structural analyses of UAV components are reliable and lightweight. Provide complimentary insight of appropriate material selection. Chris, Luke, Matt, T.J.
Electronics/Controls	Research and apply any and all electronic systems related to aircraft control and test-flight verifications. Brian, Chris, Kim, Luke
Propulsion Systems	Based upon aircraft dynamics, necessary engineering will determine propulsion system and related subsystems (i.e. battery, fuel). Andrew, Brian, Chris, T.J.
Manufacturing	Individuals responsible for all aspects related to the manufacturing of UAV including safety, tooling, and cost. Andrew, Eli, Shawn

14.0 Resources

14.1 Facilities

14.1.1 AES/ME Composite's Lab: Access to composite lay-up facility for constructing UAV structure.

14.1.2 AES Machine Shop: Access to machine shop for manufacturing aircraft components.

14.1.3 AES Projects Room: Access to projects room for integration, minor assembly, and storage.

14.1.4 AES Visions Lab: Access to computational tools for design and analysis.

14.1.5 ITLL: Access to additional computational tools for design and analysis and additional manufacturing facility.

14.1.6 KU Wind Tunnel: To appropriately analyze the aerodynamics of the aircraft, a prototype of the UAV will be tested in a wind tunnel located at the University of Kansas.

14.1.7 RC Field: Access to RC Field needed to test and demonstrate SHARC UAS.

14.2 Additional Advisors

Key advisors for this project include:

1. Trudy Schwartz (AES) for sensor and electrical advice.
2. Matt Rhode (AES) for manufacturing advice.
3. Michael Bertman (Sierra Nevada Corporation) to ensure SNC's satisfaction and for additional technical advice if needed.

14.3 Funds

Sierra Nevada Corporation will be the sole financial provider for the project. The standard AES department funding of $4,000 will not be available, as all Intellectual Property and assets will belong to SNC and not the University of Colorado, Boulder. Additional funding sources will not be investigated nor expected, as the customer will provide ample funding for the success of the project.

15.0 Project Acknowledgements

15.1 Customer Contacts

This group would like to acknowledge its customer Sierra Nevada Corporation. SNC provided the product requirements found within this document. They have also expressed interest in assisting the group with technical advice throughout the life time of the project.

15.2 Faculty Members

The Project Advisory Board (PAB) has provided continual assistance with the development of this document.

APPENDIX A:

Request For Proposal

for an

Unmanned Aerial Vehicle Payload Testbed

By

Sierra Nevada Corporation

4 January 2007

Abstract:

This request for proposals (RFP) specifies the requirements for a student project to design an Unmanned Aerial Vehicle (UAV) payload demonstrator aircraft for Sierra Nevada Corporation (SNC). SNC seeks an aerial platform from which it can test fly UAV payloads designed for the Spartan Unmanned Aerial System (UAS) with a minimal personnel and logistical footprint and at low cost. This document will provide both requirements for proposal submission and vehicle performance requirements.

Overview:

SNC is currently developing a tactical UAS capability called Spartan. This system consists of the Spartan air vehicle, a command and control ground stations and a variety of sensor payloads. While the complete Spartan UAS is still in development, several sensor payloads have been developed or are nearing completion for flight on the Spartan aircraft. Because Spartan is still in development, flight tests of the airframe are not yet complete and a large logistical footprint is required for flight testing. The objective of this payload demonstrator project is to provide a low cost, easy to operate and reliable UAV for testing Spartan related payloads prior to integration to the Spartan UAS.

Proposal Requirements:

The proposal at a minimum shall include a title page, table of contents, abstract, discussion of the overall vehicle design, performance expectations, itemized cost of materials and test expenses, and a project schedule. The proposal shall be no longer than 6 pages including tables and figures, but excluding the title page, table of contents and appendices. Text font shall be 12 point Times New Roman, single spaced.

The vehicle performance section shall cover in detail expected performance characteristics mapped to the design requirements list below in this document. Methods used in estimating performance will be described in this section. If necessary, detailed calculations or graphs may be provided in an appendix.

A detailed cost breakdown for the project shall be provided. While individual item costs may be listed in an appendix, categorized costs will be listed and described in the body of the proposal. Any items that are to be provided by SNC will also be listed and marked as "SNC Supplied". If SNC is expected to purchase a new item, a cost estimate must be provided.

An overall project schedule must be provided which indicates at a minimum the overall project duration, length of design, build and test phases, dates for Preliminary Design Review (PDR) and Critical Design Review (CDR) and any other key milestones. The project end date shall be no later than 31 May 2008.

UAV Requirements:

The primary objective of the UAV requirements is to produce an aircraft that may be flown as a conventional radio control (R/C) aircraft and as such flown from conventional R/C flying parks.

The aircraft shall be capable matting with an unmodified Block 2 Spartan payload bay and will provide the necessary electrical and mechanical interfaces (to be provided by SNC) to allow the payload to operate for the duration of the vehicles endurance.

The aircraft shall also be capable of being setup and operated by no more than two (2) trained people. The aircraft propulsion shall be provided by a conventional internal combustion engine(s) and a conventional propeller(s). The engine(s) may run on gasoline, diesel or methanol (R/C) fuel.

Size - The air vehicle must not exceed 7'0"(threshold), 6'0" (objective), in any dimension. The aircraft shall have the capability to be broken down to a size that will allow it to fit inside a mid-size sedan automobile for transportation.
Maximum Gross Takeoff Weight (MGTW) – MGTW shall not exceed 70 lbs (threshold), 55 lbs (objective).
Minimum Payload Weight – The aircraft shall be capable of carrying a payload module weighing at least 15lbs (threshold), 25lbs (objective).
Endurance - The aircraft shall be capable of flying for 20 minutes (threshold), 60 minutes (objective).
Stall Speed - The vehicle shall have a stall speed no more than 45 knots (threshold), 30 knots (objective).
Dash Speed - The vehicle shall have a level flight dash speed of at least 60 knots (threshold), 90 knots (objective).
Operating Altitude - The vehicle shall be capable of flight at density altitudes of at least 6,000 ft (threshold), 10,000 ft (objective)