NORTHROP GRUMMAN

NORTHROP GRUMMAN COLLABORATION PROJECT

2020-2021

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1 NORTHROP GRUMMAN COLLABORATION PROJECT OVERVIEW

The Northrop Grumman Collaboration Project (NGCP) is a research and development project where students from Cal Poly Pomona (CPP) and Cal Poly San Luis Obispo (CPSLO) partner to make advanced autonomous systems and learn industry-standard engineering principles. Funded by Northrop Grumman, the objective is to demonstrate collaboration between multiple heterogeneous, autonomous vehicles to complete a search and rescue mission. The project is on its 10th year and has previously demonstrated autonomous navigation through air, land and sea, obstacle avoidance, custom communication protocols, target detection, and autonomous payload delivery.

NGCP seeks to bring dedicated students together from multiple disciplines and simulate the engineering principles used in the development of a product from conception to teardown. The purpose of this project is to teach the students real industry problems such as applied engineering skills, rapid innovation and collaboration between multiple companies across various locations, program management, team dynamics, and more. The simulated challenge will be based on the functional needs of a humanitarian aid/disaster relief situation. Each platform will perform their own individual tasks as a sub-system of a larger system that demonstrates the completion of a realistic mission. The platforms consist of a common Ground Control Station (GCS), Unmanned Arial Vehicles (UAVs), and Unmanned Ground Vehicles (UGVs). Throughout the year, students will interact with a variety of Northrop Grumman engineers to assist in the completion of the project.

Previous years of the project have shown growth in the hardware and software capabilities of individual vehicles completing specific tasks of a search and rescue mission. This year the teams are expected to focus on the development and demonstration of a single integrated, collaborative mission that utilizes the types of vehicles developed in past years. With a mission based approach, the students at Cal Poly Pomona and Cal Poly San Luis Obispo should not consider the individual vehicle as the measure of success, but rather as a necessary component of a larger system that cannot be successful without each subsystem working properly.

2 STATEMENT OF WORK

2.1 BACKGROUND

According to the National Parks Service:

There were nearly 4,200 search and rescue (SAR) operations in the national parks in 2017. In most of these scenarios, hikers had wandered off trail and gotten lost in the wilderness.

(https://nps.maps.arcgis.com/apps/opsdashboard/index.html#/b526c87ae21f4a669eb6c9238c2c4bcf)

While SAR operations are possible using helicopters or manned search teams, these can be expensive and dangerous to the rescuers. In order to explore the capabilities of a low cost autonomous system, small scale vehicles are to be developed which can locate and rescue a human who is lost and possibly injured in the wilderness.

(https://smokymountains.com/safe-and-found/)

2.2 SYSTEM OVERVIEW

This Request for Proposal (RFP) is for the design, manufacture, and validation of a fully functioning system of unmanned vehicles with the proper infrastructure to quickly locate and rescue a hiker who is lost in the wilderness. In order for the system to be effective in various scenarios, it will be assumed that the hiker cannot be seen visually, is injured to a point of full immobility, and cannot survive in the weather conditions for more than a few hours. The hiker is equipped with a walkie talkie which can be detected to find the hiker's location.

This mission will be achieved using two unmanned aerial vehicles (Multirole Aircraft, Med-Evac Aircraft), one unmanned ground vehicle (Emergency Response Unit), and a common ground control station. These three vehicles will complete their primary missions autonomously and also have the capability of manned control. All vehicles must also communicate across a common communication network. To ease the development of this advanced system, one air vehicle and one ground vehicle will be developed at Cal Poly Pomona CPP and one air vehicle at CPSLO with a joint GCS developed by both campuses.

For this mission an example illustration of the mission domain elements can be seen in Figure 1. Table 1 summarizes the responsibilities of the vehicles. The domain in Figure 1 consists of:

1. Mission Headquarters (HQ): This area will contain an operational base from which all vehicles shall be remotely operated through the GCS. Direct line of sight to any vehicle should not be achievable from the operator's tent. This area will also have an area for an audience and will be considered a no-fly zone.

2. Hospital Helipad: This location is where the Med-Evac Aircraft will take off and land from. This location will be set by the team before mission start.

3. Runway: This runway will be used by the Multirole Aircraft to take off and land on.

4. Search Area: The lost hiker is assumed to be within this predefined area.

5. Hiker Location: The exact location of the hiker will be unknown to HQ at the time of mission start. However, it will be within the Search Area.

6. Evacuation Point (EP): This point will be clear of overhead obstacles. The Med-Evac Aircraft will retrieve the hiker from the Emergency Response Unit at this location. The EP will be defined by the student team after surveying the mission domain.

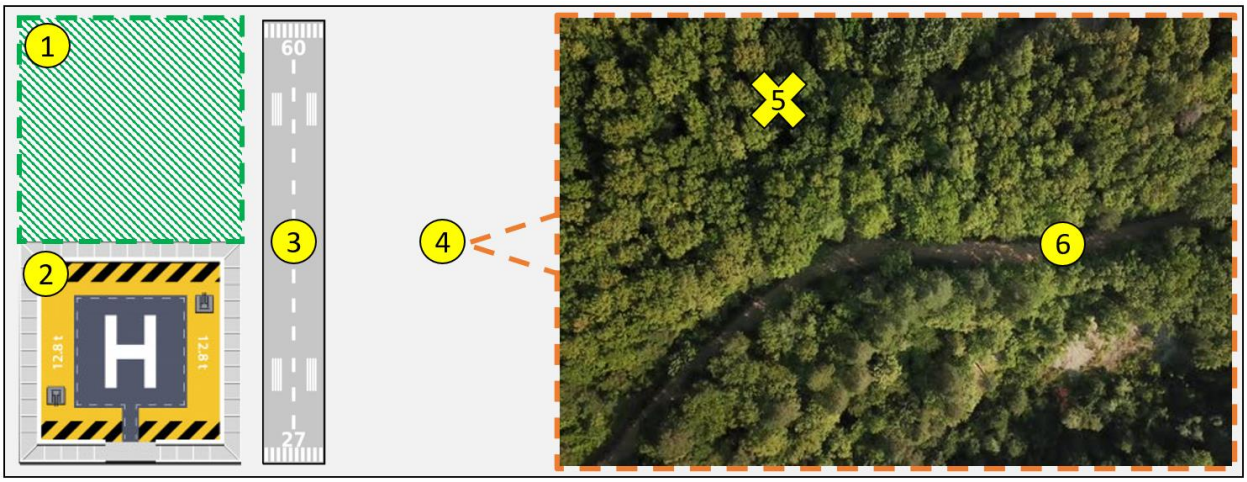

Figure 1 – Mission Domain Elements

Table 1 – Summary of Vehicle Responsibilities

Role	CPP UAV (Multirole Aircraft)	CPP UGV (Emergency Response Unit)	CPSLO UAV (Med-Evac Aircraft)	GCS
Primary	Detect hiker location, transmit location, and drop Emergency Response Unit nearby	Prepare and transport hiker to Evacuation Point	Receive and transport hiker to safety	Receive and send information from all vehicles, control manual operations of ground vehicles
Support		Detect hiker location	Detect hiker location	Manual control of all vehicles

3 SYSTEM REQUIREMENTS

Mission or system-level requirements are used to define the system's function, characteristics, and constraints. The following mission requirements are defined for the entire system of vehicles.

[SYS_01] The system shall be able to geolocate a walkie talkie broadcasting on Family Radio Service (FRS) channels to an accuracy of 10 ft (TBR).

[SYS_02] The system shall transport an immobile hiker (miniature human figurine) from their location in the wilderness to a predesignated medical center on a medical stretcher.

[SYS_03] The system shall be able to load a hiker onto a medical stretcher provided by the system before any transportation begins.

[SYS_04] The system shall be capable of transporting a hiker of no less than 11.5 inches tall (TBR).

[SYS_05] The system shall be capable of transporting a hiker weighing no less than 0.4 lb. (TBR).

[SYS_06] The system shall transport a hiker out from a densely covered area and into a cleared/open area.

[SYS_07] The system shall perform an aerial transport of the hiker from a cleared/open area to a predesignated medical center.

[SYS_08] All subsystems being heterogeneous in design shall be interoperable.

[SYS_09] The entire system shall be commanded and controlled from a single ground control station using one standardized communication network.

[SYS_10] The system shall be able to locate and transport a hiker to a medical facility within 20 minutes of mission start.

[SYS_11] Once found, the hiker's position shall be displayed to HQ (GCS) at all times until safely back at the helipad.

[SYS_12] The system shall be able to operate in weather conditions consisting of sunny to overcast, no rain to light rain (0.02 inch per hour), no wind to winds up to 15 mph, and dry and wet/ puddles on active field.

[SYS_13] All system components shall be able to be repaired and running within 10 minutes of component failure.

[SYS_14] The system shall be able to resist and recover from mission deviations and natural or external interference in real time without scrubbing or putting mission on hold.

[SYS_15] The system shall be able to display and control all subsystems through a central HQ (GCS) and monitor mission status.

Note: All vehicles need to perform feasibility study to determine endurance/ time specification for all mission segments and maneuvers to meet Mission Level Requirement and provide feedback to customer (NGC) on requirements that contain TBR (to be refined).

4 VEHICLE LEVEL MISSION OVERVIEW AND REQUIREMENTS

The vehicle level mission overview and requirements are discussed in the following sections. These requirements have been provided to ease the development of the advanced system due to constraint in project schedule. Further requirements shall be derived and further refined by the respective teams.

4.1 MULTIROLE AIRCRAFT (CPP UAV)

As an aircraft with capabilities for air-to-ground delivery and geolocation functionality, the designation of multirole will be assigned to this platform.

4.1.1 MISSION

The vehicle will demonstrate fully autonomous flight and navigation, hiker geolocation, and payload delivery to a chosen location. The vehicle will demonstrate manual takeoff while carrying the CPP UGV. The vehicle will autonomously survey the search area and geolocate the hiker. The vehicle will then drop the CPP UGV into an open/cleared location. After mission completion the vehicle will be switched back to manual flight and land.

4.1.2 PERFORMANCE/DESIGN REQUIREMENTS

To meet the requirements of a simulated mission for NGCP, the vehicle and supporting documentation shall satisfy guidelines below.

Performance Requirements:
[MAC_01] The vehicle shall autonomously drop the CPP UGV with an accuracy of 50 ft
[MAC_02] The vehicle shall have a minimum, fully loaded, endurance flight time of 10 minutes
[MAC_03] The vehicle shall be aerodynamically stable in all axes
[MAC_04] The vehicle navigation should be fully autonomous during flight operations
[MAC_05] The vehicle shall be capable of taking off and landing from asphalt runways
[MAC_06] The vehicle shall perform manual takeoff and landing for safety constraints
[MAC_07] The vehicle shall autonomously obey geofence boundaries provided by the GCS
[MAC_08] The vehicle shall meet all FAA Part 107 requirements.

Design Requirements:
[MAC_09] The vehicle shall be a blended wing aircraft architecture without vertical surfaces.
[MAC_10] The vehicle shall have all avionics components on a removable electronics tray

4.1.3 REQUIRED ANALYSIS

The vehicle analysis package will include documentation that supports the items discussed in the Data Item Description (DID), Appendix - Section (A3) System/Subsystem Design Description.

4.2 Emergency Response Unit (CPP UGV)

4.2.1 Mission

This vehicle will demonstrate survivable hard landing capability, hiker detection, hiker transportation. The vehicle will be carried by the CPP UAV to the hiker's vicinity, released during flight, and make a safe landing near the hiker's vicinity. It will then navigate to and prepare the hiker for transport. After the hiker is properly secured, the vehicle will transport the hiker from underneath dense cover to an open area where the Med-Evac Aircraft can perform a transfer. The vehicle's mission is complete when it is back in the HQ area.

4.2.2 Performance/Design Requirements

To meet the requirements of a simulated mission for NGCP, the vehicle and supporting documentation shall satisfy guidelines below.

Performance Requirements:
[ERU_01] The vehicle shall be able to survive in-flight drop from Multirole Aircraft.
[ERU_02] The vehicle shall drive up a 57.7% grade hill at 3 mph while fully loaded (TBR)
[ERU_03] The vehicle shall have the capability of remote manned operation through video feed
[ERU_04] The vehicle should be able to autonomously navigate to a specified GPS location
[ERU_05] The vehicle should detect and avoid obstacles such as rocks and trees along its path
[ERU_06] The vehicle shall be capable of preparing an immobile hiker for transportation
[ERU_07] The vehicle shall be capable of transporting the hiker 1500 ft away from the hiker's original position.

Design Requirements:
[ERU_08] The vehicle shall have all avionics components on a removable electronics tray

4.2.3 Required Analysis

The vehicle analysis package will include documentation that supports the items discussed in the Data Item Description (DID), Appendix - Section (A3) System/Subsystem Design Description.

4.3 MED-EVAC AIRCRAFT (CPSLO VTOL)

4.3.1 MISSION

The vehicle will demonstrate mid-flight payload retrieval and transport of a hiker. The vehicle will receive the location of the prepared hiker from the GCS and navigate to the CPP UGV. The vehicle will then connect to the medical stretcher and extract the hiker. Once the hiker is secured, the VTOL will return to the medial helipad and safely drop the hiker to ground level.

4.3.2 PERFORMANCE/DESIGN REQUIREMENTS

To meet the requirements of a simulated mission for NGCP, the vehicle and supporting documentation shall satisfy guidelines below.

Performance Requirements:
[MEA_01] The vehicle shall be able to remotely connect to the medical stretcher without landing
[MEA_02] The vehicle shall be capable of transporting the medical stretcher from a cleared/open area to the medical helipad
[MEA_03] The vehicle shall be capable of completing the design mission with components as follows:

- Cruise: 1.5 miles
- Loiter: 10 minutes
- Cruise: 1.5 miles (loaded with hiker/stretcher unit)
- Land: On helipad of 10 ft diameter

[MEA_04] The vehicle shall take off and land vertically
[MEA_05] The vehicle shall be aerodynamically stable and controllable in all axes
[MEA_06] The vehicle shall autonomously obey geofence boundaries provided by the GCS

Design Requirements:
[MEA_07] The vehicle shall have all avionics components on a removable electronics tray

4.3.3 REQUIRED ANALYSIS

The vehicle analysis package will include documentation that supports the items discussed in the Data Item Description (DID), Appendix - Section (A3) System/Subsystem Design Description.

4.4 Ground Control Station (GCS)

4.4.1 Mission

The GCS will act as the primary command and control station for all vehicles within the system using custom code and dedicated hardware. The GCS will be used by a team at HQ to remotely view vehicle status, display key mission data, and send commands to all vehicles. The GCS will be able to remotely control the UGV with the use of a video feed. The GCS will collect and display the real-time location data of all active vehicles throughout the mission.

4.4.2 Performance Requirements

To meet the requirements of a simulated mission for NGCP, the GCS and supporting documentation shall satisfy guidelines below. To exercise the team's ability to perform a full design cycle, the GCS will be designed and built from scratch using contemporary software engineering methodologies. No part of the legacy GCS shall be re-used for the 2020-2021 school year.

Performance Requirements:

[GCS_01] The GCS shall have the capability of sending all mission commands that are not flight or safety critical to any vehicle*
[GCS_02] The GCS shall provide user(s) the capability to command all vehicles simultaneously
[GCS_03] The GCS shall display location information from all vehicles at 1 Hz on a single map
[GCS_04] The GCS shall display health and status information of all vehicles at 1 Hz
[GCS_05] The GCS shall be capable of manually controlling the UGV
[GCS_06] The GCS shall receive video feed from the UGV during manual control
[GCS_07] The GCS be capable of relaying geofences (both keep-out and keep-in zones) to all vehicles
[GCS_08] The GCS shall display and be able to receive, or command search areas
[GCS_09] The GCS shall be able to command an emergency stop/loiter for all vehicles
[GCS_10] The GCS shall be capable of ignoring messages sent by unidentified systems

*Mission Commands refer to communications such as position information and waypoints which do not control the vehicle state directly.

APPENDIX A
1 SUMMARY OF KEY INFORMATION

1.1 KEY MILESTONES

Important milestones for the 2020-2021 program are noted in Table 2 below.

Table 2 – Key Milestones

August 2020	RFP Released
Early October 2020	System Requirements Review (Online Review)
Mid/End October 2020	Integrated Baseline Review (EVMS, Schedule, etc.) (Online Review)
December 2020	Preliminary Design Review (PDR)
February/March 2021	Critical Design Review (CDR) (TBD- Online/In-Person)
June 2021	Demonstration Day (In-Person Demo)

Note: Technical Interchange Meetings (TIMs) with NGC advisors shall be scheduled by student teams, recommended monthly.

Note: If In-person Demonstration Day isn't feasible due to COVID-19, a Year End Report shall be submitted to NG representatives in its place.

1.2 COST + MATERIALS

The cost of all parts and materials are provided by Northrop Grumman. It is the project management team's responsibility to monitor project budget and individual team's responsibility to monitor their systems budget. All parts and materials purchased shall be purchased and approved by system leads and faculty advisors. Off the shelf vehicle kits are NOT permissible on any vehicle. Additional material or funding from outside sources shall be made cognizant to and approved by Northrop Grumman.

1.3 GENERAL INSTRUCTIONS

All analysis shall be performed by the student; it cannot be provided by mentors or professors.

1.4 CONTRACT DATA REQUIREMENTS LIST (CDRL)

Throughout the 2020-2021 academic year, students shall meet the following deliverables:

A1. Project Management Plan

A2. Integrated Master Schedule

A3. System/Subsystem Design Description

A4. Membership Demographic Charts

1.5 DATA ITEM DESCRIPTION

This section contains specific information and description of the CDRL. A data item description (DID) contains the format and content preparation instructions for the specific contract data requirement in the contract. The deliverables must be received by Northrop Grumman Representative by the deadlines described in the following subsections.

1.5.1 (A1) PROJECT MANAGEMENT PLAN

The Project Management Plan (PMP) shall be a consolidated program plan addressing how the CPSLO and CPP campuses will execute the program. The PMP shall contain the organizational structure, key roles with responsibilities, team communication plan, work breakdown structure, high level schedule

showing major program milestones, details of how each major milestone will be supported, budget, critical success factor and student retention/ recruitment plan. The PMP should contain EVMS.

Preparation Instructions:

- Format: MS PowerPoint
- Alternate presentation styles: other presentation styles are acceptable when the data required can be made more readable using these styles (diagrams, tables, matrices, etc)
- Content requirements:
    - Scope: shall contain identification, overview, table of contents, reference documents
    - Section for each requested data
- Due Date: One week prior to the Integrated Baseline Review

1.5.2 (A2) Integrated Master Schedule

The data in the Integrated Master Schedule (IMS) shall include high level milestones and the detailed design, manufacturing, and test activities for each vehicle. The schedule shall include the critical path for each vehicle and the overall project.

Preparation Instructions:

- Format: MS Project
- Alternate presentation styles: other presentation styles are acceptable when the data required can be made more readable using these styles (diagrams, tables, matrices, etc)
- Content requirements:
    - Milestones
    - Top Level Program schedule
    - Detailed vehicle level schedule (design, manufacturing, test)
    - Critical Path
    - Risk to schedule
- Due Date: One week prior to the Integrated Baseline Review

1.5.3 (A3) System/Subsystem Design Description

The system/subsystem design description shall contain all pertinent information with respect to the design, analysis, and development of each vehicle and ground control station. The following information shall be captured in PowerPoint presentations, part/assembly drawings, electrical drawings, and interface control documents. Each vehicle shall have a list containing the requirements stated in this RFP specific to the vehicle and an accompanying list of derived requirements with sufficient detail to show how the system will validate the primary requirements. The data shall be provided to NG representatives one week prior to any review.

A systems engineering model shall be developed jointly by both schools in a commonly used Model Based Systems Engineering (MBSE) such as CORE9 or Enterprise Architect. This model should include the following:

1. Customer requirements
2. Derived requirements
3. Operational Activities with their associated measures of effectiveness, operational hazards and other related elements. (Presented at SRR)
    a. A simulation of the operational activities is desirable
4. System Functions with their associated Key Performance Parameters (KPPs), malfunctions, and other related elements (Presented at PDR)
5. System Components with their associated Key System Attributes (KSAs), failure modes, and other related elements (Presented at CDR)
    a. Failure mode analysis should be completed
    b. A component hierarchy tree should be created

The technical information that shall be captured in the technical data package include:

1. Performance summary sheet
2. Mission Profile
3. Compliance matrix and risk mitigation
4. Design trade studies
5. Sizing and layout
6. Structural Analysis
7. Performance Analysis (aerodynamics, stability/controls, propulsion, etc…)
8. Electrical schematics and layout
9. Manufacturing approach
10. Description of autonomy algorithms
11. Interface Control Documents (ICDs)

Preparation Instructions:

- Format: MS PowerPoint, PDF, MS Word
- Alternate presentation styles: other presentation styles are acceptable when the data required can be made more readable using these styles (diagrams, tables, matrices, etc)
- Document Numbering: All documents shall be contained in one database with a defined numbering system
- Title and Identifier: Each document shall include a title, identification number and date
- Content Requirements:
    - Scope: Shall be broken into three sections (identification, system overview, document overview)
    - Reference Documents
    - System-Wide Decisions

        - inputs, outputs, interfaces with other systems, configuration items, and users
        - system responses (performance, response time, description of physical system modeled, algorithms/equations)
        - design and construction decisions or hardware (physical size, weight, material, color, markings, etc)
    - System Architectural Design
        - System components
        - Concept of execution
        - Interface design
        - Requirement Traceability
        - Notes: background information, etc
        - Appendices: provide information documented separately for convenience in document maintenance

1.5.4 (A4) Membership Demographics Charts

The membership demographics charts shall include summary diagrams of the following demographics:

- Years on Project
- Major
- Academic Year
- Campus breakdown at the program level, subproject-level (e.g. BWB, GCS, etc)
- Post-Academic year Employment Location (Intern, New Hire, graduate school, on-campus jobs)

The data shall be provided to NG representatives one week prior to major reviews, specifically Integrated Baseline Review, PDR, CDR, Demo Day.

Note: Demographic charts shall be representative of the entire project between both schools, further breakdowns can be provided at the digression of the PM's. Personal information and individual responses to surveys shall be confidential to NGCP Faculty/Staff or responsible student leaders (such as PM), with only summary charts provided to NGC.

Preparation Instructions:

- Format: MS PowerPoint
- Alternate presentation styles: other presentation styles are acceptable when the data required can be made more readable using these styles (diagrams, tables, matrices, etc)