UAV platform. The SPAARO ("Small Platform for Autonomous Aerial Research Operations") was designed by a team of researchers in Virginia Tech's Aerospace & Ocean Engineering Department. The platform has a 12 ft wingspan and a 16 ft^2 wing area. The SPAARO is equipped with a 75 cc 3W-75iUS gasoline engine (3W, Germany) that produces 7.5HP at 8,500 RPM and a Biela 22X12 3-blade pusher prop (Smigla, Poland). The empty weight is 48 lbs, which includes 10lbs for the mission payload. The maximum takeoff weight is 55 lbs. The SPAARO is balanced with a 22% static margin to ensure stable flight. Figure 1 shows the SPAARO fully assembled for taxi tests at Kentland Farm, VA.

Figure 1: Taxi test of SPAARO at Kentland Farm, VA

SPAARO has a large mission payload bay (21"x12"x7") in the forward section of the fuselage. This segregated payload bay keeps mission-related hardware (related to the aerobiological sampling apparatus) physically separated from flight critical hardware (autopilot, GPS antennas, avionics power supply, etc.). Figure 2 shows the mission payload bay.

Figure 2: SPAARO Payload Bay

Extensive Modeling. To ensure adequate flying qualities, the researchers performed extensive modeling and analysis, both computational and experimental. An aerodynamic model, structural model, and propulsion model were combined to create performance models, enabling designers to verify performance predictions. This model was used to develop an accurate FlightGear simulation, enabling pilots to fly the SPAARO in a realistic R/C simulation.

Figure 3: Aerodynamic (left) and pitch inertia (right) experiments.

Primary flight control system. Cloud Cap Technology's Piccolo II autopilot (Cloud Cap Technology, Hood River, OR) is the primary flight control system. The system comprises an avionics unit on-board the aircraft and a ground control station (GCS). The system allows manual flight control, via an R/C-style control unit, through the autopilot's 900 MHz spread-spectrum link. The system also enables the UAV to navigate GPS waypoints while providing the GCS operator real-time motion telemetry. The Piccolo II avionics unit is a printed circuit board enclosed by a carbon fiber box. The unit includes 3-axis gyros and accelerometers to provide measurements of tilt attitude and angular rate. Differential GPS (DGPS) hardware provides position and course angle measurements with errors as low as 2cm horizontally and 4cm vertically. A static pressure sensor provides barometric altitude and a pitot-static pressure sensor provides airspeed. A magnetometer module provides magnetic heading (in addition to the DGPS heading measurement). All control surfaces can be manually controlled by the pilot through Piccolo II system. The control signal for the servos passes through a servo board, allowing independent power supplies for the acutators and avionic unit. The autopilot and DGPS hardware are powered by 11.1 volt lithium-ion battery packs with 2200 mAh capacity. The UAV control surface servos use a 6.6 volt lithium ion phosphate (LiFePO4) battery pack with a 3200 mAh capacity.

Engine. The 3W-75iUS engine was chosen because of its relatively high power in its given weight class. Also, this engine can accommodate a custom-designed starter, enabling the engine to be restarted in flight, if necessary. Engine failures are the main cause of UAV losses. The ability to re-start the engine in flight was considered paramount for ensuring reliability.

Fully Autonomous Capability. To minimize human-induced errors in normal operation, the SPAARO is capable of fully autonomous operation – an entire mission (including take-off and landing) can be flown without a human pilot operating the control surfaces. However, during any flight operation, the primary pilot shall always have the primary manual flight control device in hand and the secondary pilot shall have the secondary manual flight control device in hand, in case either detects the need to take manual control. Basic maintenance, pre- and post-flight checks, and assembly/disassembly will be performed by qualified Virginia Tech employees.

Redundant control via the RxMUX for increased safety. An additional safety feature on the SPAARO is the RxMUX (Reactive Technologies, Merrimack, NH), a servo control signal multi-plexer which permits the integration of a redundant, manual flight control system. For the SPAARO, this back-up control system consists of a standard R/C receiver. The RxMUX takes signal inputs from two sources inputs and selects one set of signals according to the state of a binary switch. The primary control system is the Piccolo II Autopilot, which provides manual control through a 900MHz link. The secondary control system, the backup R/C receiver, operates on a standard 2.4GHz R/C channel. The 2.4G Hz receiver has a dedicated channel that allows the secondary pilot to switch from 900MHz to 2.4G Hz control at any time. The RxMUX also accommodates a redundant power supply, ensuring that control can be passed from one pilot to another even if the primary power supply fails.