THE FIRST GOVERNMENT SANCTIONED DELIVERY OF MEDICAL SUPPLIES BY REMOTELY CONTROLLED UNMANNED AERIAL SYSTEM (UAS)

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The first government sanctioned delivery of medical supplies by UAS occurred at Wise, Virginia, on July 17, 2015. The "Let's Fly Wisely" event was a demonstration of the humanitarian use of UAS to facilitate delivery of medical supplies to remote or otherwise difficult-to-reach areas. The event was the result of coordinated efforts by a partnership which included the National Aeronautics and Space Administration (NASA) Langley Research Center (LaRC), Virginia Polytechnic Institute, the Mid-Atlantic Aviation Partnership (MAAP), Flirtey Corporation, Lonesome Pine Airport, Remote Area Medical (RAM), Health Wagon, SEESPAN Aerial Interactive, Rx Partnership, and Wise County, Virginia. The historic event occurred during the annual Remote Area Medical clinic at the Wise County Fairgrounds. The medical supplies in small packages were delivered to the Wise County Fairgrounds from the Lonesome Pine Airport by UAS operated by Firtey. A larger supply of medical supplies were delivered to the Lonesome Pine Airport from the Tazewell County Airport by NASA Langley's SR22 UAS Surrogate Research aircraft. The UAS Surrogate aircraft was remotely controlled for most of the flight by a UAS Ground Control Station located at the Lonesome Pine Airport. The medical supplies were delivered from the UAS Surrogate to Flirtey for final delivery by Hex Multi-Rotor UAS in smaller packages and multiple trips to the fairgrounds. A Certificate of Authorization (COA) issued by the Federal Aviation Administration (FAA) designated the site as an authorized UAS test site. The paper will present additional details of the historic delivery of pharmaceuticals by UAS during the "Let's Fly Wisely" event. The paper will also provide details of NASA's SR22 UAS Surrogate Research aircraft. The UAS Surrogate was designed to investigate the procedures, aircraft sensors and other systems that may be required to allow Unmanned Aerial Systems (UAS) to safely operate with manned aircraft in the National Airspace System (NAS).

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INTRODUCTION: What is "Let's Fly Wisely"?

The idea of "Let's Fly Wisely" resulted from discussions which began at the Aerospace Days at the Lonesome Pine Airport in Wise County, Virginia, April 2014. The two-day event was attended by thousands of people including hundreds of Boy and Girl Scouts, private and public school students. There were demonstrations by amateur high-powered rocketry clubs, hobbyist remote-controlled micro-jets, helicopters, fixed wing aircraft, and many other UAS vehicles. Also attending were the Virginia Secretary of Technology, members of the Virginia State Senate and the Virginia House of Delegates. During the event, there were discussions with key officials about the future role of Wise County in the emerging UAS industry and how it could help diversify the economy, promote aviation technology and innovation in the area. These discussions led to later discussions with wider participation. Contributing to these discussions were multiple groups including the Wise County Economic Development Authority, Health Wagon, the Mid-Atlantic Aviation Partnership, Remote Area Medical, Lonesome Pine Airport, and others. As a result of these discussions, the idea of the UAS delivery of medical supplies emerged. As a result, "Let's Fly Wisely" was born. This led to MAAP contacting Flirtey, an Australian UAS package delivery startup about participation. More meetings and discussions ensued about ways to safely demonstrate the UAS delivery of medical supplies during the yearly Wise County free medical clinic. Wider discussions and planning meetings were held involving Virginia State officials, NASA, the FAA, and others.

CONCEPT OF OPERATIONS

As conceived, the "Let's Fly Wisely" concept of operations (CONOPS) included the primary goal of the delivery of specific medical supplies to pre-identified end users at the annual free medical clinic at the Wise County Fairgrounds via unmanned aerial system (UAS) from the Lonesome Pine Airport. The CONOPS also included the bulk delivery of medical supplies to Lonesome Pine Airport from a remote airport via a larger UAS or manned aircraft. The bulk medical supplies would be broken down into smaller packages for delivery via small UAS. The final task was the delivery of the medical supplies from the local airport to the end users via UAS through multiple trips. The local airport was the Lonesome Pine Airport (KLNP) which is located less than one nautical miles south of the Wise County Fairgrounds, the final destination of the medical supplies. The remote airport was the Tazewell County Airport (KJFZ) in Richlands, Virginia. The Tazewell Airport is located 35 nautical miles east of Lonesome Pine.

VIRGINIA TECH UAS TEST SITE FLIGHT AUTHORIZATION

The FAA Modernization and Reform Act passed by the US Congress on February 8, 2012, directed the FAA to create six test sites to further integration of UAS into the National Airspace System (NAS)[1]. In December of 2013 a proposal submitted by the Virginia Tech (VT) Institute for Critical Technologies and Applied Science (ICTAS) resulted in the designation of VT as one of these six test sites. The Virginia Tech UAS Test Site, also known as the Mid-Atlantic Aviation Partnership (MAAP), began coordination with industry, government, and academic partners to conduct research for UAS integration.

Virginia Tech partnered with NASA Langley and Flirtey Corporation during the "Let's Fly Wisely" effort to conduct aeronautical research related to UAS delivery and resupply applications and with SEESPAN Aerial Interactive for application of UAS to news gathering. The location for these activities was selected to leverage the realistic use case offered through coordination with the Remote Area Medical (RAM) annual clinic in Wise County Virginia. The RAM clinic is held annually at the Wise County Fairgrounds and is approximately 0.8 nm from the Lonesome Pine Airport (KLNP). Lonesome Pine Airport was chosen as the launch/recovery location for the Flirtey

aircraft to enable "long-haul" medical supply via the NASA Langley SR22 UAS and transfer of supplies to the Flirty aircraft for "last mile" delivery. SEESPAN aircraft could be operated at both KLNP and the Fairgrounds to capture video of the event and conduct research into media gathering using UAS.
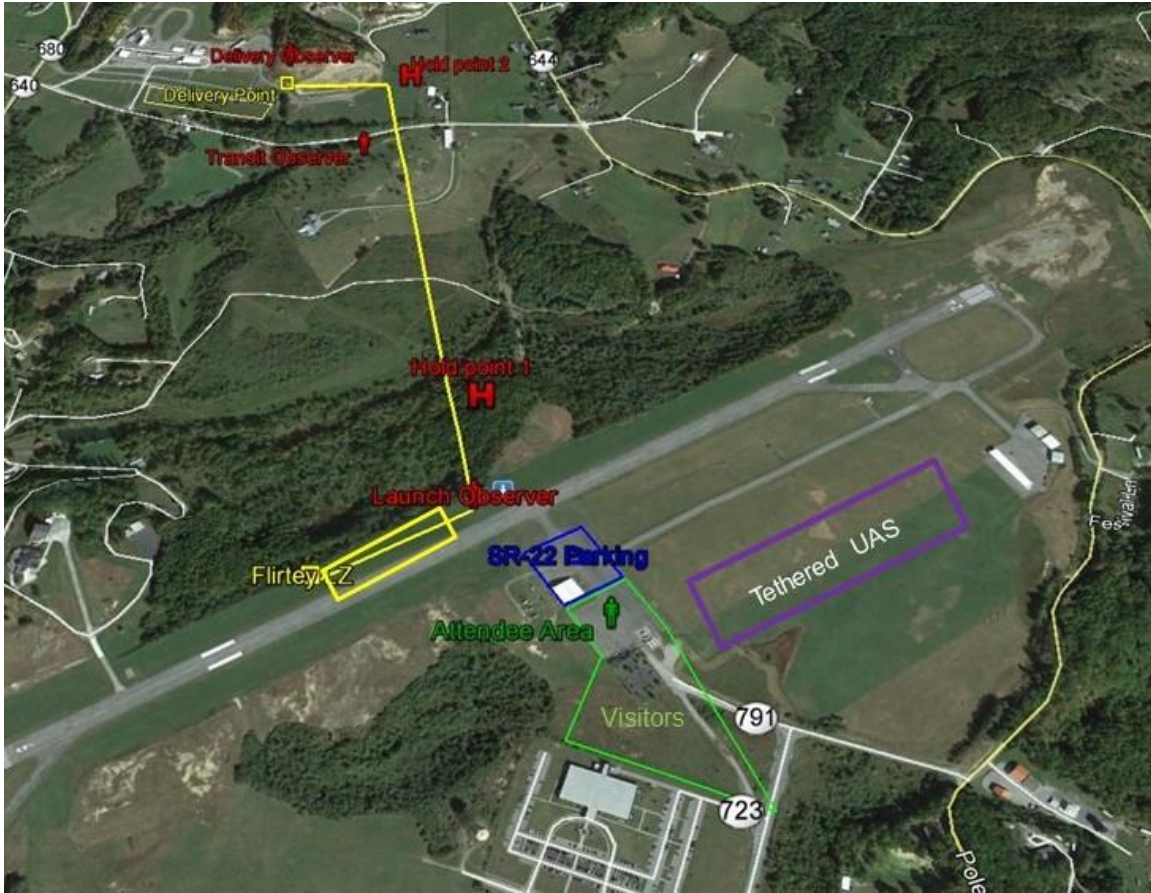
Figure 1. Flirtey UAS Flight Path and Lonesome Pine Safety Areas

Figure 1 shows the Flirtey flight operations area and the planned flight path from the Lonesome Pine Airport to the Wise County Fairgrounds. Reserved areas for SR22 aircraft and attendees are also shown.

FEDERAL AVIATION ADMINISTRATION CERTIFICATE OF AUTHORIZATION

Government approval of the UAS delivery of medical supplies came in the form of an FAA issued Certificate of Authorization (COA). A Certificate of Waiver or Authorization or COA is an authorization issued by the FAA Air Traffic Organization to a public operator for a specific unmanned aircraft activity. After a complete application is submitted, the FAA conducts a comprehensive operational and technical review. Specific provisions and limitations may be imposed as part of the approval to ensure the unmanned aircraft can operate safely with other airspace users. In most cases, FAA will provide a formal response within 60 days from the time a completed application is submitted[2]. The COA process is very specific about the conditions under which a UAS can be operated. It specifies the geographic boundaries, altitude limitations, time of the operation, weather conditions and other details. In general, a COA does not allow the simultaneous operation

of manned and unmanned aircraft within the COA boundaries. The "Let's Fly Wisely" CONOPS was designed such that manned and unmanned aircraft would not be flying in the same airspace at the same time.

Once the area of operations and aircraft were known, Virginia Tech began development of the Federal Aviation Administration (FAA) Certificate of Authorization (COA) required to authorize public aircraft operations of the Flirtey F2.4 and SEESPAN 3DR X8+ aircraft. The COA development efforts included developing documentation for the airspace request, communications plans, UAS airworthiness, and flight crew certification among others. The airspace requested for these activities was a 5 nm radius from KLNP at or below 500ft AGL in Class G airspace under the jurisdiction of Indianapolis Air Route Traffic Control Center (ARTCC).

Virginia Tech, in conjunction with the KLNP airport manager, developed airport operations and communications procedures so that UAS could be operated from this relatively busy Class E airport without disruption to traditional manned aviation. Knowledge of local pattern traffic altitudes and locations along with the development of communications plans to monitor standard Universal Communications (UNICOM) frequencies and Instrument Flight Rules (IFR) flights provided the UAS operators the situational awareness required to integrate UAS and manned aviation activities safely. The UAS Pilots in Command (PICs) for both Flirtey and SEESPAN aircraft announced UAS position and intentions via standard aviation radios and also communicated with the KLNP airport manager and NASA via Family Radio Service (FRS) long range radios. The FRS radios were also used by the Flirtey/VT flight crew to communicate between the PIC, External Pilot (EP), and Visual Observers (VOs) that were located at both KLNP and the fairground delivery location.

Public aircraft operations require that the public entity, in this case, Virginia Tech, self-certifies airworthiness of the subject aircraft. Airworthiness certification of the Flirtey F2.4 and SEESPAN 3DR X8+ aircraft followed the MAAP process for small multi-rotor UAS and consisted of Subject Matter Expert (SME) evaluation of aircraft system documentation and inspection of the aircraft systems.

NASA SPACE ACT AGREEMENT

In order for NASA to cooperate with "Let's Fly Wisely" partners, a legal framework was required. As a result, NASA Langley Research Center, Virginia Polytechnic Institute, and State University entered into a Non-reimbursable Space Act Agreement (SAA). The Space Act Agreement is a legal contract that allows NASA and its partners to collaborate in mutually beneficial activity. The agreement allows the partners to collaborate, share data and other information while each partner bears the cost of its participation and no funds are exchanged between the parties. Consequently, Space Act Agreement No. SAA1-20614 was signed by NASA Langley's Aeronautics Research Director and Virginia Tech's Associate Director for Strategic Planning and Development[3].

NASA SAFETY PROCESS

The "Let's Fly Wisely" partners agreed and accepted the requirements of the NASA Langley Safety Review and Approval Processes. Aside from the FAA COA process, the NASA Langley Airworthiness and Safety and Review Board (ASRB) became the safety authority for the "Let's Fly Wisely" partners. The ASRB is chartered to assure that appropriate reviews are conducted for, and provide guidance for, all research-related atmospheric flight vehicle activities that are funded, managed, or conducted by the NASA Langley Research Center. The ASRB reviews all of the operational and safety aspects of NASA Langley flight research projects as well as flight projects involving NASA Langley partners. The ASRB reviews all project related hazards that must be prepared by project personnel. The hazard process is a safety assessment process that identifies, classifies, assesses the risks, and introduces controls for all identified hazards. The ASRB also

ensures that all required engineering and safety related reviews are conducted, documented, and all revealed issues are properly addressed. The ASRB also reviews the Flight Test Operations and Safety Report (FTOSR) which is also prepared by project personnel. The FTOSR spells out in detail critical aspects of the flight test such as location, time, flight conditions, weather conditions, data recording requirements, and many other flight test details[4]. The ASRB reviews these documents as well as conducting a live presentation by project personnel. The ASRB may recommend changes to the flight test based on the presented material. When the ASRB is satisfied with the flight test project and that it meets all required review and safety requirements, a Flight Safety Release (FSR) is issued. The FSR is required to conduct the flight test.

Figure 2. UAS Surrogate Ground Control Station at Lonesome Pine Airport [***]

AIRPORT OPERATIONS

In order to separate manned aircraft from unmanned aircraft and people from all aircraft, the Lonesome Pine Airport surface was divided into several designated areas. The Flirtey flight operations were reserved for an area on the North side of the airport runway. This area also provided a clear view of the Wise County Fairgrounds, the medical supply delivery point for the Flirtey aircraft. In this area, Flirtey personnel set up all required equipment to control and service the Flirtey aircraft. The ramp area around the airport hangar was designated for parking the NASA Langley UAS Surrogate aircraft and for designated participants. An area between the hangar and airport terminal was designated for spectators and attendees. Another UAS operations area was also designated for other UAS operations. This area was located adjacent to the spectator area and

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[***] Stroup, Jim (Photographer). (2015, July 17), VT113795_2015243631.jpg, Retrieved from http://www.photoli-brary.unirel.vt.edu/pages/search.php?search=%21collection101153&k=6e3d363911

parallel to the runway. The SEESPAN tethered UAS aircraft were designated to operate in this space. All designated areas provided safety by separating the visitors and observers from the UAS operations and manned aircraft operations. The airport safety areas are shown in Figure 1.

NASA WISE SITE SURVEY AND PRACTICE FLIGHTS

In order to prepare for the "Let's Fly Wisely" event, a group from NASA Langley traveled to Wise in order conduct a site survey. The site survey was intended to answer many questions about operating in Wise. Questions concerning aircraft hangar facilities, fuel availability, maintenance support, ground support equipment and other aircraft related questions were answered during the trip that occurred on May 30, 2015. Other questions related to the UAS Surrogate Ground Control Station were also answered. These questions included where to install communications antennas, radios, computers, and displays. Other questions concerned the possibility of radio interference and the operating range of the radio data link systems. Radio equipment was used to scan for interference on the authorized voice communications and data link frequencies and no interference was found. As a result of the site survey, the team determined what equipment was needed for the later deployment to Wise.

Figure 3 The NASA Langley UAS Surrogate delivers medical supplies to Lonesome Pine[†††]

A second day trip to Wise was made on July 1, 2015, in order to test radio communications and other systems and fly a test flight. A portable UAS Surrogate Ground Control Station was set up in the Lonesome Pine Airport Hangar, VHF communications and data link radios were installed and antennas were temporarily installed on the hangar roof. A UAS Surrogate flight test was conducted in order to verify proper operation of required systems. The flight test from Lonesome Pine to the Tazewell Airport and surrounding area tested the voice and data link systems and verified remote control of the aircraft from the Ground Control Station. The test flight demonstrated that the

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[†††] Stroup, Jim (Photographer). (2015, July 17), VT112371_2015243606.jpg, Retrieved from http://www.photoli-brary.unirel.vt.edu/pages/search.php?search=%21collection101153&k=6e3d363911

planned "Let's Fly Wisely" flight could be performed provided the required weather conditions prevailed on July 17, 2015.

EVENTS OF JULY 17, 2015

The NASA Cirrus SR22 UAS Surrogate aircraft departed Lonesome Pine Airport at 8:47 a.m. with a crew of two, a Safety Pilot and a Research Systems Operator (RSO). Once airborne and at an altitude more than 500 feet above the ground, control of the aircraft was turned over to the UAS Surrogate Ground Control Station at Lonesome Pine as shown in Figure 2. The UAS Ground Control Station Operator then flew the pre-planned route from Lonesome Pine to Tazewell using heading, altitude and speed commands. All commands were coordinated with the Safety Pilot via radio voice communications. The UAS Ground Control Station Operator flew the aircraft to the approach to the Tazewell County Airport, a distance of approximately 35 miles. Observers at Lonesome Pine could watch the progress of the flight on the 60-inch video monitors specifically set up for the event. A public address system was also set up to allow the observers to hear the voice communications between the aircraft and the UAS Ground Control Station. The Safety Pilot took control and landed the aircraft at Tazewell at 9:09 a.m. A four-member team from the Appalachian County College of Pharmacy was at Tazewell with the bulk medical supplies for delivery back to Lonesome Pine. The pharmacy team delivered the 10 pounds of medical supplies in two insulated bags. The NASA UAS Surrogate flight crew loaded the medical supplies into the aircraft in the right front passenger area and secured the bags.

Event Schedule for July 17, 2015

8:47 a.m.	NASA UAS Surrogate departs Lonesome Pine for Tazewell
9:09 a.m.	SR-22 lands at Tazewell Airport to pick up bulk medicine
9:26 a.m.	SR-22 departs Tazewell Airport with bulk medicine
9:45 a.m.	Virginia Tech President Sands, Governor McAuliffe arrive at Airport
9:55 a.m.	SR-22 circles above Lonesome Pine demonstrating Ground Control Station
10:31 a.m.	SR-22 lands at Lonesome Pine and medicine is transferred to Flirtey
10:50 a.m.	Flirtey1 UAS departs airport for Fairgrounds, delivers supplies, and returns
11:00 a.m.	Governor McAuliffe and President Sands depart airport for fairgrounds
11:15 a.m.	Flirtey2 UAS departs Lonesome Pine and travels to the fairground

Figure 4. Flirtey F2.4 Hexcopter UAS package delivery aircraft

The UAS Surrogate aircraft departed Tazewell at 9:26 a.m. with the Safety Pilot controlling the aircraft. Once stable and above 500 feet altitude, aircraft control was passed to the UAS Ground Control Station Operator at Lonesome Pine for the return flight. The pre-planned return flight under UAS Ground Control Station Operator control was used to demonstrate UAS Surrogate flight operations to observers at Lonesome Pine. Observers watched the flight progress on the two 60-inch flat panel displays with the moving map on one display and the aircraft attitude display on the other. Also shown on the displays were command and status information transmitted from the aircraft. As the aircraft got closer to Lonesome Pine, a decision was made to postpone the landing due to the anticipated arrival of the Governor of Virginia at the Lonesome Pine Airport. The postponed landing was also used to demonstrate the remote control of the aircraft. Under UAS Ground Control Station control, the aircraft circled the airport at an altitude of about 1000 feet. Ground observers were able to see the aircraft circle overhead, observe the Ground Control Station commands, see the aircraft respond on the displays, and hear the voice communications between the aircraft and ground.

After about twenty minutes of circling over the airport, the Safety Pilot took control of the aircraft and landed the aircraft on runway 26 at 10:31 a.m. About 500 observers were at the Lonesome Pine Airport to witness the event. Included were the Virginia Governor, the President of Virginia Tech, Virginia State Government Officials, members of the press, and the public. The aircraft taxied to a pre-defined ramp area adjacent to the main airport hangar. At engine shutdown, the medical supplies were unloaded from the aircraft as shown in Figure 3, transferred to a designated team for

transport of the supplies via golf cart to the Flirtey flight operations located on the other side of the main runway.

Figure 5 Flirtey personnel load medical supplies for delivery to Fairgrounds[‡‡‡]

The 10 pounds of medical supplies were broken into smaller packages for delivery by the Flirtey unmanned aircraft shown in Figure 4. The Flirtey team loaded the medical supplies in a container designed to attach to the underside of the Flirtey UAS and to be lowered to the recipients while the aircraft hovers a safe distance above the delivery point. The Flirtey team is shown preparing the aircraft for flight in Figure 5. The first Flirtey delivery aircraft departed the Lonesome Pine Airport at 10:50 a.m. for the 0.8-mile flight to the Wise County Fairgrounds. The first Flirtey medicine delivery at the Fairgrounds occurred at 11:00 a.m. The first delivery of medical supplies at the Wise County Fairgrounds is shown in Figure 6. Figure 7 shows one of the multiple Flirtey medical supply deliveries being received by the Virginia Governor and other officials at the RAM annual free clinic at the Wise County Fairgrounds.

[‡‡‡] Stroup, Jim (Photographer). (2015, July 17), VT112374_2015243609.jpg, Retrieved from http://www.photoli-brary.unirel.vt.edu/pages/search.php?search=%21collection101153&k=6e3d363911

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Figure 6. Flirtey UAS delivers medical supplies to the Wise County Fairgrounds[§§§]

[§§§] Stroup, Jim (Photographer). (2015, July 17), VT112392_2015243612.jpg, Retrieved from http://www.photoli-brary.unirel.vt.edu/pages/search.php?search=%21collection101153&k=6e3d363911

Figure 7. Virginia Governor McAuliffe receives medical supplies delivered by Flirtey UAS[****]

NASA'S CIRRUS UNMANNED AERIAL SYSTEM SURROGATE RESEARCH AIRCRAFT

The basis for the NASA UAS Surrogate Flight Research Aircraft is a Cirrus Design SR22 single engine, four-place, composite construction, general-aviation aircraft as shown in Figure 8. The aircraft has been used as a flight test research aircraft since 2001. Over the years, many modifications were made to transform the aircraft into a research platform. These modifications include the installation of instrumented surfaces and controls, a data acquisition system, video cameras and recorders, an air data and heading reference system (ADAHRS), automatic dependent surveillance-broadcast (ADS-B) in-out, and a system of networked research computers. Specific UAS Surrogate modifications include the addition of redundant VHF data link radios, a modified two-axis autopilot to provide a means for remote control, a custom designed auto-throttle system, and a Ground Control Station.

The major system components include the general purpose computer #3 (GPC-3) that is the main research computer and the heart of UAS Surrogate System. This computer is connected to the major aircraft systems and sensors as shown in Figure 9. These include the ADAHRS that supplies the research system with air data, position, attitude, and inertial data. The GPC-3 is directly

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[****] Stroup, Jim (Photographer). (2015, July 17), VT112392_2015243627.jpg, Retrieved from http://www.photolibrary.unirel.vt.edu/pages/search.php?search=%21collection101153&k=6e3d363911

connected to the modified S-Tech 55X Autopilot via discrete signal wires and the Aeronautical Research Incorporated (ARINC) 429 serial interface. These connections allow the computer to control the autopilot's modes, vertical speed settings, and supply steering signal inputs. The modified Avidyne EX5000 Multi-Function Display (MFD) is also connected to GPC-3 and displays the research computer generated moving map and other symbology. An instrument panel switch allows the Avidyne MFD to display normal navigation data or research video from GPC-3. Two full duplex Teledesign TS-4000 VHF radio modems (data link) are connected to GPC-3 via the RS-232 serial interface. Aircraft position, state, and status data are passed through the radios to the Ground Control Station for the generation of Moving Map and Primary Flight Displays (PFD). Command messages which include altitude, heading, vertical speed and airspeed are sent to the aircraft from the Ground Control Station to the computer via the same VHF data link radios. The GPC-3 also receives ADS-B, TIS-B, and other data from the Garmin GDL 90 UAT via both RS-422 and RS-232 serial interfaces. The human interface to the computer is via an Operator Workstation consisting of a high-resolution flat-panel display, keyboard, and 3-button mouse.


Figure 8. The NASA Langley UAS Surrogate Research Aircraft

A second (GPC-1) and third general purpose computer (GPC-2) are used to host external algorithms and provide separate partitioning of the flight research software. The main computer, GPC-3, has the job of interfacing with the aircraft systems and sensors, gathering data, and flying the aircraft through the autopilot and auto-throttle. The two additional computers are intended only to host auxiliary software and do not interface directly to any of the aircraft systems other than the 10/100/1000 Mbs network switch and the Operator Workstation. The data processed by

GPC-1 is served to it by GPC-3 over the network. Processed results are passed back to GPC-3 over the network. The GPC-1 is a 2.26 GHz, Intel dual-core system with dual-boot Windows 7 and Scientific Linux operating systems.
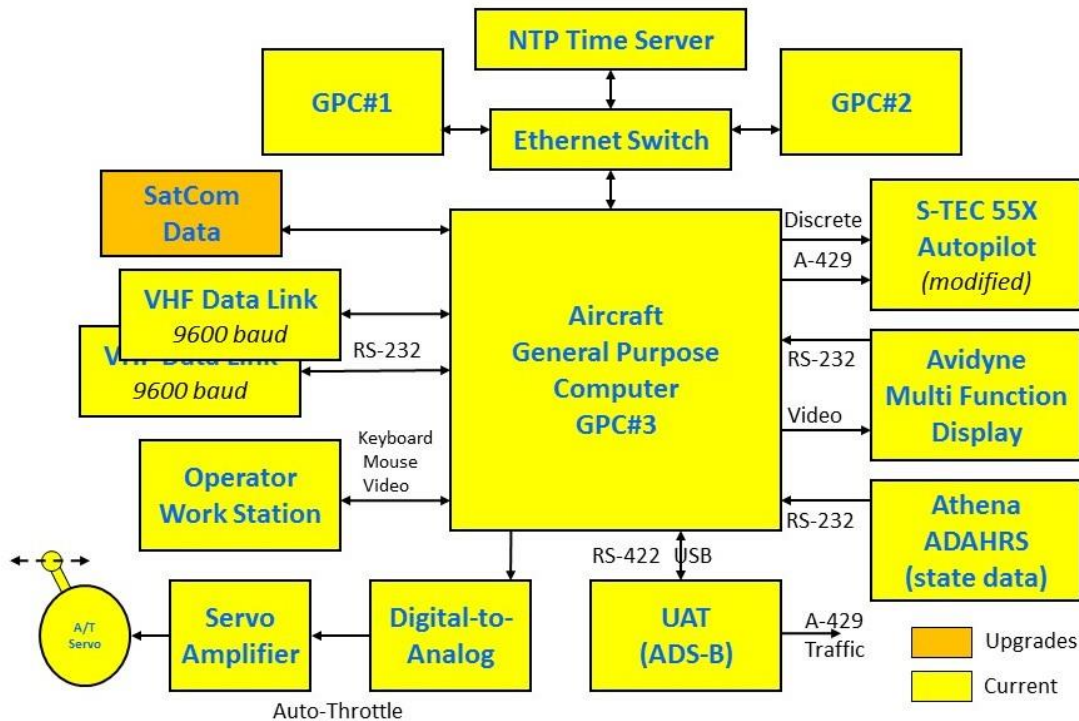
Figure 9. UAS Surrogate System Block Diagram

UAS Surrogate Intended Use

The UAS Surrogate System was created to serve as a research platform to aid in the investigation and testing of systems, sensors, and procedures that will make it possible to safely integrate unmanned aircraft into the national airspace system (NAS). The UAS Surrogate System makes use of many research systems previously installed to enhance its role as a research platform. These systems include the ADAHRS, video cameras, video recorders, instrumentation, multiple research computers, Operator Workstation, and other systems. It was envisioned that researchers from NASA, other government agencies, and academic institutions would use the UAS Surrogate to research and test UAS technology. The basic UAS Surrogate concept of operations (CONOPS) requires an experienced NASA Safety Pilot and Research Systems Operator (RSO) on board for all research flights. This CONOPS makes it possible to "file and fly" almost anywhere in the NAS and interoperate with other air traffic under existing ATC rules. This makes it possible to perform research and test systems in the NAS under real-world conditions with other traffic and subject to normal air traffic control (ATC) rules. Real unmanned systems cannot be used in this way and must be segregated from other manned aircraft by the use of test ranges, special use airspace, and Certificates of Authorizations (COA).

Capability Description

The UAS Surrogate is capable of remote control from the UAS Ground Control Station, the onboard Research Systems Operator, or autonomously via onboard software. In all three modes, the remote control is accomplished via the issuance of four commands: altitude, vertical speed, heading, and airspeed. The remote control process begins when the aircraft is 500 feet or more above ground level (AGL) as specified by safety procedures. The aircraft must be above 500 feet before the modified autopilot circuit breaker may be engaged. When the UAS Ground Control Station is in control of the aircraft, the range of operation can extend from 35 to 40 nautical miles from the Ground Control Station. The UAS software can command heading changes by sending GPS Steering (GPSS) signals to the autopilot. This results in bank angle commands of up to ±25 degrees. The autopilot may further limit this external command according to internal control laws based on the aircraft ground speed to maintain turns to 90% of standard rate. In most cases, the actual bank angle command is 17 to 20 degrees for a significant heading change.

Figure 10. Cirrus UAS Surrogate Cockpit Controls

To engage the UAS Surrogate mode and control of the aircraft, a series of actions are required by both the Safety Pilot and the Systems Operator. The sequence begins with enabling power to the modified S-TEC Autopilot at a predetermined altitude above 500 feet AGL. When the aircraft is in level flight and stable at a pre-briefed altitude and speed, the Safety Pilot activates a switch that switches the autopilot steering signal source from the Garmin GNS 430 navigation unit to the

GPC-3 research computer. A second switch is activated to engage the clutch in the Research Auto-throttle drive servo. At this point, the Research Systems Operator may set a Boolean in the software that enables computer control of the S-TEC Autopilot and autothrottle. In this configuration, the Ground Control Station is able to send commands to the aircraft for transfer to the autopilot and auto-throttle. If the plan is for the Research Systems Operator to control the aircraft, a second Boolean must be set to disable Ground Control Station control and enable the Systems Operator to send commands. In the Autonomous Mode, software running on a separate computer (GPC-1) is enabled and allowed to pass UAS Commands over the network to GPC-3 for translation into autonomous aircraft maneuvers. The UAS Surrogate cockpit controls are shown in Figure 10.

Safety Features

Many safety features are designed into the UAS Surrogate System. The main safety feature centers on the use of the autopilot to provide UAS Surrogate control of the aircraft. The autopilot is a limited authority device that can be overridden, disengaged or disabled by the pilot. The UAS Surrogate System is indirectly flying the aircraft via sending commands to the limited authority autopilot. The autopilot can be disengaged by pressing the autopilot disengage button on either the Pilot's or Co-Pilot's side arm controller. The autopilot disengage signal is also read by the UAS Surrogate software and is programmed to terminate any command or control signals to the A/P or auto-throttle. The Systems Operator can also disable all A/P and A/T command and control signals by resetting the Enable Remote Control Boolean in the software. By design, the Safety Pilot can also disable the autopilot by pulling the A/P circuit breaker without looking for it. A collar was placed over the A/P circuit breaker to enable the Safety Pilot to feel and pull it without seeing it.

The auto-throttle can be overridden by applying more force than the 11.7 ft-lbs (41.3 in-lbs) set in the drive servo clutch. The auto-throttle can also be disabled by the deactivating the Clutch Enable Switch that is conveniently located on the center console. An additional safety feature is a quick-disconnect on each end of the auto-throttle drive shaft. Cotter pins on each end of the shaft allow for quick and easy removal of the throttle drive shaft. This action will completely disable the auto-throttle and return the throttle to its normal unmodified condition.

The Safety Pilot or the Research Systems Operator can disable all research power with one centrally located Research Power Switch on the center console. This action will remove power from all research systems and stop all inputs to the autopilot and auto-throttle. The combination of an experienced Safety Pilot and a Research Systems Operator is also one of the UAS Surrogate safety features. The Systems Operator is responsible for the operation and control of all the research systems hardware and software. This division of responsibilities makes it possible for the Safety Pilot to concentrate on safely flying the aircraft and other normal pilot duties.

Research Systems

Several research systems were installed specifically for the UAS Surrogate mode of operations. The Teledesign TS-4000 VHF radios operate as redundant full duplex message conduits between the aircraft and the UAS Ground Control Station and operate on two authorized frequencies in the 150-174 MHz VHF band. Customized half-wave dipole antennas were built in-house and installed for the radios. Both antennas are tuned to their respective operating frequencies for maximum efficiency. The auto-throttle was also an in-house design and customized for the aircraft. The auto-throttle drive servo is a standard Cobham S-TEC model 108 pitch servo customized to drive the aircraft throttle. The digital to analog converter is also a standard off the shelf component. The auto-throttle servo amplifier, mounting structure, and drive shaft were designed and built in-house. The auto-throttle is also easy to completely remove from the aircraft when it is desired to restore the aircraft to the non-research mode. The auto-throttle mounting structure is designed to use the same mounting pins that secure the rear seats. This makes the structure very secure and easy to remove.

The UAS Surrogate Autopilot is a modified Cobham S-TEC 55X two-axis model that is common and found in general aviation aircraft. For the modifications, a model 55X was purchased and reverse engineered for methods to externally control it remotely. It was discovered that the modes could be controlled by ground-open discrete signals at certain points inside the unit. It was further discovered that the operation of the vertical speed knob could be duplicated by specific patterns of three discrete signals. Modifications were made inside the autopilot and wiring was added and brought outside the unit on unused rear connector interface pins. The additional wiring is connected to GPC-3 to enable mode and vertical speed control. Lateral steering is accomplished in the NAV GPS Steering Mode and inputting ARINC 429 steering and ground speed signals from GPC-3 in place of the Garmin GNS 430 navigation unit. With the ability to control the autopilot mode, vertical axis, and the lateral axis, three-dimensional flight is possible from the research computer. A Condor Model CEI-520 Peripheral Component Interconnect (PCI) computer card in GPC-3 has both ARINC 429 and discrete input/output capability to control the autopilot.

Human Machine Interface

The UAS Surrogate human machine interface is accomplished through the use of switches, knobs, a keyboard, a mouse, computer generated video screens, and the software graphical user interface (GUI). The mouse is a custom designed three button joystick arrangement that is built into the right rear seat armrest for use by the Research Systems Operator. The joystick has a duplicate left mouse button at the top for ease of use when flying. When the UAS Surrogate applications software is running, a series of GUI menus can be activated to control all aspects of the software in the aircraft and in the Ground Control Station. A system of GUI's is used by the RSO to enable or disable certain software functions, change control law gains, change filter parameters and enter the four UAS commands. When entering a command, the System Operator has the option of entering the command from the keyboard or using the joystick mouse button to click a GUI + or – symbol to advance or retard the existing value. A separate GUI "Send Command" button must be activated to initiate command transmission. When commands are sent from the Ground Control Station and received in the aircraft, they are echoed back to the Ground Control Station for display on the moving map display. This confirms to the Ground Control Station Operator that the commands were received in the aircraft. The aircraft moving map display also displays the commands. Voice radio communications are also used between the Safety Pilot and the Ground Control Station to verify operations[5].

"LET'S FLY WISELY" PARTNERS

From the very beginning, the success of "Let's Fly Wisely" was based on the partnership of several groups contributing in many different ways to the success of the event. The event was held during the 16th annual Wise County Free Clinic held at the Wise County Fairgrounds. Individuals in desperate need of health care line up for days in advance to get needed services such as free, eye, dental and medical care. Most of the clinic patients have no insurance or may have insurance but have high co-pays and deductibles. Over 2,000 people received free medical treatment at the clinic in July 2015. The yearly free clinic is also a partnership involving many volunteer organizations as listed.

The **Remote Area Medical** (RAM) Volunteer Corps is a non-profit, volunteer, airborne relief corps dedicated to serving mankind by providing free health care, dental care, eye care, veterinary services, and technical and educational assistance to people in remote areas of the United States and the world. Founded in 1985, RAM is a publicly supported all-volunteer charitable organization. Volunteer doctors, nurses, pilots, veterinarians, and support workers participate in expeditions (at their own expense) in some of the world's most exciting places. All of RAM's medical supplies, medicines, facilities, and vehicles are donated and RAM is one of the main sponsors of the annual clinic.

The **Health Wagon** with its mobile clinic and two stationary clinics has remained a pioneer in the delivery of health care in the central Appalachian region for more than three decades and is another of the main organizations that sponsor the annual clinic at Wise. The Health Wagon serves individuals and families with free, integrated health care that is culturally sensitive. The Health Wagon has partnerships with academic institutions that allow upcoming physicians, nurse practitioners and nurses to a name a few to have valuable educational experiences along with helping individuals in dire need of health care.

Rx Partnership (RxP) is a public/private partnership which exists to increase access to medication for Virginia's vulnerable populations and serve as a resource to the organizations that support these populations. To accomplish this, RxP serves as a broker – soliciting donated bulk medications from six pharmaceutical companies and arranging for their distribution to 20 Affiliate free clinics with licensed pharmacies throughout the Virginia. Since 2003, RxP has performed an essential role in the health safety net and increased access to free medication for uninsured citizens across Virginia.

The **Appalachian College of Pharmacy** offers a three-year doctor of pharmacy program and is committed to serving the needs of rural and underserved communities in Appalachia as well as throughout the world. Located in Southwest Virginia, the College was founded in August 2003 as the University of Appalachia. The College is strategically positioned in Buchanan County, Virginia, which shares borders with Kentucky and West Virginia in the center of the Appalachian coalfields. By bringing higher education and advances in healthcare to the region, the College is well-positioned to be a catalyst for positive changes in economic development, education, and healthcare.

SEESPAN Aerial Interactive Inc. is an aerial interactive media startup company. SEESPAN safely acquires dynamic photographic coverage of favorite public venues with its unique tethered unmanned aerial systems (TUAS) so audiences can see the action from the sky, and share their experiences in real-time with friends and followers, wherever they are. The unique combination of the mobile SEESPAN Flight Control System (patent pending) and SEESPAN interactive media properties creates an online platform that enables consumers to see their worlds from the sky and engage each other as never before.

The **Mid-Atlantic Aviation Partnership at Virginia Tech** provides UAV flight testing and training services to public and private entities interested in incorporating unmanned vehicles into their operations. With academic partners, the University of Maryland and Rutgers University, Virginia Tech operates one of only six FAA-approved UAV test sites in the country. MAAP is dedicated to promoting the safe and efficient integration of UAS into the national airspace.

Flirtey is package Delivery Company that was founded in Australia and designed to deliver packages via unmanned aerial vehicles also known as drones. Flirtey was established in Sydney in 2013 and is today based in Nevada, USA. Flirtey is the world's first commercial drone delivery service and was founded with the vision of revolutionizing four industries – humanitarian, courier delivery, fast food, and online retail.

NASA Langley Research Center, the first civilian aeronautics laboratory in the U.S., has more than 95 years of aviation research experience, from designing and testing airfoils to developing next generation aircraft. Researchers at the Hampton facility are using their expertise in airspace operations, unmanned systems, and air traffic sense and avoid technology, autonomy, and other technical areas to help advance and expand the safe use of unmanned aircraft systems.

Wise County, Virginia is rapidly becoming a vibrant ecosystem for high-tech innovation and entrepreneurship. In particular, the county has embraced unmanned aircraft as a technology that can strengthen the local economy and meaningfully enhance the quality of life. Over the past

year, Wise County has hosted several drone and aerospace-related events involving thousands of youth in the region. For example, in February, the county hosted a micro-drone flying competition for over 100 Girl and Boy Scouts—the first event of its kind in the United States[††††].

Other "Let's Fly Wisely" partners include the Wise County Lonesome Pine Airport KLNP and the Tazewell County Airport KJFZ.

CONCLUSION

The Let's Fly Wisely demonstration was a historic event and marked the first US Government sanctioned package delivery by a UAS in the United States. The successful event also was a clear demonstration of the possibilities for UAS to provide medical and other forms of relief during disasters or other extreme events that disrupt normal transportation. The Let's Fly Wisely event also demonstrated that UAS can safely operate in an environment involving an active airport, manned aircraft activity and a major public event involving thousands of people. While the number of people and the lengthy processes required to make the event safe was excessive to be practical in the real world of today, the lessoned learned from this and similar events will help to evolve the systems, rules and processes necessary to improve the safety and efficiency of UAS operations the future. Package delivery and disaster relief via UAS will most likely be commonplace in the near future and UAS will routinely operate in the NAS with manned aircraft. The events of September 17, 2015, in Wise County Virginia will help to further the practical and humanitarian uses of UAS technology and help to integrate UAS into the NAS in a safe and efficient manner.

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