Precision Airdrop System

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The portable Precision Airdrop System (PADS) supports ground and in-flight high-altitude airdrop mission planning for ballistic and autonomously guided system payloads. Precision Airdrop Planning System (PAPS) and Wind-profile Precision Aerial Delivery System (WindPADS) software components have been integrated and hosted on a pressure-ruggedized laptop computer and are initialized and executed through a Graphical User Interface (GUI). In-flight, the PADS laptop computer is connected to a portable UHF radio receiver that is connected to one of the airdrop aircraft's bottom UHF antennae to receive real-time in-situ wind data from GPS dropsondes hand-launched from the airdrop aircraft. Successful initial operational PADS tests have been completed for high-altitude delivery of ballistic payloads from U.S. Air Force airdrop aircraft and demonstrated significant improvement in airdrop accuracy. The integrated 802.11g wireless interface on the commercially-available PADS Laptop Computer is being developed to communicate a Mission File to the Airborne Guidance Units (AGU) of guided systems while in the aircraft's cargo bay. Initial testing and demonstration of PADS with guided system payloads, using an earlier FreeWave wireless interface, was successful. PADS is being used to support the U.S. Department of Defense (DOD) Joint PADS (JPADS) Advanced Concept Technology Demonstration (ACTD) program for guided systems as the JPADS Mission Planner (JPADS-MP). PADS is also being deployed to support U.S. DOD high-altitude airdrop operations.

I. Introduction

PADS development began in 1997 to overcome high-altitude ballistic payload accuracy problems demonstrated during the humanitarian relief of Serajevo, Bosnia-Herzegovina, 1993-1995. PADS development, sponsored by the U.S. Air Force and Army, was later reinforced and accelerated by similar airdrop accuracies observed during high-altitude airdrop operations in Afghanistan starting late-2001. The U.S. Army Natick Soldier Center managed the program which initially included the following development team members; Draper Laboratory, Planning Systems Incorporated, U.S. Air Force Air Mobility Command (AMC), U.S. Air Force Weather Agency (AFWA), and the U.S. Department of Commerce Forecast Systems Laboratory (FSL). PADS development, capabilities and results achieved with earlier prototype systems have been covered in previous AIAA conference papers[1-4]. The initial objective of the PADS development was a portable data processing system to enable ground mission planning and in-flight mission updates for execution of ballistic payload airdrops. Operational requirements have expanded the objective to include autonomously-guided airdrop systems and wireless communications by PADS of mission planning data to these systems prior to release. PADS is currently an integrated software package, databases and required interfaces hosted on a U.S. Air Force standard laptop computer with an integral 802.11g-protocol wireless communications system, pressure-ruggedized to operate in un-pressurized environments at high altitudes. The 802.11g wireless interface will be used to communicate a Mission File to guided system AGUs while onboard in the

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aircraft's cargo bay. The Mission File includes modeled wind field information and other critical parameters tailored to each AGU and planned Point-of-Impact (PI) information for each payload. Operator input and output interaction is enabled through a GUI and Graphical Map Interface (GMI).

The PADS WindPADS component assimilates wind data from hand-launched GPS dropsondes, at-altitude winds input automatically through the aircraft's 1553 data bus, or manually input as aircrew-provided Pilot Reports through the PADS GUI, as well as assimilating near real-time winds from off-board sources through a secure satellite communications system, such as wind data from ground-based radiosondes, or geostationary weather satellite winds based on cloud element tracking. Data assimilation to produce a high-resolution 3D wind/density/pressure field is done through a full-physics, tailored Local Analysis and Prediction System (LAPS) algorithm developed and maintained by FSL. The PADS PAPS component, developed and maintained by the Charles Stark Draper Laboratory, uses the 3D weather field, ballistic decelerator parameters, and the fall trajectory to the PI to determine the Computed Air Release Point (CARP) for ballistic payloads. Using error variance estimates for all components of the ballistic airdrop simulation, and Monte Carlo techniques, PAPS calculates expected error ellipses around the PI for single and multiple payload deliveries. PAPS also calculates the expected impact points for payloads with failed decelerators and the error ellipses around these points. Computed parameters and a real-time moving map display using the 1553 data bus data can be displayed on the PAPS GMI. Initial operational PADS tests for ballistic payloads from U.S. Air Force C-17 and C-130 aircraft at altitudes up to 25,000 feet MSL have been successful showing marked improvement in delivery accuracy. Initial testing and demonstration of PADS with guided system payloads, using a FreeWave wireless interface, has also been successful. A limited initial operational capability has been achieved through delivery of PADS Fly-Away Kits, user manuals and training programs to the U.S. Air Force AMC and other U.S. DOD operational users. PADS is being used to support the JPADS ACTD for 10,000-pound guided systems[5]. PADS is also being modified to be a compatible common mission planner for guided airdrop systems in the 500 to 2000 pound category with support from numerous U.S. DOD organizations. To date, the guided systems included are: Sherpa, Screamer, AGAS, and Dragonfly. PADS is also being used for other special applications, including personnel airdrop operations. PAPS and WindPADS algorithms, and the GUI, are being improved and tested as part of the JPADS ACTD, and other programs. PAPS will contain improved Guided, Navigation and Control (GN&C) algorithms for guided system simulation to calculate the Optimum CARP and surrounding Maximum Release Envelope (MRE) to achieve stand-off at given probabilities. WindPADS now contains an Improved LAPS for assimilation of full 4D in-situ wind measurements.

II. PADS Architecture and Components

The current PADS basic architecture and top-level functionalities are shown in Figure 1. The two primary software modules are PAPS and WindPADS. In Figure 1, the main functions of PAPS are denoted by the red frames, and the main functions of WindPADS are denoted by the green frames, all within the PADS Laptop Computer. PAPS has a GUI and GMI, and WindPADS has a GUI to enable the depicted interfaces. FalconView is used for the PADS GMI. The GUI and GMI functions and operator input functions are not shown in Figure 1. Also not shown in Figure 1 are two software modules resident on the laptop computer but external to the PADS architecture. One is the U.S. Air Force Combat Track II (CTII) software module that enables operation and communications with the CTII secure satellite communications terminal when installed on the airdrop aircraft. The other is the U.S. Air Force Portable Flight Planning System (PFPS) which contains the Combat Airdrop Planning System (CAPS). Wind data from WindPADS can be used by PFPS CAPS, pending PAPS upgrades for unique mission planning currently handled by CAPS.

The PAPS output is transferred to the aircrew and to AGUs of onboard guided airdrop systems wirelessly in flight and wirelessly or wired during ground payload preparation. The PADS high-level GUI enables the operator to activate GUIs for mission planning data entry (aircraft type, drop zone, payload weight, load station, decelerator type, guided system selection, release and performance data, aircraft airdrop parameters, altimeter setting); for weather data acquisition and assimilation; for calculating the ballistic payload CARP; for calculating the guided payload CARP and allowable CARP range (earliest/latest CARPs along the run-in course); for aircraft navigation data monitoring en route to the CARP; and for upload of Mission Files (winds and PI) to the AGUs of guided systems before payload release. The PADS GUI for wireless communications with guided system AGUs is currently in development and testing. Figure 2 shows the latest PADS Top-Level GUI with 3 unused buttons remaining for future use.

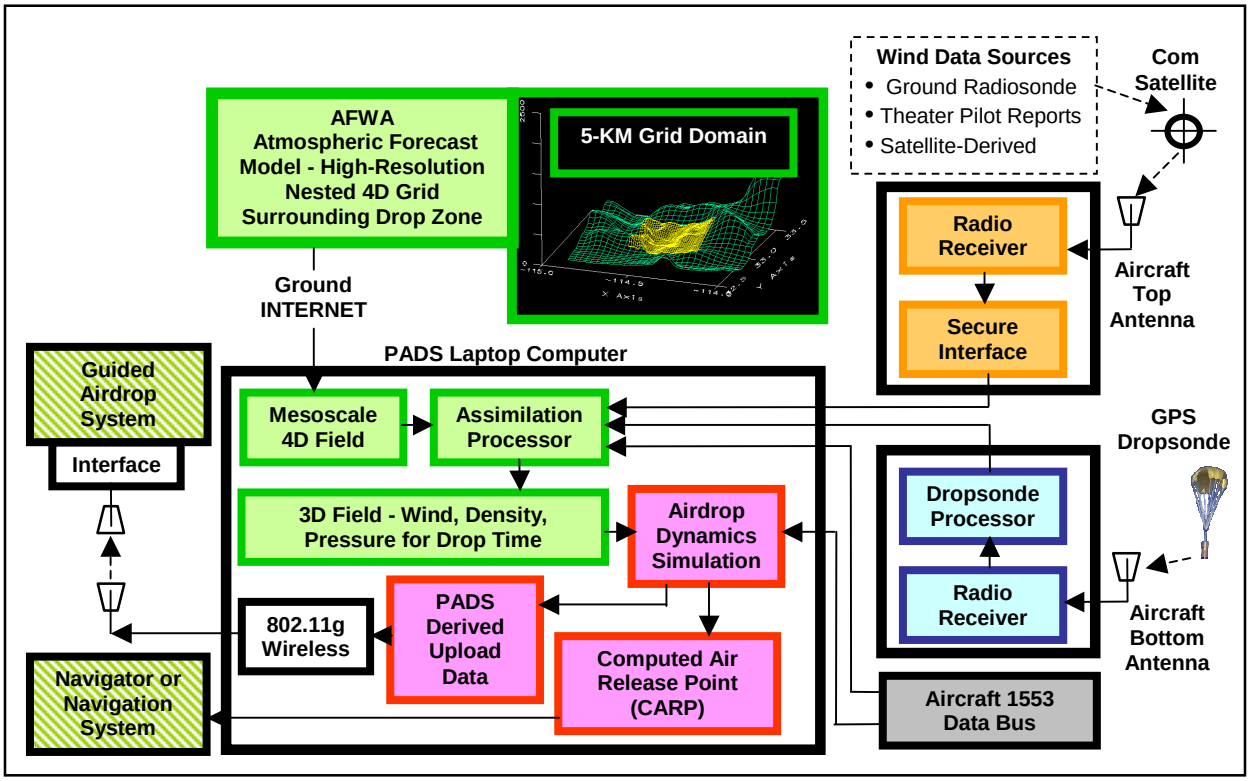

Figure 1. PADS Architecture and Top-level Functions.

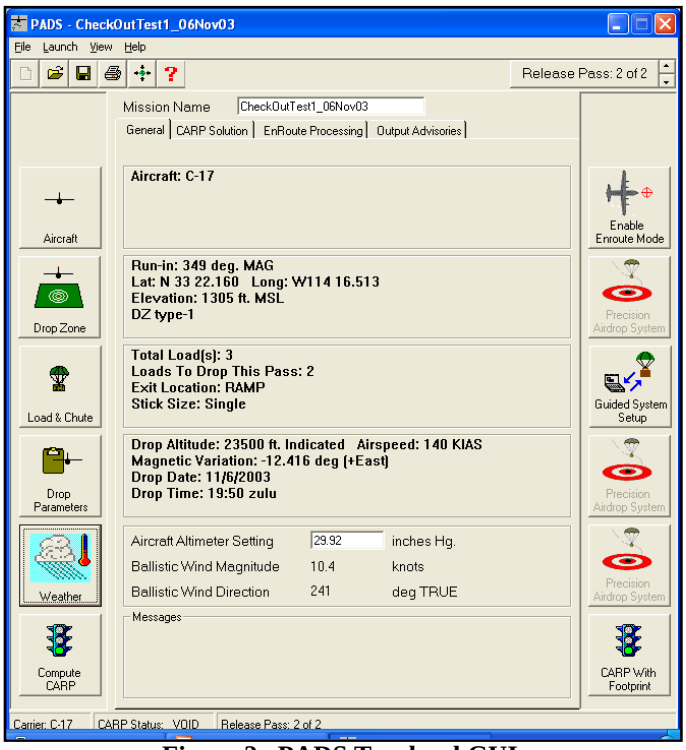

Figure 2. PADS Top-level GUI.

Figure 3 shows the Load & Chute GUI activated from the Top Level GUI through the Load & Chute button. The GUI is used to load mission planning data for ballistic payloads, including the PADS Hand-Launched GPS

Dropsonde, and the Tri-Wall Aerial Delivery System (TRIADS; free fall Meals, Ready-to-Eat (MRE) packets), and guided system payloads. The payload positions are shown on the cargo bay layout at the planned load stations. An operator "click" on the payload position results in the entered data being displayed for that payload.

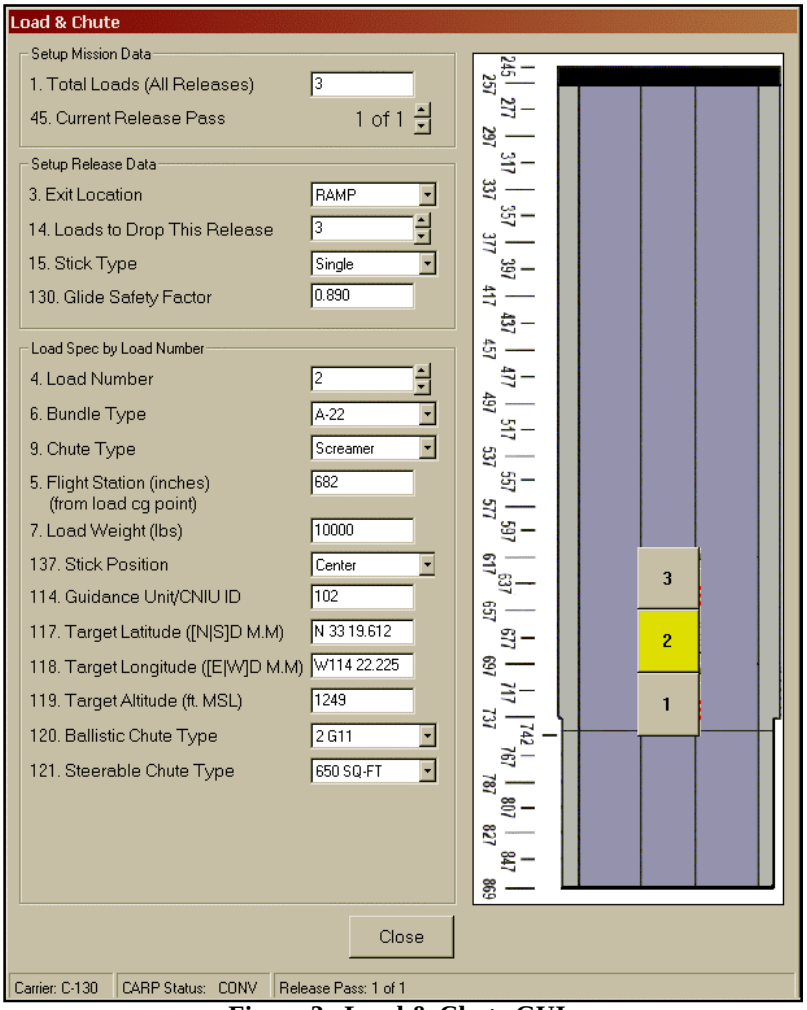

Figure 3. Load & Chute GUI

The PAPS GUI and GMI display the results of the PAPS simulations for aircrew mission planning and execution. The GUI that displays the results of the PAPS simulation resulting in the ballistic CARP, for given mission planning and weather data, is shown in Figure 4. The ballistic CARP is displayed as both a Latitude and Longitude and as distances relative to the PI and the run-in course. When the Monte Carlo function is executed, the forecast 95% Circular Error Probable (CEP) around the PI is displayed. Operator-selectable error ellipses (1, 2 and/or 3 standard deviations) are displayed on the FalconView GMI around the PI and the forecast Impact Point(s) for payloads with failed decelerators. Run-in course, CARP, PI and failed decelerator Impact Point(s) can be operator-selected for GMI display. An example FalconView GMI display is shown in Figure 5.

The PADS FalconView PAPS GMI display for guided system payloads is in development and testing. For a guided system with a given weight and performance (Lift/Drag ratio), and planned aircraft run-in course, the PAPS CARP Solution tab displays the earliest and latest release points (Latitude and Longitude) in addition to the CARP. These additional release points could be defined as the intersection of the run-in course and Maximum Release Envelope (MRE) which is the intersection of the horizontal plane at aircraft drop altitude and the guided system "Cone-of-Opportunity," inverted with apex at the PI. Guided systems, with stand-off capability, enable increased operational flexibility. All payloads released on a single pass, each separated by distances due to different roll-out and payload release times, can guide to the same PI, or guide to different PIs, as dictated by ground operational requirements. An example PADS FalconView PAPS GMI mission planning and navigation decision display for the

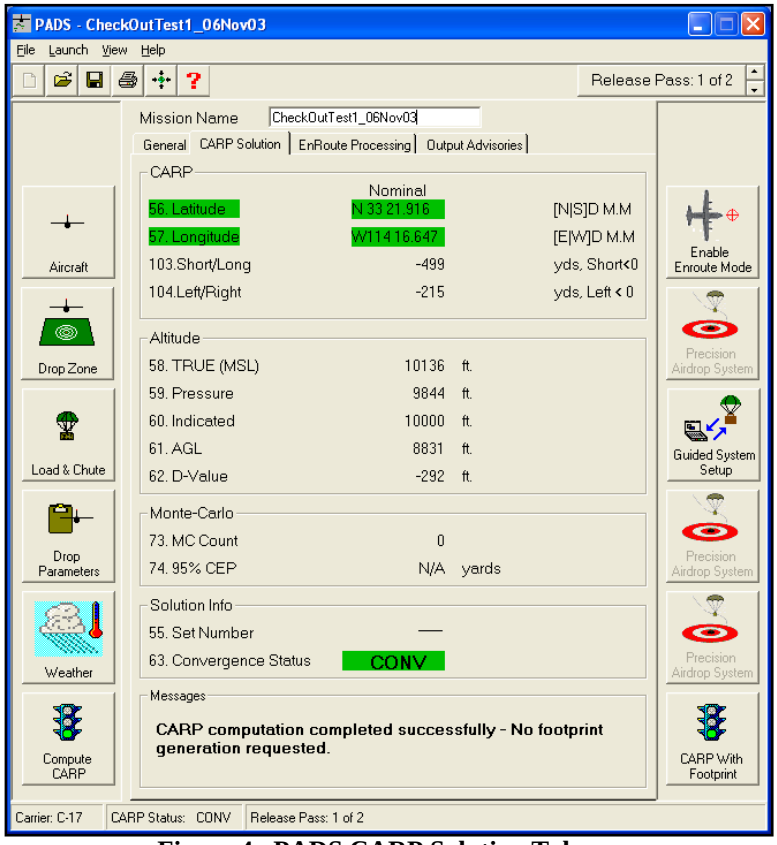

Figure 4. PADS CARP Solution Tab.

single-pass release of multiple guided system payloads (same notional Lift/Drag ratio) is shown in Figure 6 for a hypothetical no-wind condition.

The GMI depicts 3 MREs for 3 PIs and a planned run-in course. For a non-zero wind field below the aircraft, the PIs would not necessarily be at the center of the PIs, and could well be outside of the MREs for a strong wind condition. The area of MRE overlap represents the area at release altitude within which the multiple payload, single pass release can be executed and enable the guided systems to reach their respective PIs. In the example, the CARP is chosen at the approximate mid-point of the overlap region to enable optimum performance and use of the maximum available energy to correct for errors during descent. The run-in course is selected to pass over/through the Optimum CARP. If the PIs are planned too far apart there will not be a common release area, and either the PIs are changed, or the payloads are delivered to the PIs on separate passes using different CARPs. This simple example of three systems, with the same flight performance, illustrates both the complexity of planning multiple guided system airdrops and the utility that PADS will soon provide to the operational airdrop and airborne community.

The WindPADS GUI enables the operator to acquire weather data from a number of sources (historical, forecast and observed) and to assimilate the data to produce a high-resolution, high-fidelity 3D wind, pressure, and density field for application by the PAPS simulation. Weather data sources include near real-time data from GPS dropsondes, aircrew pilot reports, high-resolution 3D forecast fields from AFWA, forecast 1D vertical profiles from AFWA (extracted from the same 3D fields), ground-based balloon data (radiosondes), forecast ballistic winds from the AFWA forecast 1D vertical profiles, or from other reliable forecast sources including operational weather forecasters, and representative radiosonde climatology data normally downloaded before deployment to the area of operations. The PADS laptop computer can be connected to the Internet for direct download of data from AFWA from a file transfer protocol (FTP) site. In development and beta-test is an AFWA web-based GUI to enable the operator to download either 1D forecast vertical profiles or 3D forecast fields by entry of only the planned PI and the earliest and latest forecast valid times based on operational requirements. The AFWA web-based GUI enables automatic selection and downloading of the optimum forecast fields (horizontal grid resolution) based on the

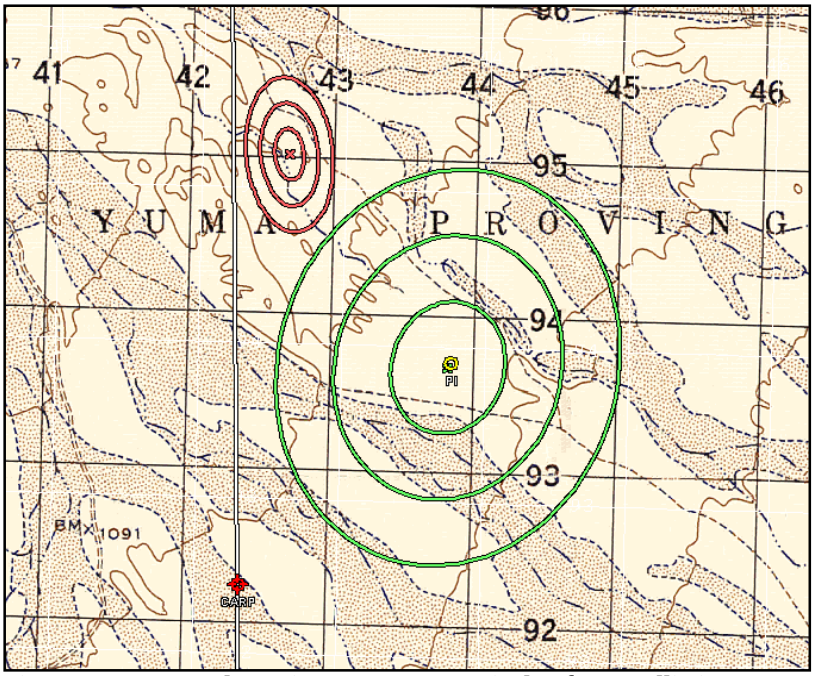

Figure 5. PADS FalconView PAPS GMI Display for a Ballistic System.

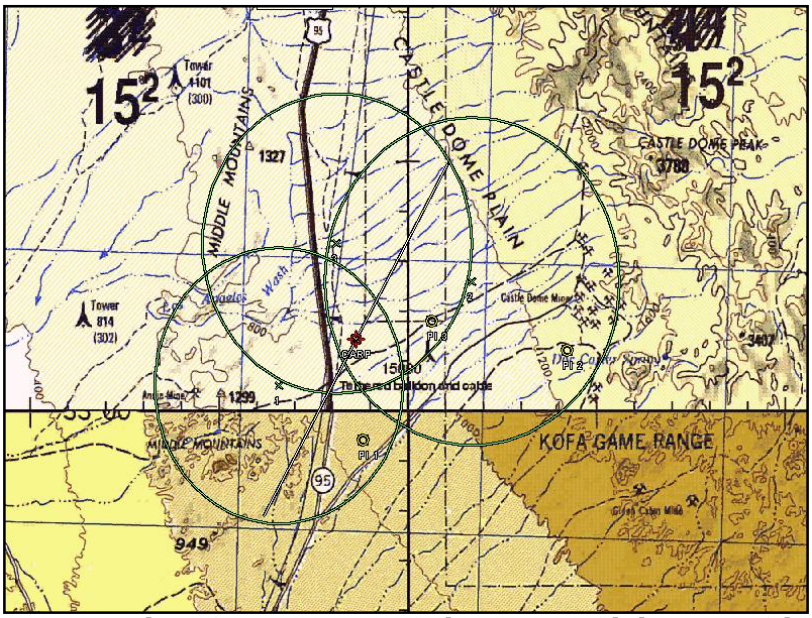

Figure 6. PADS FalconView PAPS GMI Display, Same Guided System Stick, 3 PIs.

operational location and the lead time of the selected forecast valid times. Weather data transfer can be accomplished via CD or Flash Memory from another computer with the downloaded data from the AFWA Joint Army Air Force Weather Information Network (JAAWIN) web-based GUI. The CD or Flash Memory data transfer overcomes anticipated restrictions for connecting the PADS laptop computer directly to the Internet communications system at an operational location. Airborne communications, including satellite communications can be used to download weather data depending on bandwidth and availability. The WindPADS main GUI is shown in Figure 7.

The WindPADS main GUI has two main sections. Weather Acquisition buttons and a weather inventory with valid times relative to (before) the planned drop time indicated. The other main section is for Wind File Production by assimilation of acquired weather data. The operator can select various assimilation options as shown if the necessary data has been acquired, otherwise the button is grayed-out. The order of the assimilation buttons from top

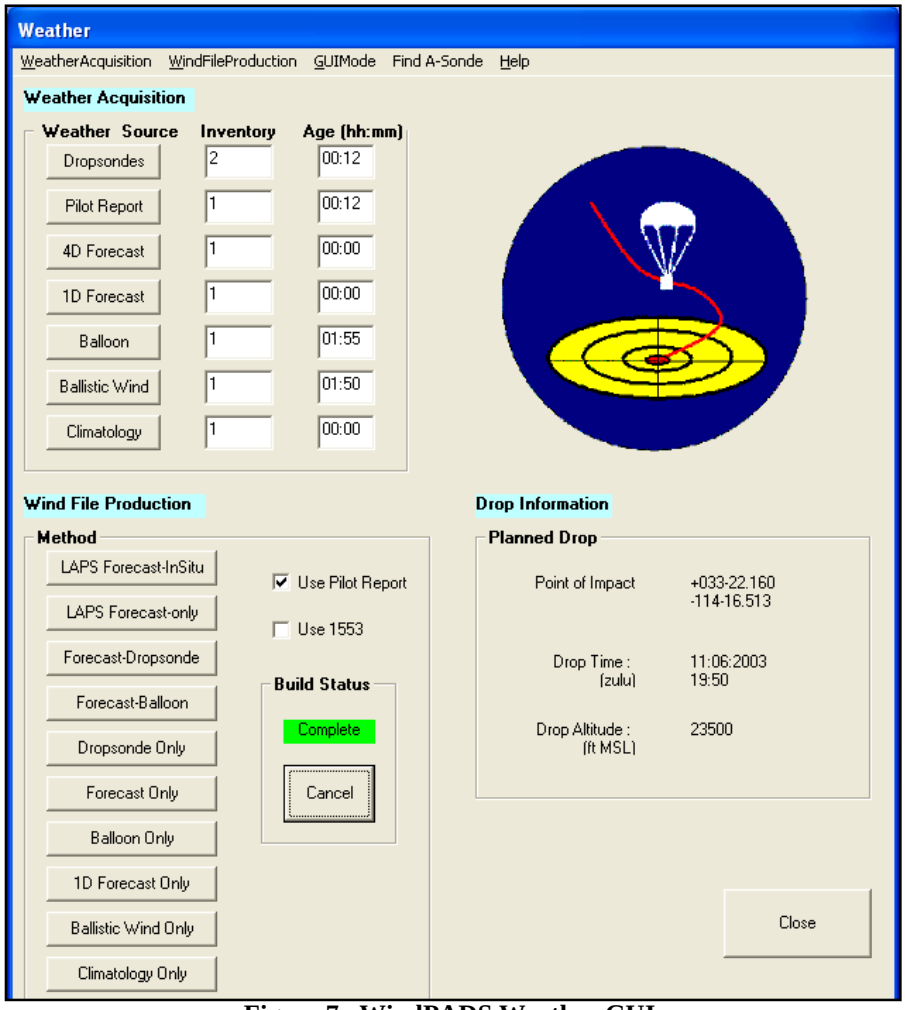

Figure 7. WindPADS Weather GUI.

to bottom is in the order of decreasing accuracy and fidelity. When the Operational GUI mode is selected, a single button execution results in the assimilation with the greatest accuracy and fidelity as permitted by the data acquired. When the build status indicates complete, a 3D Wind File for the planned drop time is available to apply the PAPS simulation. The Wind File includes both the expected values as well as estimates of error variance (standard deviation).

III. Precision Airdrop Planning System

The PAPS component of PADS, developed by Draper Laboratory, produces a high-fidelity, 3 Degrees-of-Freedom (3DOF) simulation of all the components of a ballistic system delivery from initiation of the release at the CARP ("Green Light") through ground impact at the planned PI. The result of the simulation is the CARP for the input set of mission parameters applied to the short-range forecast (on the order of 15-30 minutes) 3D wind, pressure and density field produced by WindPADS for the planned time of payload release. For ballistic payload mission planning, the simulation is based on: aircraft type, airspeed, run-in course, altitude, payload weight, decelerator type, load station, PI altitude, and the PI.

The PAPS ballistic simulation accounts for effects of roll-out time from the aircraft, parachute deployment and deceleration, and vertical acceleration to the first point of "steady state" descent (stabilization point) depending forecast atmospheric density and winds at and below the aircraft to the stabilization point. Current decelerator types include the G-12D, 26-foot Ring-Slot applied to standard Container Delivery System (CDS) payloads. Additional payload types included in PAPS are TRIADS (for humanitarian relief operations) and the PADS Hand-Launched GPS dropsonde.

In addition to the CARP, PAPS also produces Monte Carlo simulation-based error ellipses, failed decelerator (detached, streamer) impact points, and error ellipses around the failed decelerator impact points, for mission planning decision assistance. A PAPS Monte Carlo routine is applied to expected error variances (default and user selected) of each of the independent components of the ballistic airdrop simulation, including the wind error variance data produced by WindPADS.

PAPS is also being developed to support mission planning and execution of guided airdrop systems. The PAPS ballistic simulation produces the expected descent trajectory as a necessary component to generate a CARP. The ballistic trajectory for a G-12D cargo parachute system is used as a reference trajectory to enable accurate delivery (objective is within 100 meters) of the AGAS, a guided system in development. The AGAS AGU is rigged between a CDS and a G-12D canopy, which is slipped/steered by riser pulls/releases to within a selected radius around the reference trajectory that ends at the PI, until ground impact. PAPS also extracts atmospheric data from the WindPADS-generated forecast wind, pressure and density field, and generates mission file specific information tailored for each of the following AGUs of guided parafoil systems and hybrid systems in development; Sherpa, AGAS, Dragonfly and Screamer[6-10].

PAPS ground and FreeWave wireless airborne uploads of Mission Files to AGAS and Sherpa guided systems have been successfully demonstrated. Airborne uploads were demonstrated using a laptop computer serial port and a FreeWave wireless communications system. Results of earlier successful testing of a prototype version of PAPS supporting AGAS airdrops are described in previous AIAA papers[11,12]. PADS was demonstrated at Precision Airdrop Technology Conference and Demonstration (PATCAD) events at the U.S. Army Yuma Proving Ground in September 2001 and November 2003[13]. At the 2001 PATCAD, PADS CARPs were used for 26-foot Ring-Slot CDS payload drops from 10,611 feet MSL and 19,133 feet MSL, PI elevation approximately 1,100 feet MSL, with accuracies of 87 and 179 meters, respectively. Using a FreeWave wireless interface for onboard communication of the updated AGAS trajectory and updated wind profile for the Sherpa, PADS successfully supported AGAS drops at the 2001 PATCAD and Sherpa drops at the 2003 PATCAD.

PAPS is being tested to use either the PADS laptop computer serial port for wired communications with a guided system AGU, or the PADS laptop computer's integrated 802.11g interface and embedded antennae for wireless communication of Mission Files to the Sherpa, AGAS, Screamer and Dragonfly AGUs. Mission Files can be uploaded on the ground in the payload preparation area, in the cargo bay before takeoff, or in flight, en route to the DZ.

Ground and in-flight testing is in progress using the latest version of the PADS Laptop Computer (Panasonic Toughbook CF-29) with integrated 802.11g wireless communications capability. For test support and initial operational deployment, a Common Navigation Interface Unit (CNIU) is in development. The first version is shown in Figure 8. The CNIU case dimensions are approximately 5.4" X 4.1" X 1.3" with the 802.11g-compliant wireless antenna mounted on the top of the case. The CNIU is 802.11g-compliant and is externally mounted on the AGU and connected to the AGU electronics and power through a cable with a compatible connector. The CNIU will be used until 802.11g-compliant communications are integrated within each AGU to be deployed for field operations.

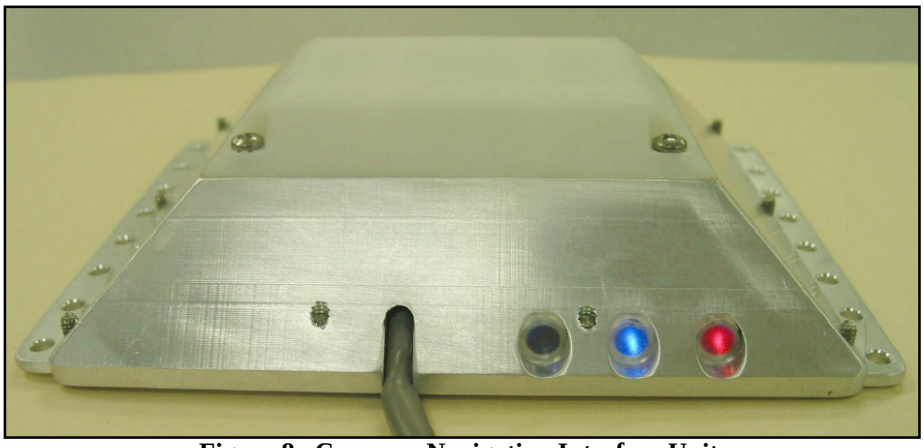

Figure 8. Common Navigation Interface Unit.

The PAPS GUI for wireless communications, in development and testing, is shown in Figure 9. Through this GUI the PADS operator is able to wirelessly upload a Mission File to each guided system on the ground in the

guided system payload rigging area, on the aircraft before take-off, and in-flight en route to the DZ before payload release, and otherwise enable 2-way data communications between the PADS Laptop Computer and each AGU. The CNIU and PADS GUI and the PADS Laptop Computer's integrated 802.11g wireless communications enables significant operational flexibility. After takeoff, the PADS operator can change PIs in response to changing ground logistics requirements and upload the latest wind data after takeoff to ensure the highest probability of the payloads achieving the accuracy required by ground operations.

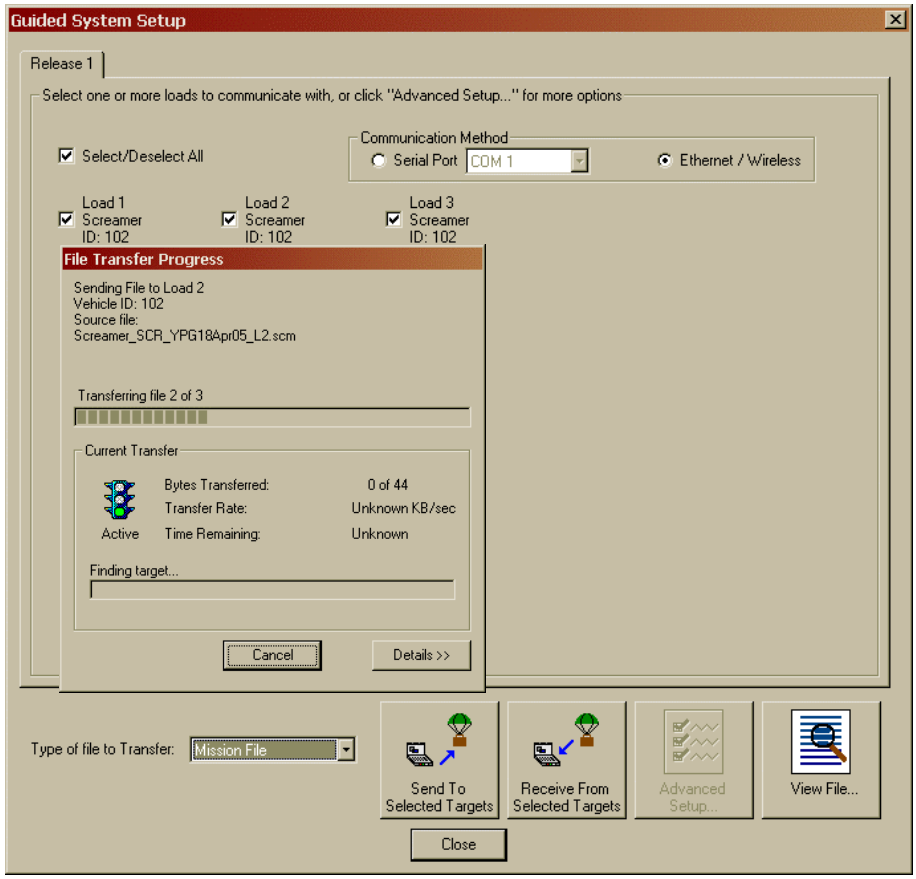

Figure 9. PADS Wireless Communications GUI.

IV. Wind-profile Precision Aerial Delivery System

The WindPADS component of PADS produces a high-fidelity, high-resolution 3D grid of winds (North-South/East-West components), pressure and density valid at the intended drop time. WindPADS is an atmospheric data acquisition, data assimilation and short-range forecasting system that parallels the functions at national operational weather forecast centers. At weather centers the forecast fields, produced by dynamic/physical forecast models executed on supercomputer platforms, valid at the next analysis time are used as the first estimate (so-called "first guess") of the atmospheric fields at that time. Received observations of global atmospheric data valid within approximately 2 hours of the analysis time are assimilated with the forecast fields, as influenced by the underlying topography, to produce the best analysis estimate. From this analysis the dynamic/physical forecast models are numerically integrated to produce 3D grid forecasts of the atmosphere in the future. Global analysis and forecast models use grids with a horizontal resolution on the order of 90 kilometers. Due to the large computational load, even with the use of supercomputers, higher resolution horizontal forecast grid domains are produced using a complex grid nesting numerical computation procedure, with the horizontal distance between grid points being 1/3rd that of the parent coarser grid. PADS downloads and can assimilate AFWA forecast fields at 5.0-kilometer, 15.0-kilometer and 45.0-kilometer resolution, depending on availability (weather centers are computer loading limited), and on the required forecast lead time. The maximum forecast lead time for the 3 forecast fields cited are 24 hours,

48 hours and 72 hours respectively. Mission planning/rehearsal beyond 72 hours must use representative climatology data for the area. The format of the forecast fields is based on the World Meteorological Organization (WMO) Gridded Binary (GRIB) standard used by all major weather forecast centers worldwide.

The PADS architecture was developed to support precision ground and in-flight airdrop operations directly, due to operational communications bandwidth and time-latency limitations, and weather center data processing schedules and limitations. A PADS-tailored version of the software is used to assimilate observed wind data and downloaded forecast atmospheric fields, and resides on the PADS laptop computer. Also resident on the laptop computer is a global topographic database at 1.0-kilometer resolution. The topographic data base is very important as topography drives the atmospheric flow in the lower layers of the atmosphere, especially in complex, rugged terrain.

A PADS-tailored version of LAPS, developed by the NOAA Forecast Systems Laboratory, is a critical component the WindPADS software suite. LAPS is complex legacy code written in Unix for execution on weather center main-frame computers. The fundamentals of LAPS are well documented within the meteorological community[14-18]. LAPS assimilates the downloaded high-resolution forecast fields from AFWA with on-scene in-situ wind and weather data observations to produce a 3D analysis field at the valid time near that of the latest wind observations. The assimilation is done using a topographic database with 1.0-kilometer resolution, an important feature to produce a 3D wind field influenced by the underlying terrain. In-situ data is currently provided by the PADS hand-launched GPS dropsonde and at-altitude wind data derived by the airdrop aircraft's navigation system. The time difference between the observed wind data and the planned time of drop is on the order of 15 to 30 minutes. In strong, rapidly changing weather conditions over rugged terrain, this time difference must be as short as the mission timeline will allow. LAPS produces the short-range forecast valid at the planned time of drop by linear extrapolation of the rate-_of-change of wind, pressure and density (determined by the time difference between 3D forecast fields), from the analysis time to the intended time of drop. This linear extrapolation deviates significantly from reality beyond approximately 60 minutes, depending on the dynamics of the actual weather situation.

FSL recently made improvements to LAPS that have been integrated into WindPADS. This improved version enables assimilation of observed data over a larger time window, on the order of 4 hours. The improved LAPS algorithm executes a number of assimilations as described above, with a short-range extrapolation serving as the analysis for the next extrapolation until reaching the planned time of drop. This process is a coarse representation of the analysis and forecasting process applied at operational weather centers. The weather center process is feasible in PADS depending on the power of in-flight computer resources available in the future.

The first version of PADS used a single-channel UHF radio receiver limiting acquisition from one sonde at a time. The PADS radio receiver has been upgraded to a 4-channel system that enables simultaneous acquisition of data from up to 4 dropsondes descending at the same time. This is an important feature to more accurately model terrain influenced 3D wind field over rugged topography through improved LAPS assimilation. WindPADS is designed for "graceful degradation" of accuracy, depending on the availability of forecast and observed atmospheric data. The optimum accuracy is achieved with the assimilation of AFWA forecast 3D forecast fields, at-altitude wind navigation system wind measurements, and vertical profile wind measurements from dropsondes or radiosondes.

LAPS is currently written in complex Unix legacy code. Consequently, the PADS laptop computer is configured as a dual operating system; real Windows Operating System (OS) for PAPS and a virtual Linux OS for WindPADS.

V. PADS Fly-Away Kit

The hardware and physical interfaces for PADS in-flight high-altitude airdrop operations are contained in a single man-portable case, called a PADS Fly-Away Kit. The kit, which weighs approximately 75 pounds, was designed to rapidly connect and disconnect PADS to/from U.S. Air Force C-17 and C-130 airdrop aircraft. The basic components of the PADS BLOCK II Fly-Away Kit are shown in Figure 10: clockwise from upper-left, Advanced PADS Laptop Computer (APLC: Panasonic Toughbook CF-29 with Pressure-Ruggedized Hard Disc Drive inserted (not shown) and the PADS GUI on the LCD screen), APLC power pack, Advanced PADS Interface Processor (APIP: 4-channel UHF radio receiver), Ethernet connector APLC-APIP), aircraft power interface cables, single antenna GPS Retransmission System (RTS: broadcast antenna, amplifier, splitter, cables), co-axial cable for connecting to aircraft bottom antenna, combiner (gold-colored metal case) for connecting bottom antenna to the APIP and aircraft UHF radio, 1553 Data Bus PCMCIA card for APLC with cables for connecting to the aircraft's 1553 Data Bus, 12 Volt DC power junction box with aircraft power cable and connectors/cables for powering the

APLC and the APIP, PADS Hand-Launched GPS Dropsonde (expendable) with removable pre-launch test power on device, and PADS Test Appliance (GPS Dropsonde electronics in a pedestal mount for positioning outside the aircraft on the ramp for APLC/APIP system installation system test).

Figure 10. PADS BLOCK II Fly-Away Kit

The GPS-RTS included in the kit attaches to an internal extension of the top-mounted aircraft GPS antenna in the cargo bay, aircraft sextant port antenna (if so equipped), or window-mounted GPS antenna. A multiple antenna Improved GPS-RTS has been developed for inclusion in the kit and is undergoing final validation testing. The Improved GPS-RTS overcomes the problem of internally reflected GPS signals resulting in destructive interference signal strength nulls. The Improved GPS-RTS will also be used to provide required GPS signals to guided system AGU GPS processors in-flight, before payload release.

Retransmitted GPS signals within the aircraft cargo bay, in-flight are important. The ability to download the latest GPS satellite ephemeris information before GPS dropsonde release enables a short time-to-first-fix (GPS navigation solution) by the dropsonde GPS processor and measurement of dropsonde 3D position and horizontal motion (winds) as soon as possible after being hand-launched from the aircraft. Also, enabling guided system AGU GPS processors to acquire the latest the latest GPS satellite ephemeris information before release enables an early AGU navigation solution and guidance commands from as high an altitude as possible, increasing the probability of the guided system reaching the PI with the required accuracy.

VI. PADS Ballistic Airdrop Operational Tests

During development testing at the U.S. Army Yuma Proving Ground, Arizona, through August 2003, PADS prototype equipment, operated by system engineers aboard the test airdrop aircraft enabled overall Circular Error Average (CEA) results on the order of 320 meters for 27 test drop cases. Drop altitudes ranged from approximately 10,000 feet to 25,000 feet Mean Sea Level (MSL) over desert terrain with elevations ranging from approximately 400 feet to 1,300 feet MSL, CDS payloads ranged from 550 pounds to 2,200 pounds, rigged with 26-foot Ring Slot decelerators.

PADS was tested under operational conditions through the U.S. Air Force AMC Operational Utility Evaluation Program (OUE). On two separate test weeks, C-17 in September 2003 and C-130 in January 2004, aircrews

received PADS training over a two day period (classroom, ground mission planning, hardware installation and operation, and one training flight). This was the first time the aircrews received PADS training. For the remainder of each test week, the operational aircrews operated PADS without assistance from PADS trainers and engineers, including loadmaster hand-launching PADS GPS dropsondes from the aircraft side door. The PADS operators were either an augmented crew member (co-pilot) for C-17 operations and the navigator for C-130 operations, while performing navigation duties. High-Velocity CDS payloads, with 26-foot Ring Slot decelerators were used, with payload weights similar to those used during engineering tests. Airdrop altitudes ranged from approximately 18,000 feet to 25,000 feet MSL for C-17 operations, and at approximately 18,000 feet MSL for C-130 operations, both over the YPG test range with ground elevation approximately 1,300 feet MSL. Test results are covered in detail in AMC OUE test reports not yet released to the public.

Results achieved with PADS using the PADS Concept of Operations (CONOPS) and procedures, were compared to that achieved using standard AFI 11-231, Computed Air Release Point Procedures and the automated version of those procedures contained in the PFPS CAPS, and aircraft navigation and mission computer systems. Payloads were dropped using CARPs from both PADS and current AMC methods. Due to the limited overall sample sizes (41 for C-17 operations and 53 for C-130 operations), hypothetical airdrop accuracies were determined by using wind forecasts produced under the respective alternative methods, determining the change in the CARP, and applying that change to the actual ground impact point of the payloads and analyzing the resulting distance from the planned PI. Test data from C-17 high-altitude airdrops conducted at Edwards Air Force Base, California, in May and June 2003, using PADS engineers and flight test aircrews, is included in the 41 test data cases. The overall results are that the use of PADS resulted in a CEA improvement of 70% (308 meters versus 1,036 meters) when compared to current methods used for C-17 operations, and in a CEA improvement of 56% (260 meters versus 595 meters) when compared to current methods used for C-130 operations. Both test reports concluded that PADS effectively improved high altitude CDS airdrop accuracy from C-17 and C-130 aircraft, and that PADS is potentially suitable for use on these aircraft. Consequently, PADS Fly-Away Kits, and PADS GPS hand-launched dropspondes, have been, and are being fabricated for delivery to the U.S. Air Force AMC for initial operational deployment to support real-world high-altitude airdrop operations. Later operational training and testing of PADS systems aboard U.S. Air Force Special Operations Command (AFSOC) aircraft, with similar results to that achieved during the AMC OUEs, has resulted in initial fielding AFSOC airdrop operations.

VII. Objectives/Plans

PADS development, and use during JPADS ACTD testing and evaluation through 2006, is planned and ongoing. Modification of hardware and software for operational field use is part of the development and testing effort, as well as fielding additional systems for an initial operational capability. PADS is expanding from support for the high-altitude airdrop of ballistic payloads to the JPADS-MP for guided airdrop systems and operations with wireless communications capabilities for flexible in-flight guided system airdrop operations. PADS communication and compatibility with additional guided systems being developed around the world may also take place. The tailoring of PADS for Special Operations Forces (SOF) applications is one of the overall PADS development objectives.

VIII. Conclusion

PADS has proven to be an effective and operationally suitable high-altitude airdrop mission planning system for ballistic payloads, significantly improving ground impact accuracy. PADS capabilities are suitable for supporting high-altitude guided airdrop system operations, including use as the common mission planner, JPADS-MP, for multiple guided airdrop systems minimizing workload and training. PADS has been, and continues to be, used operationally by Special Operations Forces for High Altitude High Opening (HAHO) personnel airdrop missions in which PADS weather predictions are used to determine HAHO CARPs. PADS represents a major step forward enabling high-altitude precision airdrop of a variety of ballistic and guided systems, including the precision aerial insertion of combat forces.

Acknowledgments

The authors would like to extend their sincere appreciation to the many U.S. Air Force and DoD military and civilian personnel who have helped assure that the PADS is user-friendly, operationally suitable and meets the needs of critical DOD customers, the warfighters. Organizations that have supported the PADS effort include: The U.S. Army Natick Soldier Center, U.S. Air Force Air Mobility Command, U.S. Transportation Command, U.S. Joint Forces Command, U.S. Air Force Special Operations Command, and the U.S. Air Force Weather Agency. Of particular note is the support, energy, and overall program management and guidance provided by Lt Col Chris Hunter (U.S. Air Force AMC) who helped shape and accelerate the development of PADS over the last two years.

The success of the PADS program to date is due to the countless hours that members of the above and other organizations have contributed to the program over the last few years. Their support, interest, energy, real-life experience, and intimate involvement throughout the program have been the most critical factors to assuring the PADS program's success.

This material is based upon work supported by the U.S. Army Research, Development and Engineering Command under U.S. Army Contracting Agency – Yuma, Contract Numbers: DATM07-02-C-0036, DABJ49-03-C-0015 DABK41-03-C-0125, W9124R-04-C-0128 and W9142R-05-C-0118. Any opinions, findings and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the U.S. Army Research, Development and Engineering Command.

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