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NATO ARMY ARMAMENTS GROUP (NAAG)

Final Report on Fire Control Standard Shareable Software Suite (S4) Application to Ballistics Airdrops

LAMP Reference: IF-003

1. The NAAG Integrated Capability Group Indirect Fire (ICGIF) Sub Group 2 on Ballistics, Effectiveness and Fire Control Software concluded their work on Ballistics Airdrops with the enclosed Final Report. This report is aimed to contribute to the Precision Air drop (PAD) Capability.

2. This report is published as a NAAG Document, and forwarded to the NAFAG and OCS to establish a reference for any discussion or work concerning PAD in these communities.

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1 Enclosure

Use of NATO Sharable Fire Control Software for Ballistic Airdrops

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Abstract

This report describes the effort to develop and test prototype software for mission planning of ballistic airdrops. The software was developed to demonstrate a NATO capability using components from the NATO SG/2 Sharable (Fire Control) Software Suite (S4). The ballistics technology that was developed for implementation into the software is described as well as the software development, testing, results, current status, and expected benefits. This document started as a draft paper written on behalf of the NATO Army Armaments Group, Integrated Capability Group-Indirect Fire, Sub-Group 2 on Ballistics, Effectiveness and Fire Control Software (SG/2).

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Executive Summary

This report provides an overview of prototype airdrop mission planning software that was developed with components of the NATO SG/2 Sharable (Fire Control) Software Suite (S4) (Ref. 1). The ballistics technology that was developed for implementation into the software is described as well as the software development, testing, results, current status, and expected benefits. This report is written on behalf of the NATO Army Armaments Group, Integrated Capability Group-Indirect Fire, Sub-Group 2 (Panel) on Ballistics, Effectiveness and Fire Control Software (SG/2).

NATO sharable software has been developed by SG/2 to support multinational fire control systems. NATO allies within SG/2 supported S4 expansion of applicability beyond fire control into the airdrop domain. This expansion leveraged existing cost and development benefits being realized by the NATO ally fire control communities. The modeling necessary for both projectiles and parachute systems are similar. In conjunction with SG/2 improvements in meteorological information, use of the software for sharable airdrop mission planning with the goal of improving delivery accuracy was enacted. A small, initial effort was conducted by a group of interested countries to establish the necessary technology, modify the appropriate components of the S4, and combine them to demonstrate an initial capability to produce computed air release points (CARPs) for unguided (ballistic) parachute systems.

The software developed from this effort uses a point mass model in order to produce an accurate computed air release point (CARP). This software simulates all phases of the airdrop of material, including movement of the pallet within the aircraft, extraction, parachute deployment, and descent to the target zone. By using existing S4 technology, this software has the ability to use high fidelity four dimensional meteorological data and terrain mapping currently in use in NATO fire control systems to improve the accuracy of airdrops without the use of multiple aircraft passes over the drop zone, dropsonde data, or target zone surveys.

While the software is still in a prototype phase, and not intended for operational use, the point mass model and airdrop methodology have been reviewed by airdrop experts in interested NATO nations. This prototype software contains a limited database of extraction methods, ballistic parachutes, and cargo aircraft. A set of drop scenarios was established and run in the NATO airdrop prototype software and in the U.S. Joint Precision Airdrop System (JPADS) (Ref. 2) and then compared. The results were used to calibrate database values and to identify a rough order of magnitude of the difference in the CARPs and impact points between the two models. Analysis of the trajectories of these scenarios shows the potential for improvements in ballistic air drop accuracy by using the completely physics-based NATO Armaments Ballistic Kernel (NABK) (Ref. 1) software versus using JPADS, which uses look-up tables to estimate certain parameters. In order for this software to move beyond the prototype phase, it will need to be updated to meet the S4 coding standards, expand the ballistic parachute system and aircraft databases, and be validated against actual airdrops.

Introduction

This report is presented on behalf of the NATO Army Armaments Group, Integrated Capability Group-Indirect Fire, Sub-Group 2 (SG/2) (Panel) on Ballistics, Effectiveness and Fire Control Software. SG/2 developed prototype software to demonstrate mission planning capability for airdrops of ballistic parachute systems. This prototype was rapidly created from existing software developed and maintained by the SG/2 for surface to surface fire control applications. The existing software provided most of the capabilities necessary to accurately simulate a ballistic parachute system, including coordinate frames, gravity model, Earth model, meteorological models, computation and integration schemes, and database structure. By leveraging this software, this prototype required only modifications to the equations of motion and minor changes to the databases and integration schemes. While this initial prototype is limited to the simulation of a single main ballistic parachute, the technology used can easily be extended to model multiple parachutes as well as multiple parachute phases.

Representatives from a subset of nations within SG/2 have expressed interest in use of such a product if a formal development effort is established. The hope is that one of these nations will commit to leading such a project. The code is open source within NATO and fully sharable amongst the NATO and Partner-for-Peace nations that participate in the software development and maintenance effort under SG/2 (Ref. 1). The S4 software, as applied to ballistic weapons and projectiles, has been proven to be reliable in operational use and shows consistent acceptable performance across varied simulated and combat conditions. The expectation is that this reliability and performance will extend for ballistic drop systems. The technology and databases for airdrops can be expanded to address all classes of ballistic parachute systems and can even be expanded for application to guided parachute systems using SG/2 existing technology for guided projectiles. Additionally, use of four dimensional forecast meteorological data at the time and location of the drop has the potential to improve drop accuracy over current mission planning software. The use of this meteorological data may also increase survivability by eliminating the need for an initial aircraft pass to obtain dropsonde wind data.

The project team that was created to develop the prototype established a work plan and had to coordinate with appropriate persons from the precision airdrop community to understand the necessary aspects of the domain, obtain data, and establish peer review. Persons working in support of SG/2 established the technology for ballistic airdrops in an annex to NATO Standardization Agreement (STANAG) 4355, for which SG/2 is a proponent. Through coordination with the precision airdrop community in the U.S., the technology and software development team obtained a copy of the U.S. Joint Precision Airdrop System (JPADS) software (Ref. 2) to use as a benchmark for existing mission planning software. The original intent was to develop the prototype and test against existing drop test data where the release points were calculated by JPADS, comparing the test data against the prototype and JPADS. The existing data obtained did not have all of the inputs necessary to develop the prototype software or to run the comparison scenarios, so a decision was made to do software testing and validation against JPADS itself. Real validation may occur against drop tests in the U.S. where the release points for the drops are calculated by the prototype software. The technology and software development team coordinated with the U.S. Army Natick

Soldier Research Development and Engineering Center (NRDEC). It is the hope that other nations involved in the NATO precision airdrop community will be able to use the prototype and conduct such drops, and help build a database of drop data to use in validation. This software is not intended for operational use.

Background of Prototype Software Development

In the early to mid-2000s, NATO established prioritized capabilities that needed to be developed or exploited to achieve Defense Against Terrorism (DAT). DAT #5 entitled "Precision Airdrop Technology for Special Operations Forces" was one of two DATs in which SG/2 was asked to be involved and to see if there is anything the ballistics community could do to contribute. Denmark was the lead nation in SG/2 for this. The NATO definition of precision airdrop at the time included two areas for which SG/2 thought it could make some contribution, namely mission planning tools and use of weather forecast data, because of two activities the group was working at the time.

The first activity involves software for ballistic computations. The SG/2 charters a formal umbrella cooperative programme with a set of cooperative projects underneath called the SG/2 Sharable Software Suite or the S4 for short. (Ref. 1) Each project develops one or multiple software products. The suite is comprised of the separate software products, all designed to be embedded in the executive level software of a fire control computer. When combined, these products provide the basic capability required by a fire control computer for mission planning and accurate fire except for communication and the soldier-machine interface. The specific components used in the prototype software are noted in the section titled "Software Implementation."

The second activity regarding use of weather forecast data was a result of a mandate given to SG/2 by its parent body to investigate ways to improve artillery delivery accuracy at extended ranges (greater than 30km). A SG/2 document on tube artillery accuracy (Ref. 3) identified inaccuracies in meteorological (MET) measurement as the largest error contributor. These inaccuracies included insufficient data over the mission area as well as untimely updates. Two "team of experts" meetings, one in 1997 and one in 1998, were conducted which concluded that using 4-dimensional (latitude, longitude, altitude, time) MET data in the gunnery solution provides the most promise to significantly reduce this error. A side effort under the project was spawned that resulted in two NATO tests, one in Denmark in 2003 and the other in Turkey in 2006, that validated this conclusion. (Refs. 4, 5, and 6) As a result of this work, NATO nations started to adopt the use of 4-dimensional MET data for fire control, using a subset of the format specified in NATO STANAG 6022. (Refs. 7 and 8) The fire control ballistics community calls the 4-dimensional data in this form a METGM (short for gridded MET).

Since there is much similarity between the ballistics for projectiles and for parachute systems, and since SG/2 is responsible for software for ballistics processing, including components that manage meteorological messages, SG/2 sent personnel to the Precision Airdrop Technology Conference and Demonstration (PATCAD) 2005 (Ref. 9) as observers to identify and initiate contact with key persons within the airdrop community and to determine appropriate areas where S4 products could be applied. The observers determined that the current suite products, with some modifications, would be most appropriate for ballistic airdrop systems as an "off-the-shelf" NATO alternative to current models for airdrop mission planning. It was also determined that METGM could be the most beneficial item to airdrops due to the accuracy of forecasted winds and timely communication provided by METGM. Using a 4-D set of data for ballistic airdrop calculations has potential for improved accuracy over 1-D data, especially for drop systems with very long glide paths. As a result, SG/2, through Denmark, provided an SG/2 liaison to the lead NATO body for precision airdrop, namely the Joint Precision Airdrop Capabilities Working Group (JPACWG) under the NATO Air Force Armaments Group (NAFAG). Additionally, SG/2 through Denmark, Turkey, and the United States, set up a project team to develop and demonstrate prototype mission planning software for ballistic airdrop systems based on S4 components. From that time, the liaison and members of the project team have maintained a dialogue with the JPACWG community. SG/2 was also represented as observers at PATCADs 2007 and 2009 (Refs. 10 and 11).

Technology Development

Overview of Model

A 3 Degree of Freedom (3-DoF), or point mass, model was used to simulate the ballistic parachute drops. This model accounts for all of the major forces required to determine the trajectories necessary to produce a CARP (Computed Air Release Point) or an expected impact point within reasonable tolerances. A 3-DoF model requires fewer aerodynamic inputs and physical properties to research, develop, modify, and test than a more complex 6-DoF model. The primary limitation of the point mass model for airdrops is the inability to properly simulate gliding parachutes (parafoils) or guided systems. The S4 community has 6-DoF and guidance capabilities and implementation of these abilities for airdrops is a possibility with the appropriate level of NATO support.

The equations of motion for aircraft-dropped pallets were separated into five phases:

1. from rest to aircraft ramp
2. from aircraft ramp to aircraft exit
3. from aircraft exit to the end of free fall stabilization (beginning of main parachute deployment)
4. main parachute inflation
5. from the end of main parachute inflation to ground impact

These phases were chosen to represent segments of the total trajectory which require different forces to properly simulate a wide range of ballistic air drop systems. Despite several of these phases representing very similar forces and equations, defining them separately allows for the most flexibility and expandability for modeling various types of aircraft, extraction methods, and parachute types, numbers, and descent stages. These phases can be repeated to simulate multiple parachute descent stages with minimal change to the software. The simulation utilizes 3-DoF equations of motion for all phases with seamless transitions from phase to phase. No hard-coded values or table lookups are used. This was done to make the simulation as robust as possible in order to produce reasonable results when run with a wide range of non-standard inputs, such as initial speed, altitude and aircraft orientation, meteorological conditions, and pallet weight.

Coordinate Frame

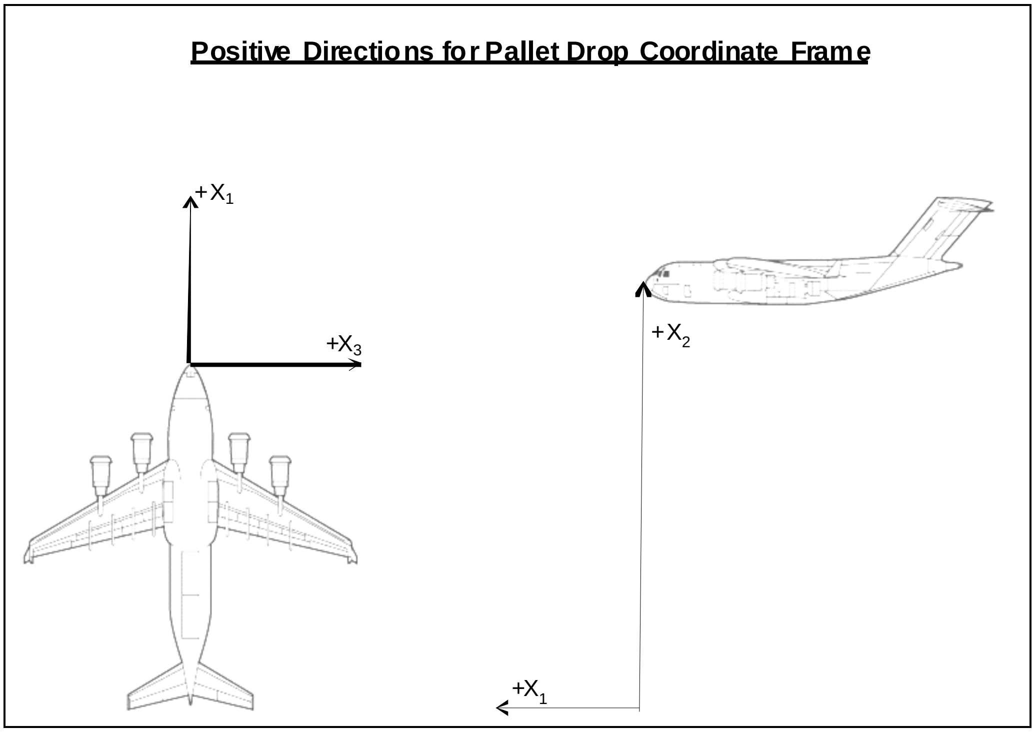

Figure 1. Positive Directions for Pallet Drop Coordinate Frames

All vectors have as a frame of reference a right-handed, orthogonal, Cartesian coordinate system. The origin of this coordinate system is the projected point on the ground of the nose of the carrier aircraft, as seen in Figure 3. The aircraft initial orientation is free in rotation about the X_2 (yaw) and X_3 (pitch) axis. No rotation is allowed about the X_1 axis (roll), and the aircraft is always assumed to have zero roll (wing parallel to the ground). Positive values are as defined in STANAG 4355 (Ref. 12). Velocities are given with respect to the ground-fixed coordinate frame. Initial velocity corrections are required if indicated airspeeds from aircraft instrumentation are used as input to the simulation.

Phase 1 begins at time zero, when the signal to drop the pallet is sent. The initial velocity of the pallet system is equal to the aircraft velocity, which is assumed to be constant and is measured with respect to the ground. The pallet remains stationary at its initial station number (position within the aircraft) until time of first movement (t_{fm}), when the pallet first moves along the cargo deck. The term t_{fm} is used to model the delay time between giving the signal to drop and when the pallet is cut loose. This phase ends when the pallet center of mass reaches the aircraft ramp. During this phase, the pallet motion is constrained to motion along the aircraft cargo deck. The pallet is initially at rest with respect to the aircraft and is motionless on the aircraft cargo deck. The terms α_A and α_D are used to represent the vertical angle of the aircraft with respect to the horizon and the angle of the cargo deck in relation to the angle of the aircraft, respectively. These terms aid in all extraction methods, but are primary drivers for the time of aircraft exit for gravity extraction.

Additionally, these terms are used to constrain the motion of the pallet to the cargo deck, defined as $\vec{X}_P$.

Phases of Pallet Drop Trajectory

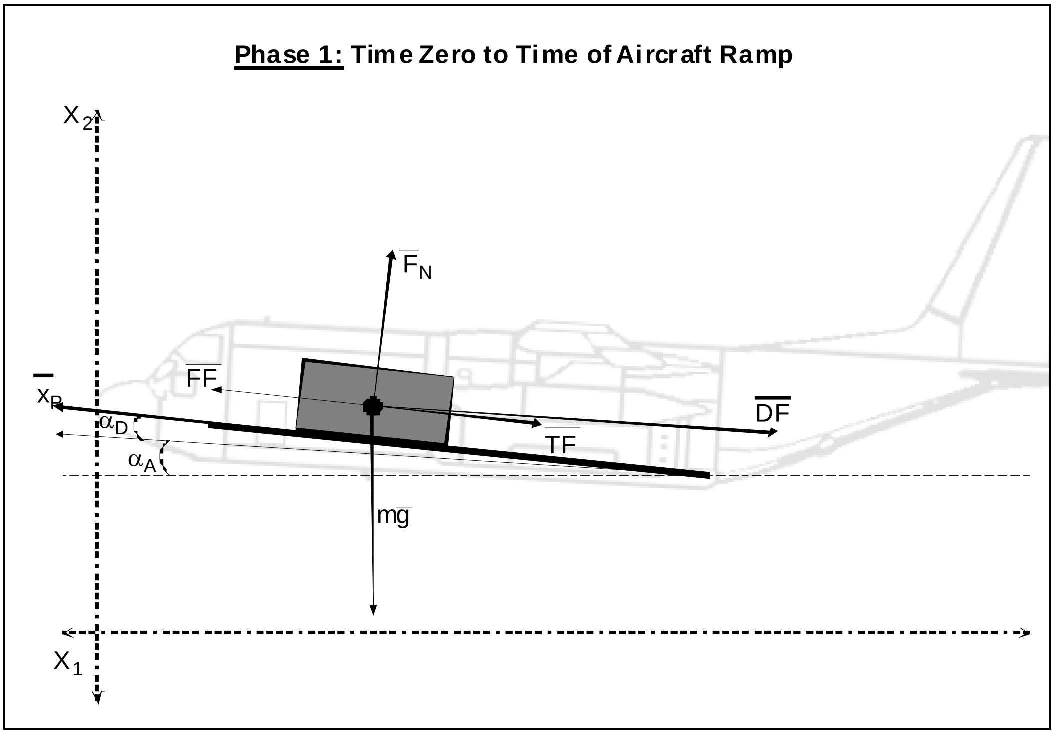

Figure 2. Phase 1: Time Zero to Time of Aircraft Ramp

The drag force $\left(\overrightarrow{DF}\right)$ of the extraction parachute or the thrust force $\left(\overrightarrow{TF}\right)$ of personnel pushing the pallet, friction force between the pallet and the aircraft cargo deck $\left(\overrightarrow{FF}\right)$, normal force of aircraft acting upon the pallet $\left(\vec{F}_N\right)$, acceleration due to gravity $\left(\vec{g}\right)$, and acceleration due to Coriolis $\left(\vec{\Lambda}\right)$ are considered during this phase. Forces applied to the pallet are shown in Figure 4. Mass of the system represents the full rigged weight, including the cargo, pallet, rigging, main parachute, and extraction parachute (if applicable). The equation of motion of the center-of-mass of the pallet during this phase is given by Equation 1. Equations for each force are defined in STANAG 4355. Phase 1 ends when the center of mass of the pallet moves to the end of the aircraft cargo deck. The length of travel for this phase is computed from the initial position of the cargo deck and the total cargo deck length.

$$\vec{F} = m\dot{\vec{u}} = \overrightarrow{DF} + \overrightarrow{TF} + \overrightarrow{FF} + \overrightarrow{F_N} + m\vec{g} + m\vec{\Lambda} \qquad \text{(eq 1)}$$

Phase 2 begins when the pallet center of mass reaches the end of the cargo deck and begins moving along the cargo ramp. This allows for simulation of motion when the aircraft has a ramp oriented at a different angle than the floor of the aircraft cargo section. The ramp is represented by adding an additional angle, α_R, defining the angle of the ramp with respect to the aircraft deck. This term is used to compute a new $\vec{X}_P$, which defines the constraint of pallet motion to the aircraft cargo ramp. If $\alpha_R = 0$, then $\vec{X}_P$ for phase 2 is equal to $\vec{X}_P$ for phase 1.

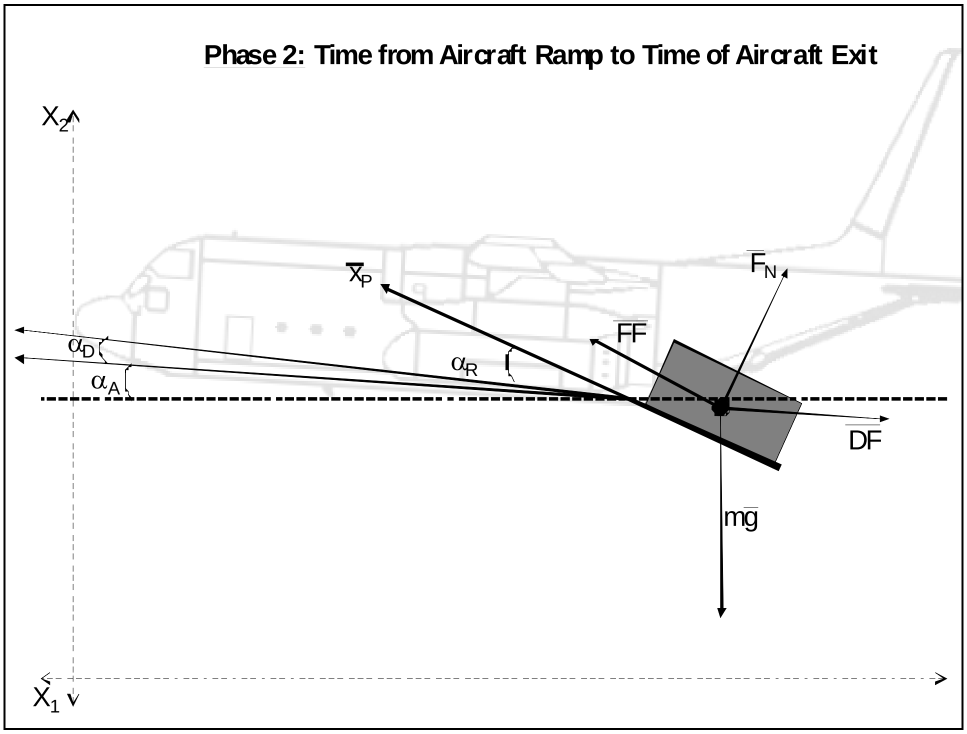

Figure 3. Phase 2: Time from Aircraft Ramp to Time of Aircraft Exit

The drag force $(\overrightarrow{DF})$ of the extraction parachute, friction force between the pallet skid and the aircraft cargo deck $(\overrightarrow{FF})$, normal force of aircraft acting upon the pallet $(\vec{F}_N)$, acceleration due to gravity $(\vec{g})$, and acceleration due to Coriolis $(\vec{\Lambda})$ are considered during this phase. No thrust force is considered for this phase. Mass of the system is the same as phase 1. Forces applied to the pallet are shown in Figure 5. The pallet motion is constrained to the aircraft cargo deck ramp. The equation of motion of the center-of-mass of the pallet during this phase is given by Equation 2. Phase 2 ends when the center of mass of the pallet moves to the end of the aircraft cargo ramp and exits the aircraft. The time of aircraft exit is recorded as t_{AE} for use in timing events in the simulation. The length of travel for this phase is determined from the cargo ramp length of the aircraft modeled.

$$\vec{F} = m\dot{\vec{u}} = \overrightarrow{DF} + \overrightarrow{FF} + \vec{F}_N + m\vec{g} + m\vec{\Lambda} \qquad \text{(eq 2)}$$

When the pallet reaches the end of the aircraft ramp, it is no longer constrained by the aircraft and is in a free fall stabilizing motion. This phase can be simulated with or without the extraction parachute providing drag. The force of the aerodynamic drag (relative to wind velocity, *V*) acting on the pallet is added to the total force equation for phases 3-5. The equation of motion of the center-of-mass of the pallet during this phase is given by Equation 3. Phase 3 ends at the time when the main parachute begins to deploy. This phase end is determined by a database value for t_P.

$$\vec{F} = m\,\dot{\vec{u}} = \overrightarrow{DF_P} + \overrightarrow{DF} + m\,\vec{g} + m\,\vec{\Lambda} \qquad \text{(eq 3)}$$

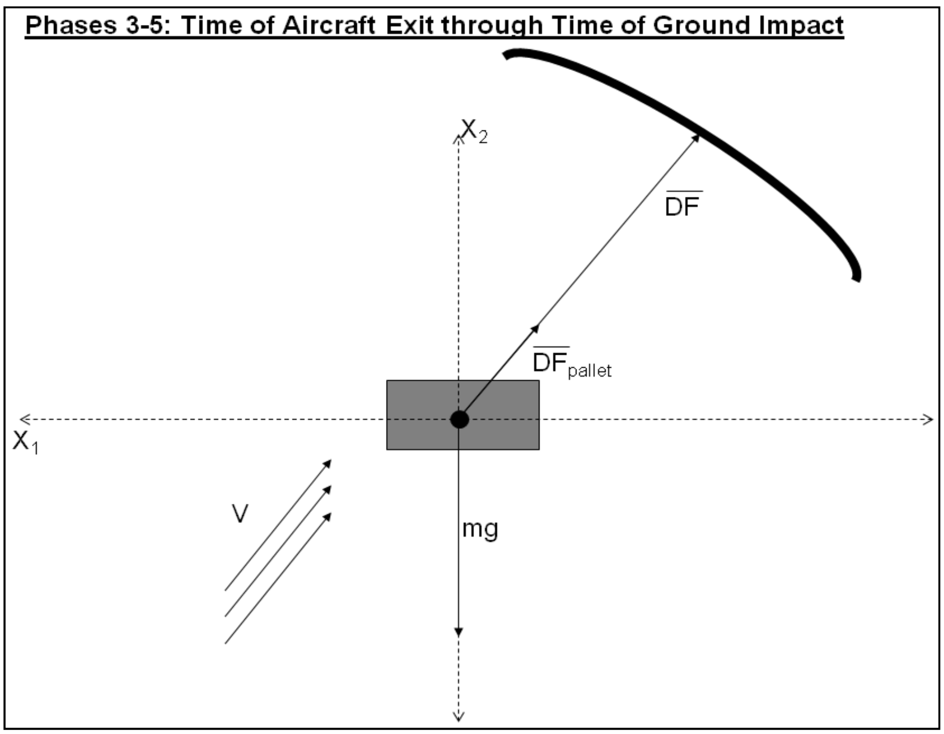

Figure 4. Phases 3-5: Time of Aircraft Exit through Time of Ground Impact

Phase 4 models the transition of the parachute-pallet system from free fall or extraction parachute stabilization to free fall with the main parachute fully deployed. This phase uses the same total force equation as phase 3 with changes to the $\overrightarrow{DF}$ term only. $\overrightarrow{DF}$ is computed using the database values for the main parachute and the coefficient of drag used in $\overrightarrow{DF}$ is changed as a function of time to represent the inflation of the main parachute during deployment. Forces applied to the pallet are shown in Figure 6. A delay time, t_{de}, was added to allow the extraction parachute to be jettisoned and have the pallet in free fall just before the main parachute begins to deploy. Equations 4 and 5 describe the coefficient of drag ($C_{D_0 MI}$) for this phase in 2 parts: prior to main parachute deployment and during deployment. The transition between the pallet free fall without the main parachute to the pallet free fall with the main parachute deployed was modeled as a linear transition as illustrated in Figure 5. Changes can be made to Equation 5 to make this non-linear if required. The time of main parachute inflation, t_i, is determined by Equation 6 (Ref. 13) and is a function of the main parachute diameter, fabric porosity, and velocity at the time of deployment. Phase 4 ends when the main parachute is fully inflated, defined by t_i. This timeline is illustrated in Figure 5.

$$C_{D_0MI} = 0 \qquad \text{for} \qquad (t_{AE} + t_P \le t < t_{AE} + t_P + t_{de}) \qquad \text{(eq 4)}$$

$$C_{D_0MI} = \frac{C_{D_0M}}{t_i}\{t - (t_{AE} + t_P + t_{de})\} \qquad \text{for} \qquad (t_{AE} + t_P + t_{de} \le t \le t_{AE} + t_P + t_{de} + t_i) \qquad \text{(eq 5)}$$

$$t_i = \frac{2D_0}{3\pi V_s\left(\frac{9}{70} - \frac{C_e}{3}\right)} \qquad \text{(eq 6)}$$

where:

D_0 = circumferential diameter of the fully inflated parachute

C_e = effective porosity of parachute fabric

V_s = velocity at beginning of inflation ($t = t_P + t_{de}$)

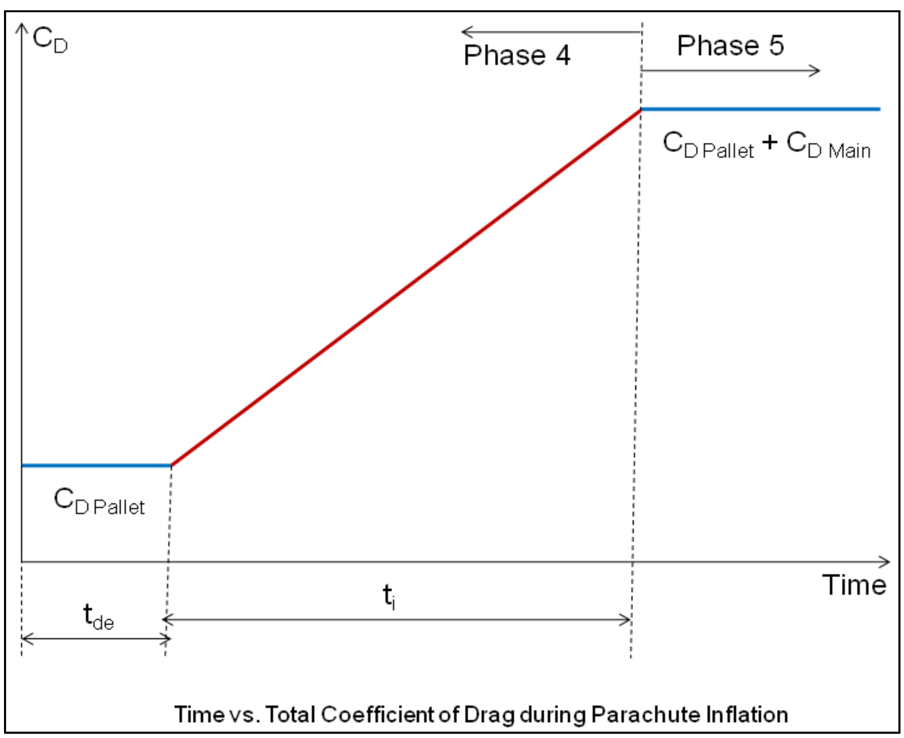

Figure 5. Time vs. Total Coefficient of Drag during Parachute Inflation

Phase 5 begins when the main parachute is fully inflated. This phase uses the same total force equation as phase 3 with changes to the $\overrightarrow{DF}$ term only. $\overrightarrow{DF}$ is computed using the database values for the main parachute when fully inflated with a constant coefficient of drag. System is in a state of equilibrium at terminal velocity, perturbed only by changes in air density and wind speed and direction. Phase 5 ends at the termination of the trajectory when the parachute-pallet system intercepts the ground.

Trajectory Comparison to JPADS

An example of the differences in computing the resulting accelerations between JPADS and the prototype are illustrated in Figure 6 and Figure 7. These plots show the acceleration in the U2 (vertical) and U1 (downrange) directions, with respect to the ground, for a sample test case and highlight the different approaches to computing an airdrop trajectory. JPADS acceleration in the vertical direction was adjusted due to a difference in referencing the pallet at rest in the vertical direction. The prototype software output shows the net acceleration of the pallet, which would be 0 when at rest. JPADS uses a reference of 9.8 m/s (1g) when under no acceleration, as would be read by an on-board accelerometer. Therefore, all values from the JPADS output for vertical acceleration were translated by -9.8 m/s to put both plots on a common frame of reference. These plots illustrate the prototype's ability to produce accelerations for each distinct phase of the trajectory, rather than producing an overall estimate or curve fit of the aggregate of several phases. This segmentation allows more flexibility in modeling the trajectory of various types of pallet drops, such as multiple main parachute phases, as long as accurate aerodynamic data is available.

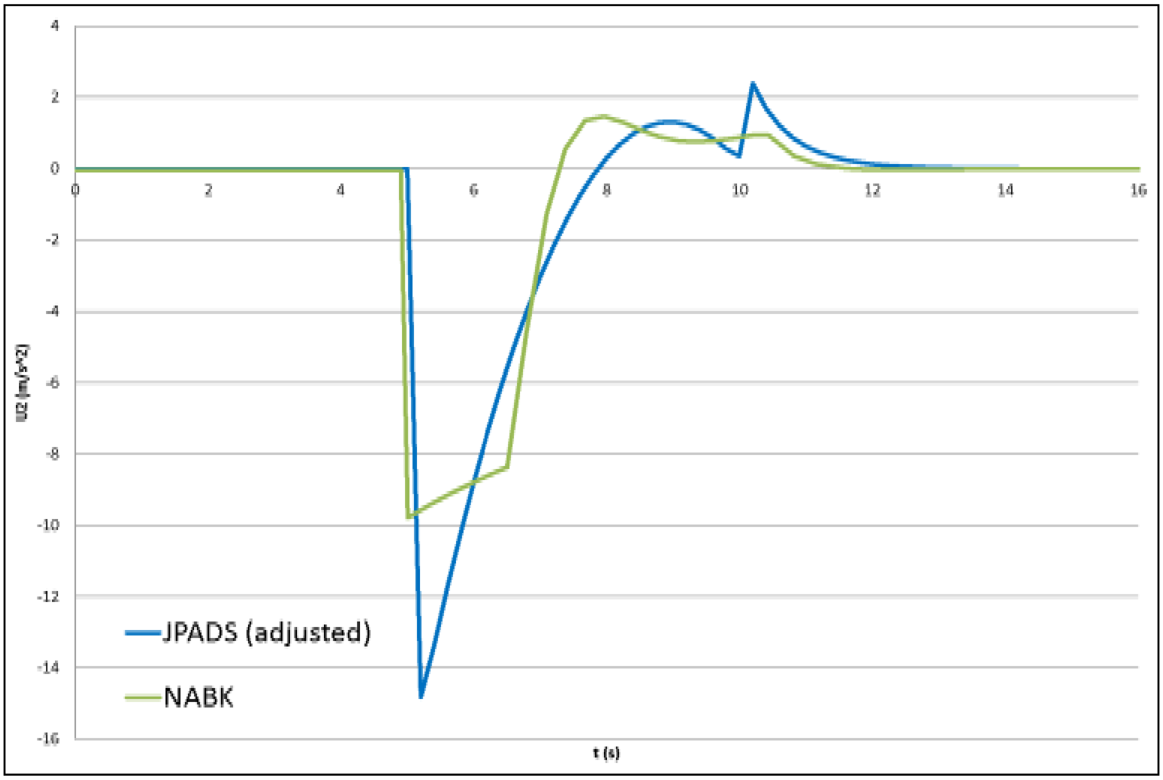

Figure 6. Vertical (U2) Acceleration JPADS vs. NABK Comparison

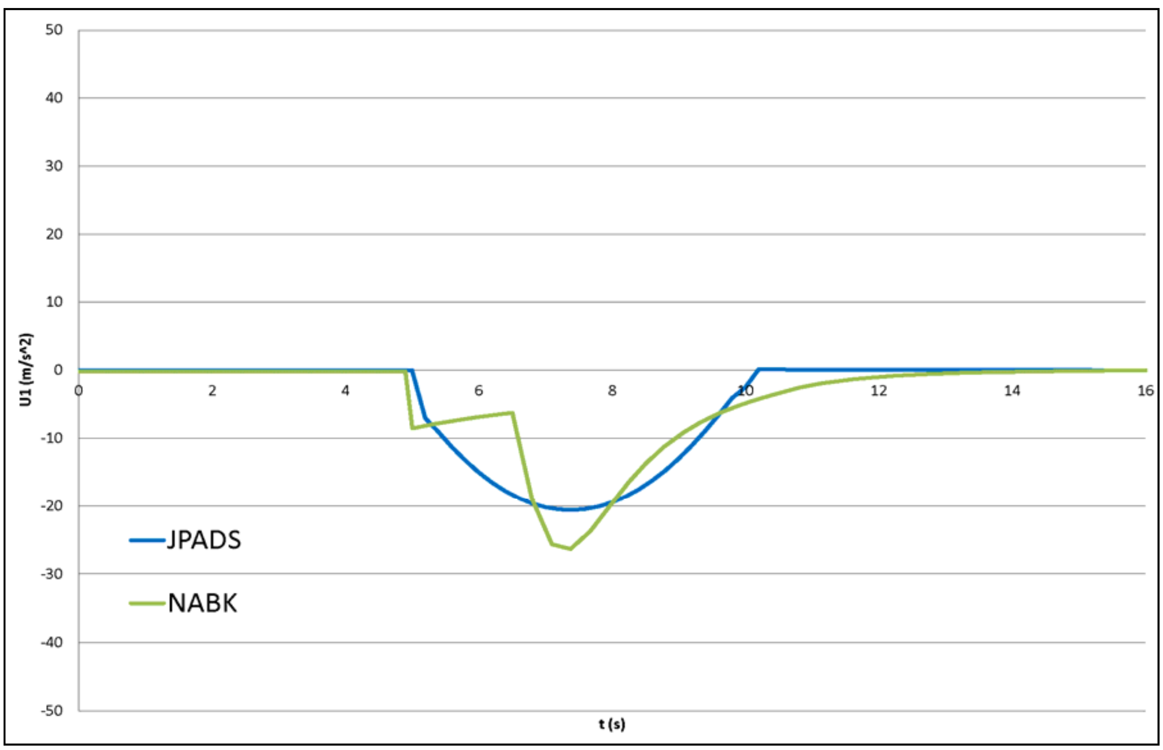

Figure 7. Downrange (U1) Acceleration JPADS vs. NABK Comparison

Database Selection and Development

Databases with the necessary inputs to drive the trajectory model in the prototype software were developed through use of reference materials and historical test data, and through test cases with the established mission planning tool, JPADS. The project team coordinated with the airdrop community to identify two ballistic drop systems that are used operationally by many of the NATO nations. The goal was to sample from common airdrop systems in order to easily find historical data and to demonstrate the software with aircraft and parachutes in widespread use in the militaries of many nations. Databases were created for two aircraft and two ballistic parachute systems under standard usage (Refs 14, 15, 16, 17, and 18). The two aircraft selected were the C-130J (Ref. 13) and the C-17 (Ref. 19). The two main parachutes chosen were the 26ft ring-slot (Ref. 20) and the G-12D/E (Ref. 21). For each aircraft/parachute combination there are three allowable extraction methods: gravity extraction, pushing or tossing, or extraction parachute. Three common sizes of extraction parachutes were included in the database: 8ft, 15ft, and 22ft diameter.

Several database values remained unknown during implementation, such as coefficient of friction between the aircraft cargo deck and the pallet, effective porosity of the main parachute, and the time delay of the main parachute deployment. To complete the NABK databases, initial estimates were used as placeholders while comparison runs were conducted on the reference simulation, JPADS. From this comparison, database values were updated to provide the best match to JPADS across all aircraft/parachutes for gravity extracted systems. These databases were tested under non-standard conditions to ensure that the values selected were robust and did not fit a single run or limited set of initial conditions. This testing included using five 1-D meteorological profiles that are standards for S4 testing (standard atmosphere with no winds, temperate with wind shear, arctic conditions, tropic conditions, standard atmosphere with global mean winds), various starting positions within the aircraft, altitudes, aircraft speed, and aircraft direction (change to wind orientation). The development team determined that these parameters were sufficient to show that the simulation will produce acceptable results across all reasonable drop conditions. These test conditions were used to conduct testing against JPADS, described in the section titled “Software Testing.”

Software Implementation

Several components of the S4 were required to implement the technology for ballistic air drops: the NATO Armaments Support Services (NASS) product, the NATO Armaments Ballistic Kernel (NABK) product, and two products under the NATO Armaments Meteorological Kernel Project, namely the Meteorological Manager (METM) product and the METGM verification (GMVerify) product. NABK (v10.0) (Ref. 22) was the primary component modified. The NABK provides ballistics related computations required by technical fire control systems (artillery, mortars, tanks and small arms) to compute firing solutions. The NASS (v4.0) (Ref. 23) supports underlying code structures and algorithms across the S4, and modification to this component required only a minor change made to track the trajectory of a parachute with a long drop time. The METM (v2.2) (Ref. 24) product was integrated as is so METGMs (4-D met) can be used. A limitation is METM v2.2 can only accept Edition 1 formatted METGM. GMVerify (v2.5 Golf) (Ref. 25) is used as is by the Graphical User Interface (GUI) to scan METGMs for relevant information and to convert STANAG 6022 Edition 2 formatted METGMs to Edition 1 formatted METGMs.

To serve as a mission planner, the prototype software expands on the existing features of the NABK to produce a CARP. In addition, the ability to calculate the impact point on the ground given a release point was implemented into the prototype. This capability is currently not in the reference mission planning software, but it is useful for technology development in a laboratory setting. The equations of motion in the NABK were modified to incorporate the new variables and equations described earlier in the section titled "Technology Development." The projectile trajectory phases in the NABK were also altered to include the additional airdrop phases. The NABK was further modified to account for the pallet motion within the moving aircraft. As described in the introduction, many of the existing features of the NABK were utilized in the prototype to reduce the development effort.

One of the key benefits of the prototype software is the ability to use forecasted four dimensional meteorological data (METGM) for ballistic drop systems. The airdrop community does use forecasted four dimensional met data for determining way points for guided parachutes but not for ballistic drops. For ballistic drops, one dimensional dropsonde data is used for the calculations. Using the higher resolution data will increase the accuracy of drops, especially at higher altitudes, by providing a more accurate atmospheric profile over the target area at the time of the drop mission. Air drops with long flight paths and times will benefit the most. With high quality forecast data, drops conducted with forecasted met could be completed with one aircraft pass instead of the current two pass mission, which requires a first pass to deploy a dropsonde to collect the meteorological data and a second pass for the actual pallet drop. Additionally, the single pass can be at a higher altitude, reducing the aircraft and crew exposure/vulnerability over the drop zone and shortening mission time.

A GUI was created for the prototype as a Windows-based executable that gives the end user an easy way to enter mission parameters into the prototype software, as illustrated by the GUI "Mission" tab (Figure 8). The GUI outputs data associated with the CARP and impact point for the full trajectory including location, speed and acceleration of the pallet as a function of descent time, as illustrated in the GUI "Results" tab (Figure 9). Meteorological data can be read in two standard formats: (1) a one dimensional METCM (Ref. 26) which contains wind direction, wind speed, air temperature, and air pressure data and (2) a four dimensional METGM (Refs. 7 and 8). From the trajectory output data (Figure 9), the GUI generates nine different graphs associated with the pallet trajectory. These graphs show the position, velocity, and acceleration in the three orthogonal planes. Additionally, the GUI can echo out the trajectory input data used, and it can produce a report containing the mission input parameters, CARP, trajectory data, graphs and database values. For all details on the operation of the prototype and on the description of the GUI, please see the "Guide to the NATO SG/2 S4 PAD Prototype Demonstration Software" (Ref. 27).

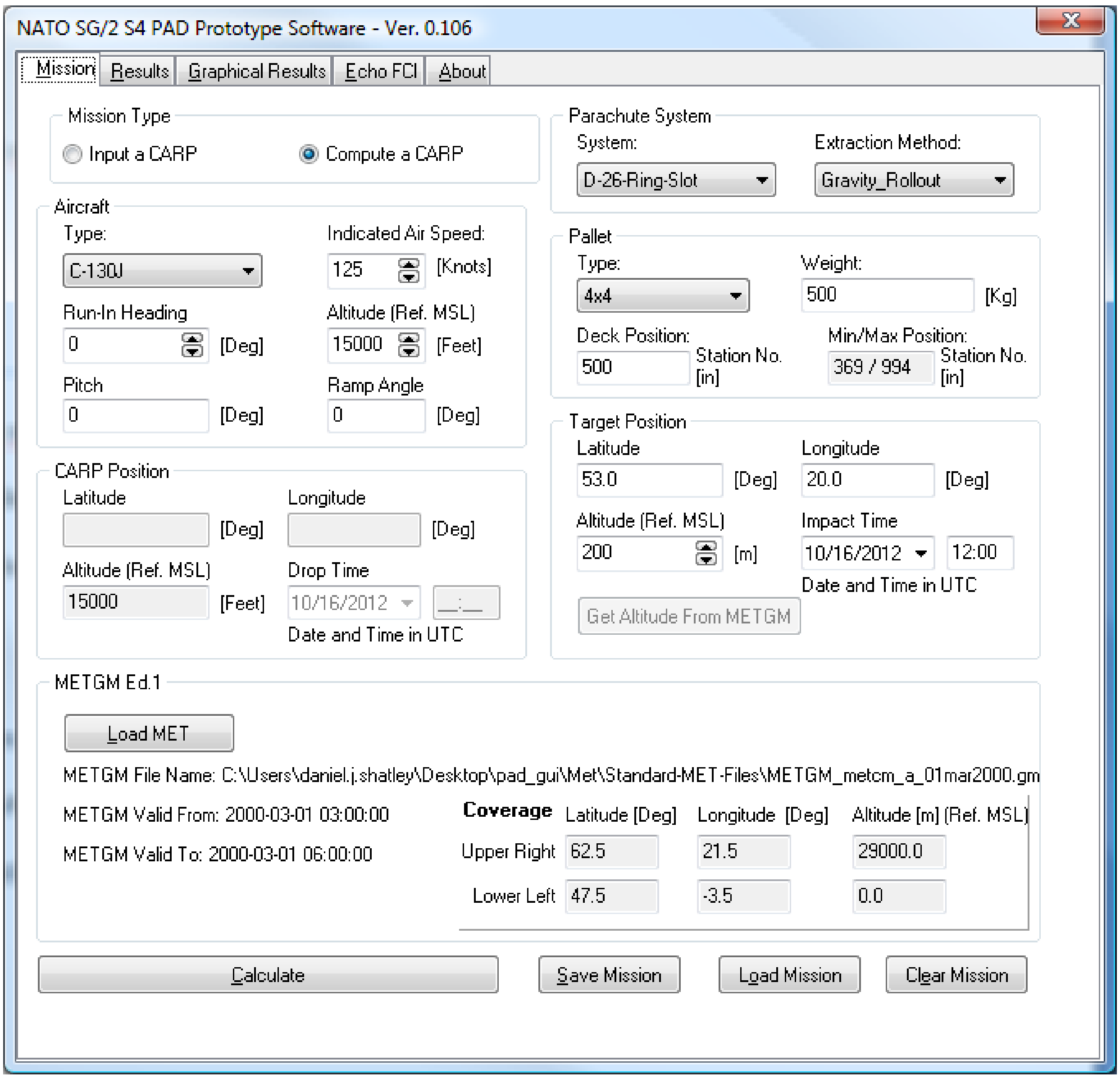

Figure 8. GUI Mission Tab

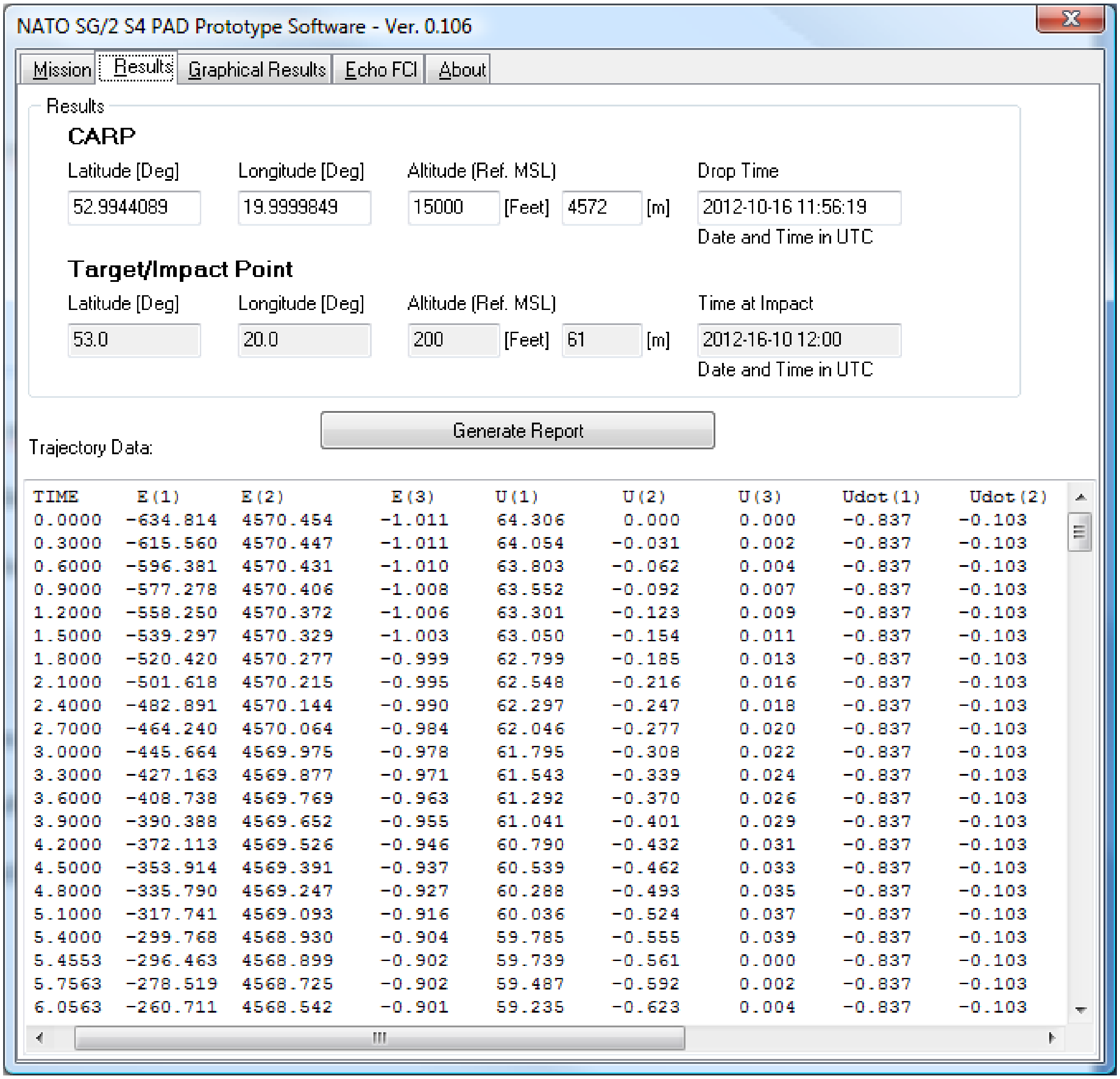

Figure 9. GUI Results Tab

A convergence algorithm was created for the prototype to generate a CARP. Initially, the CARP is set directly above the target at the planned aircraft altitude, and the simulation computes an airdrop trajectory. The simulation determines how far off the pallet landed from the target. For the next iteration, the CARP is moved the same magnitude, but in opposite direction, as the miss distance. A single iteration is sufficient to place the impact point on the desired target when using a METCM, since this meteorological data does not change with position or time. For a METGM however, the prototype uses the same method but runs multiple iterations to find a solution in which the pallet lands within 10 meters of the desired target location. Multiple iterations are required for METGM, since the meteorological data changes as a function of location and time, which results in a trajectory which is different for each iteration. If a CARP is supplied, the prototype software runs a single trajectory that tracks the pallet through the flight path to the impact point for both METCM and METGM scenarios.

Currently, the prototype supports the use of a 4ft by 4ft pallet load dropped from either the C130J or C17 aircraft using the 26 foot ring slot or G12D/E parachutes with gravity rollout or parachute extraction methods. The prototype was designed for expansion to address combinations of additional types of ballistic parachutes, pallet loads, and extraction parachutes as well as drops from other aircraft. This makes it useful for a wide variety of existing unguided drop systems and potentially for new ones. However, work will have to be done to establish input database files for the additional aircraft, parachute, pallet, and extraction parachute types.

Software Testing

This section summarizes what testing was conducted on the prototype software and the results. In lieu of validation against actual drop data, this prototype software was tested against an existing airdrop mission planning software. A software test report for the prototype (Ref. 28) contains all details for testing including the plan, procedures, results, and interpretation.

Test Plan and Procedure

Initially, testing of the prototype was to be conducted against existing drop data collected from live tests, but this proved problematic. While U.S. test data from Yuma Proving Ground were sufficient for the intended purposes of the individual drop tests conducted there, the data available across the tests were inconsistent and were missing information required to conduct an accurate comparison against the prototype software. Missing information included meteorological data, actual trajectory data (such as radar and/or telemetry tracks), accurate measurements of the aircraft position/speed at the time of the start of the drop and location of ground impact. Without a consistent set of these key pieces of data, it was determined that the best way to proceed was to test against CARPs produced by JPADS.

The prototype software was tested against JPADS with the simulation results from JPADS considered a good baseline to match due to JPADS operational use and acceptable performance history. All tests were conducted using only the gravity extraction option, since JPADS does not support other types of extraction, such as extraction by parachute and by personnel pushing or tossing cargo from the aircraft. While the prototype has the ability to use extraction parachutes and personnel pushing on the cargo, these operations cannot be validated with the chosen testing method due to those JPADS limitations.

Two types of testing were conducted. For the first type of test, JPADS and the prototype both generated CARPs for the same target point. The differences in CARP locations were calculated. This type of testing verified the CARP generation of the prototype software, which is the intended operational use of this software. The second type of test used the JPADS produced CARP for the given scenario as an input to the prototype, which then computed the impact point. The difference between the JPADS and the prototype impact points were calculated. This type of testing verified the functionality of simulating air drop trajectories from the aircraft and showed how closely the prototype trajectories are to the JPADS trajectories when given the same initial conditions.

A tolerance of 50 meters radial miss distance for the prototype software impact points from JPADS was set as the limit for what the development team considered an acceptable difference. This tolerance was based on the standard NABK tolerance used for matching indirect fire control solutions during testing and then adapted to air drop scenarios. NABK testing uses a 10 meter tolerance in radial miss distance from the comparison software and this value was scaled by a factor of 5 to account for the increased trajectory times for ballistic pallet drops. Airdrop trajectory times are on the order of 5 times greater than those for indirect fire munitions, in which small computational errors or differences between implementations would accumulate. This 50 meter tolerance is also within the bounds of most expected designated drop zones, ensuring delivery of the pallets in the desired area.

The prototype was tested with standard METCMs, standard METGMs, forecast METGMs and METCMs extracted from the forecast METGMs. The standard METCMs used in the baseline NABK testing consist of the following 5 atmospheric profiles: (1) ICAO standard atmosphere with no wind, (2) ICAO standard atmosphere with wind shear, (3) arctic temperature and high winds, (4) tropical conditions with high winds, and (5) global mean winds. The standard METGMs are equivalent to the standard METCMs. The forecast METGMs were produced by weather models for the regions of Iraq, Afghanistan, and the South of France. These METGMs were used to get an indication of how well the prototype performs with sample met from current areas of operational interest as well as in a region with complex terrain to stress the testing further. Information on the location, date, and horizontal area covered by these METGMs can be found in Table 1. Using GMVerify equivalent METCM and dropsonde files were extracted from the forecast METGMs. JPADS cannot read in METCM or METGM files so these equivalent dropsonde files were created.

File Name	Location	Date	Top Right corner	Lower Left corner
F_20050204_0300_0_AFG0_06600E_3600N.gm	Afghanistan	02/04/05	38.0 N, 68.5 E	34.0 N, 63.5 E
F_20050216_0600_0_IRQ0_04500E_3000N.gm	Iraq	02/16/05	32.0 N 47.25 E	28.0 N, 42.75 E
F_20120101_0000_0_FRA0_00650E_4350N.gm	France	01/01/12	45.0 N, 9.0 E	42.0 N, 4.0 E
F_20120101_0000_0_FRA0_00750E_4750N.gm	France	01/01/12	48.5 N, 9.0 E	46.5 N, 6.0 E
F_20120801_0000_0_FRA0_00650E_4350N.gm	France	08/01/12	45.0 N, 9.0 E	42.0 N, 4.0 E
F_20120801_0000_0_FRA0_00750E_4750N.gm	France	08/01/12	48.5 N, 9.0 E	46.5 N, 6.0 E
F_20121115_0000_0_FRA0_00650E_4350N.gm	France	11/15/12	45.0 N, 9.0 E	42.0 N, 4.0 E
F_20121115_0000_0_FRA0_00750E_4750N.gm	France	11/15/12	48.5 N, 9.0 E	46.5 N, 6.0 E

Table 1. Forecast METGMs

The prototype was tested with 440 test scenarios covering a wide range of initial conditions. These conditions are summarized in Table 2. The testing was split up into 5 sets:

1. The prototype using the standard METCMs to calculate CARPs compared to JPADS produced CARPs. This testing verifies that the prototype software produces accurate CARPSCARPs.
2. The prototype using the standard METCMs to calculate impact points from JPADS produced CARPs compared to JPADS impact point. This testing verifies that the prototype accurately calculates the pallet trajectory.
3. The prototype software using standard METGMs compared to the prototype software using standard METCMs. This testing verifies the prototype ability to read and use METGMs.
4. The prototype using the METCMs extracted from real world METGMS to calculate impact points from JPADS produced CARPs compared to JPADS impact point.
5. The prototype using the METGMs to calculate impact points from JPADS produced CARPs compared to JPADS impact point. Tests 4 and 5 aid in verifying that the prototype works correctly with real world met conditions.

These test cases provided a good mix of conditions while keeping the overall number of drop missions to a manageable amount. A summary of the test cases is shown in Table 2. See Appendix for the full list of test cases.

Test Set	# test cases	Altitudes (M)	Speed (knots)	Mass (kg)	Deck position (in)	Met type	Output
1	104	5334, 2438.4	130, 140	544.31, 816.46	494, 537, 869, 1005,	CM	CARP
2	104	5334, 2438.4	130, 140	544.31, 816.46	494, 537, 869, 1005,	CM	Impact
3	104	5334, 2438.4	130, 140	544.31, 816.46	494, 537, 869, 1005,	GM	CARP
4	64	5334	130	544.31	537	CM	Impact
5	64	5334	130	544.31	537	GM	Impact

Table 2. Test Inputs Summary

Test Results and Interpretation

All 440 tests were run on Windows 7 with the GNAT 7.02 Ada compiler.

For each of the 5 test set the prototypes release/impact points were compared to JPADS release/impact points these points given in latitude and longitude were compared and the distance between each pairing was converted to meters.

For test set 1 of the 104 test scenarios, 66 pairings fell within the 50 meter tolerance. The smallest pairing distance was 5.5 meters and the largest was 163.6 meters with an average distance of 48.8 meters. Figure 11 shows the distance resulting for each of the 104 test pairings. The majority of the test cases have a result between 20 and 60 meters, with 6 cases with larger than expected errors as seen in Figure 12. The larger than expected errors were determined to be from the meteorological inputs with high winds where a larger difference was expected. Without those 6 cases, 67% of the CARPs were within the 50 meter tolerance, and the average distance decreases to 43.2 meters.

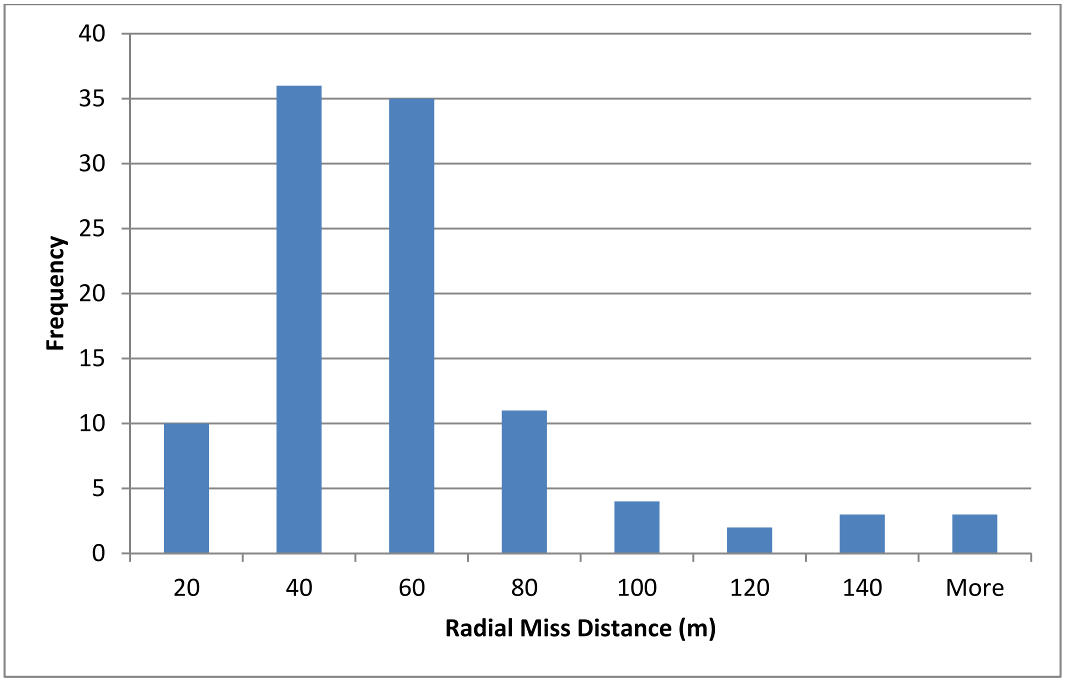

Figure 10. Radial Difference in CARPs Histogram

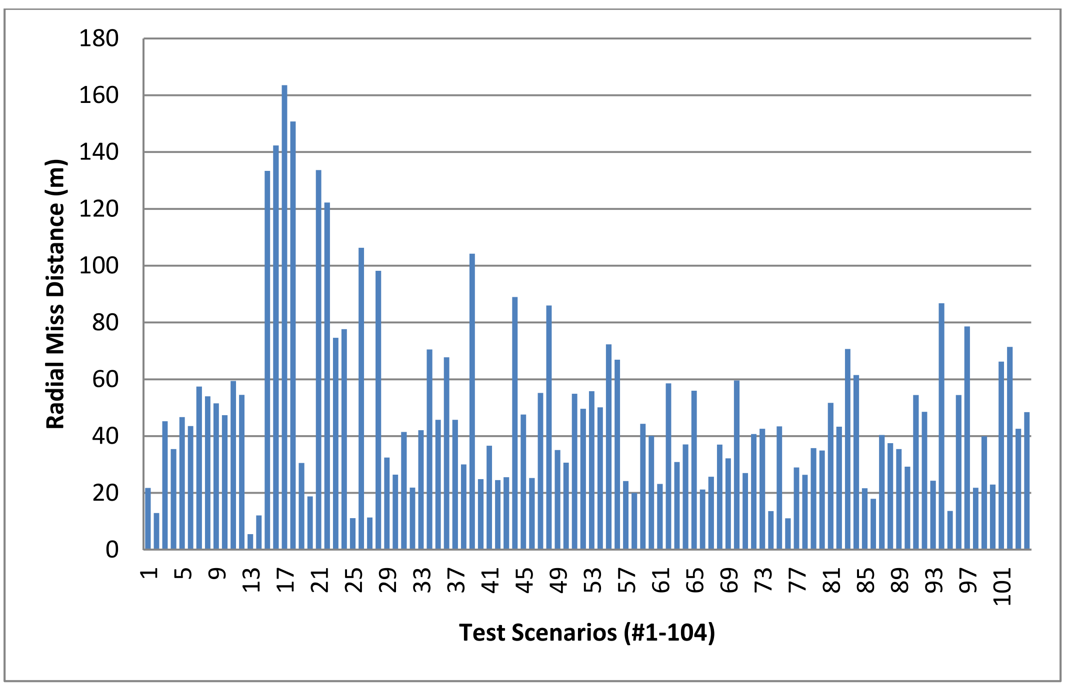

Figure 11. Radial Miss Distance between JPADS and Prototype Produced CARPs

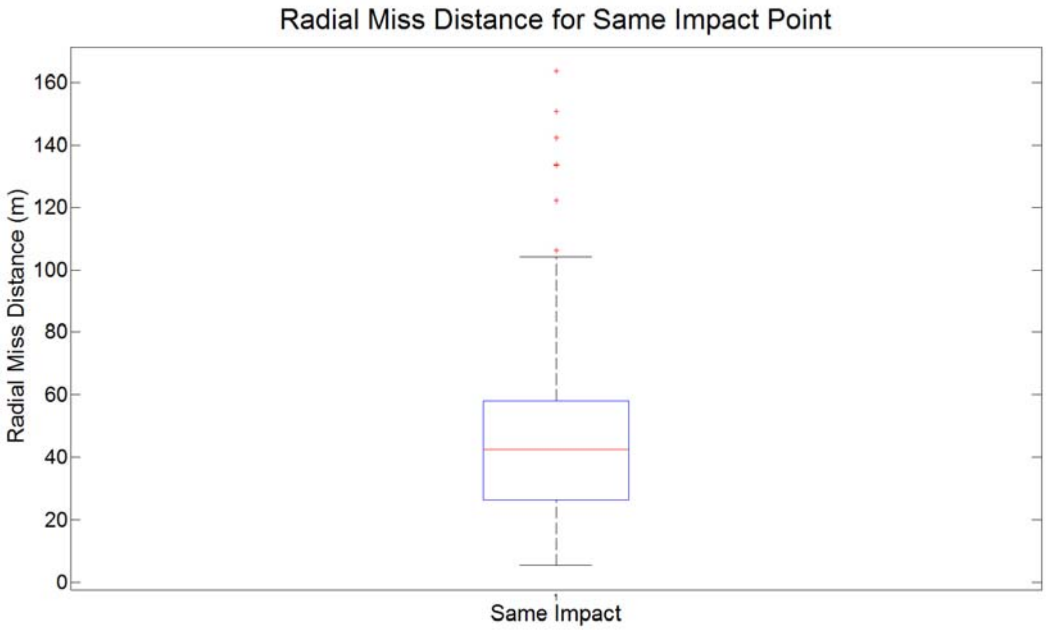

Figure 12. Radial Miss Distance of CARPs Box Plot

For test set 2, of the 104 test scenarios, 66 pairings fell within the 50 meter tolerance. The smallest pairing distance was 9.6 meters and the largest was 153.9 meters with an average distance of 49.5 meters. Figure 13 shows the distance resulting for each of the 104 test pairings. Again, the majority of the test cases have a result between 20 and 60 meters, and this time 7 cases had larger than expected errors were identified as seen in Figure 14. These cases were determined to also be from the meteorological inputs with high winds where a larger difference was expected. Without these cases, 68% of the CARPs were within the 50 meter tolerance, and the average distance decreases to 43.2 meters.

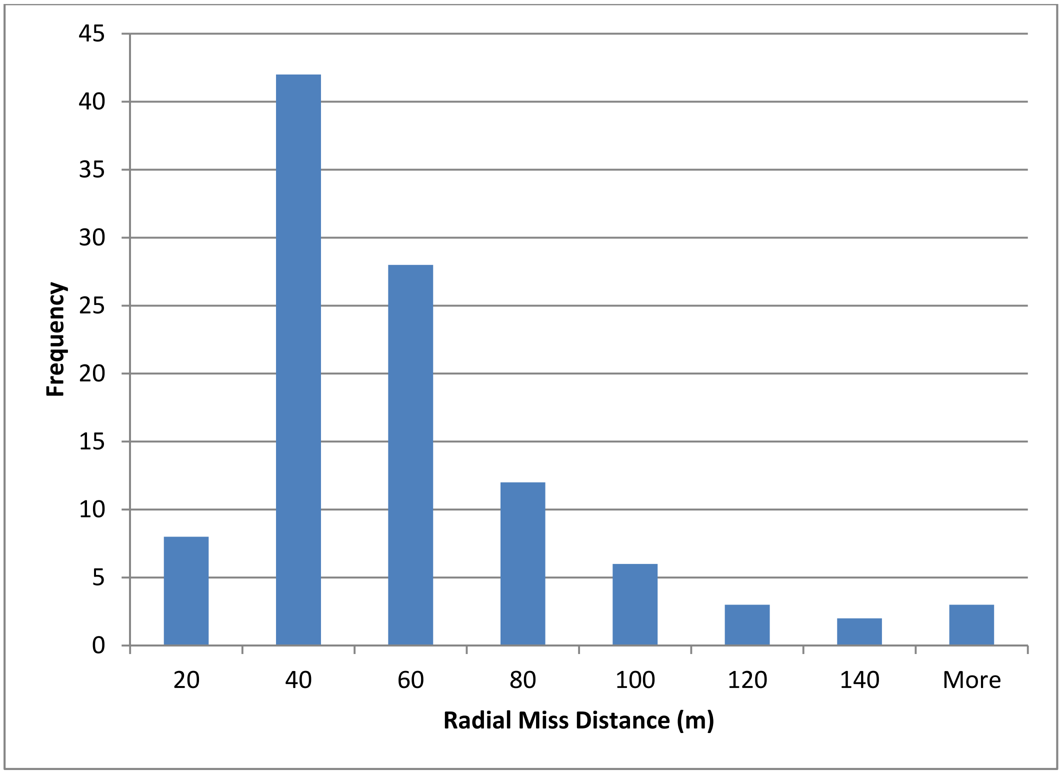

Figure 13. Radial Difference in Impact Points

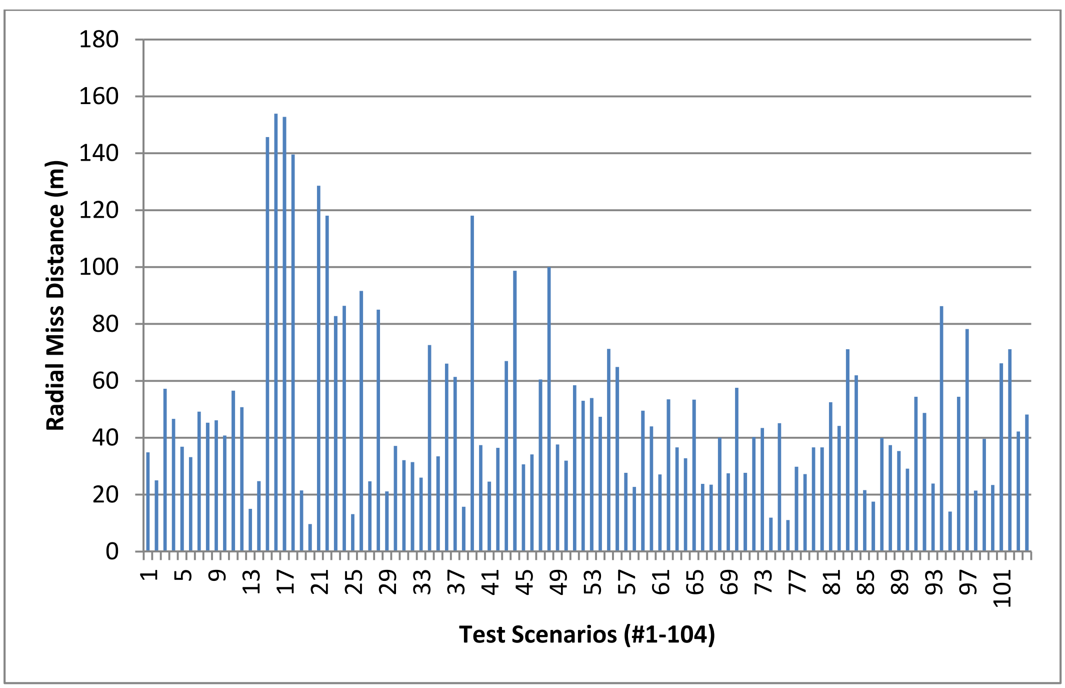

Figure 14. Radial Miss Distance between JPADS and Prototype Impact Points

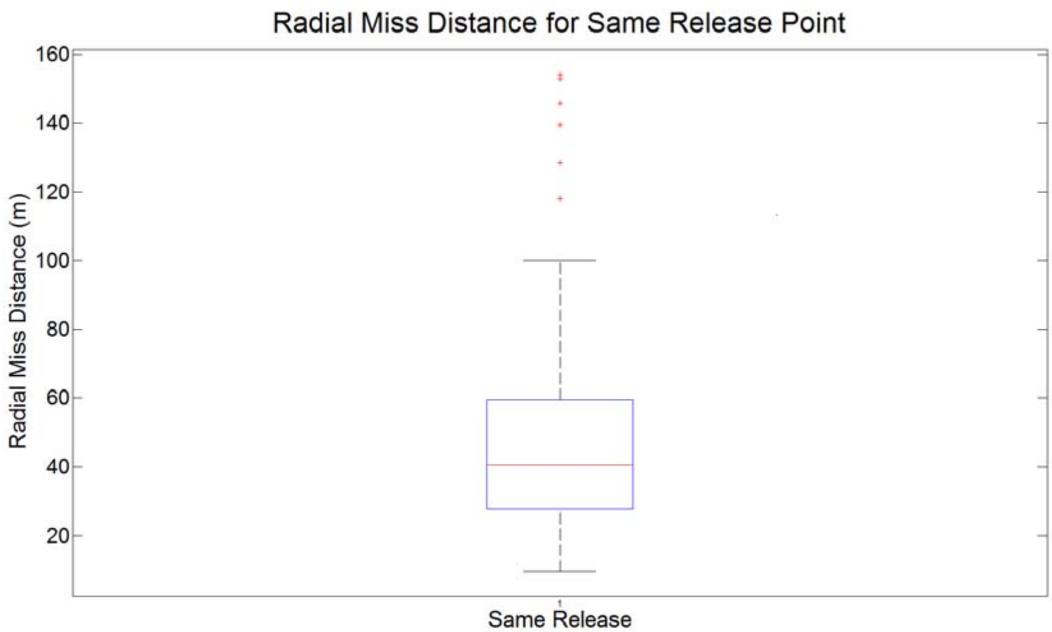

Figure 15. Radial Miss Distance of Impact Points Box Plot

For test set 3, of the 104 test pairings, only 6 had a difference greater than 1 meter. The smallest pairing distance was 0 meters and the largest was 11.435 meters with an average distance of 0.764 meters. Figure 15 shows the distance resulting for each of the 104 test pairings. These results show that the prototype reads in METGMs correctly.

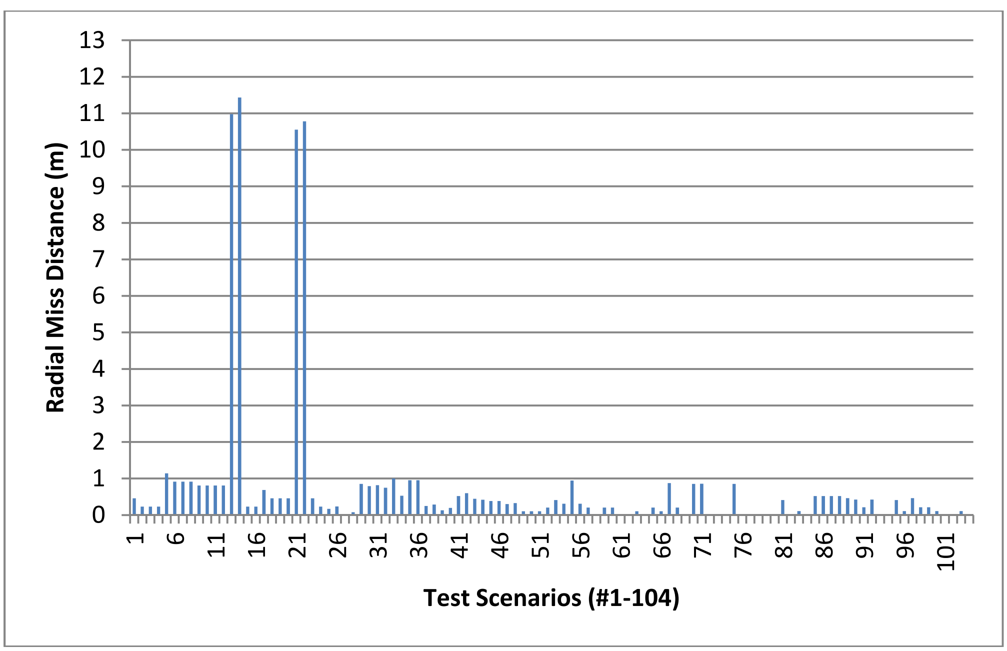

Figure 16. CM/GM Radial Differences by Test Case

For test set 4, of the 64 test scenarios, 48 pairings fell within the 50 meter tolerance. The smallest pairing distance was 7.1 meters and the largest was 82.6 meters with an average distance of 40.1 meters. Figure 17 shows the distance resulting for each of the 64 test pairings. Once again, the majority of the test cases have a result between 20 and 60 meters. There were no statistical outliers in the data as seen in Figure 18.

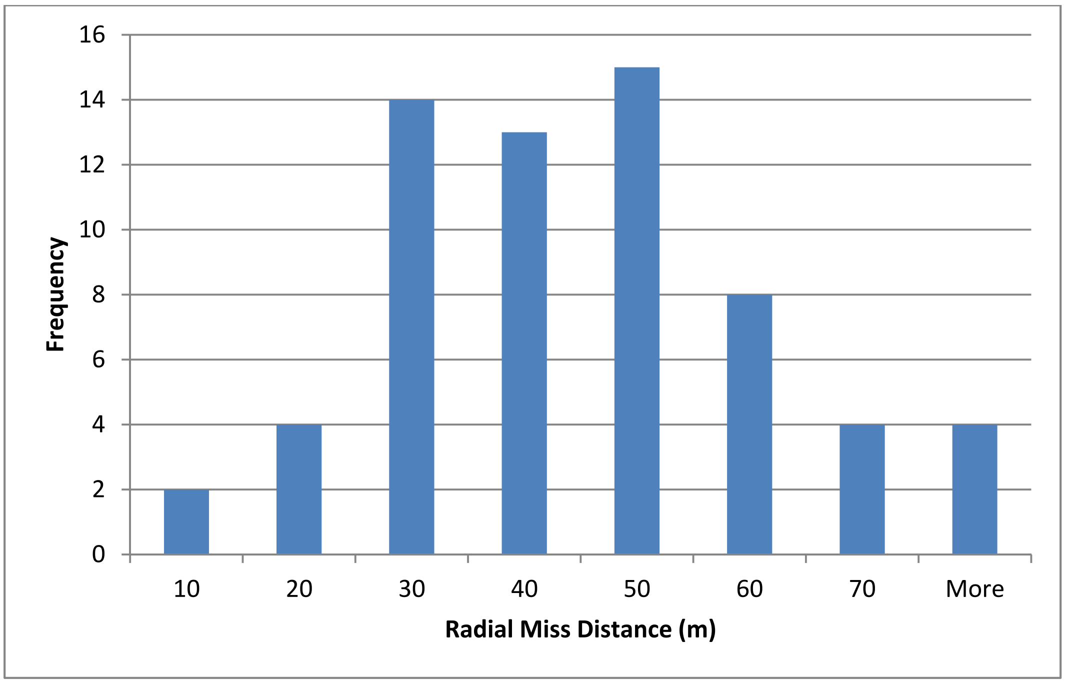

Figure 17. Forecasted CM Histogram

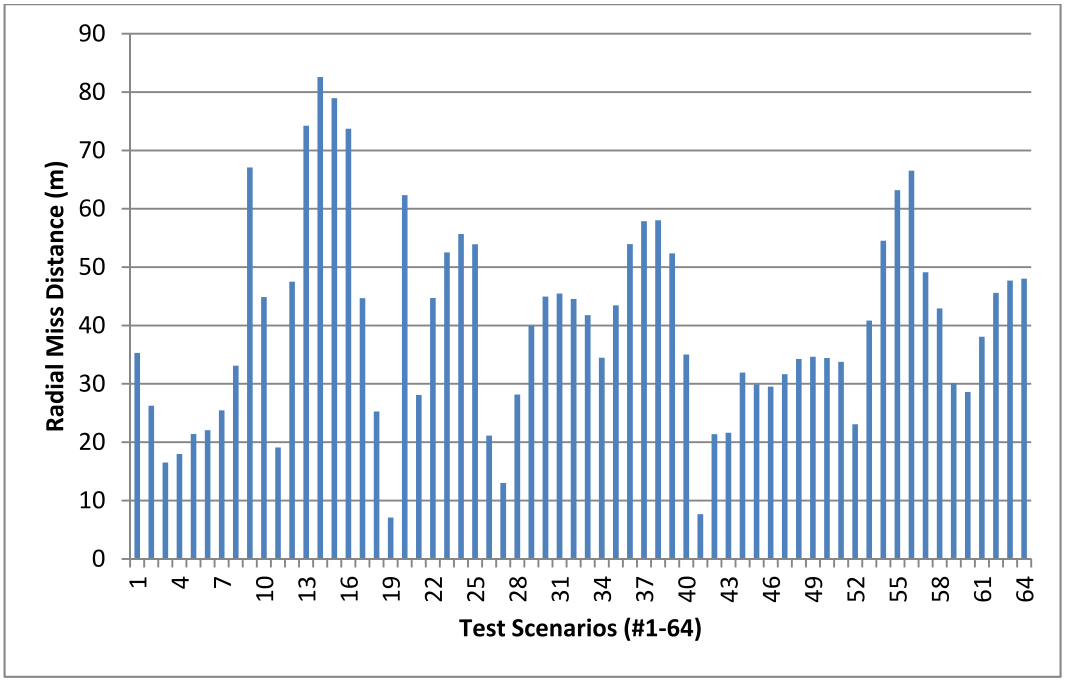

Figure 18. Forecasted CM by Test Case

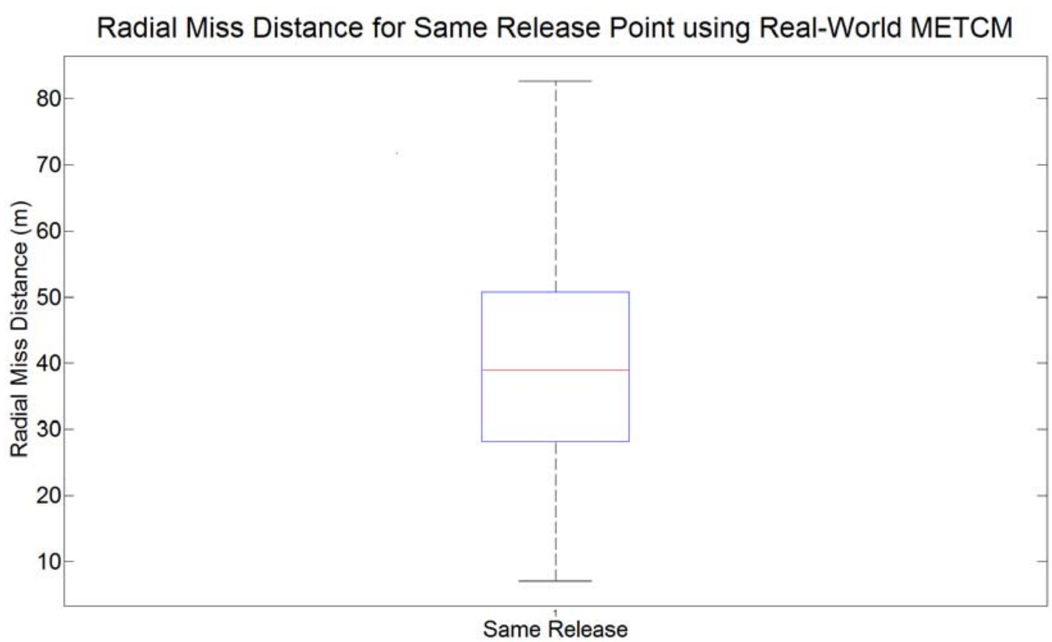

Figure 19. Forecasted CM Box Plot

For Test set 5, of the 64 test scenarios, 51 pairings fell within the 50 meter tolerance. The smallest pairing distance was 7.9 meters and the largest was 66.2 meters with an average distance of 35.3 meters. Figure 20 shows the distance resulting for each of the 64 test pairings. The majority of these test cases (80%) fall within 50 meters of the target point when using the same release point as JPADS. There were 2 statistical outliers in the data, as seen in Figure 21. The statistical outliers were only 15 meters outside of the 50 meter tolerance. Without these outliers, 83% of the impact points were within the 50 meter tolerance, and the average pairing distance decreases to 34.3 meters.

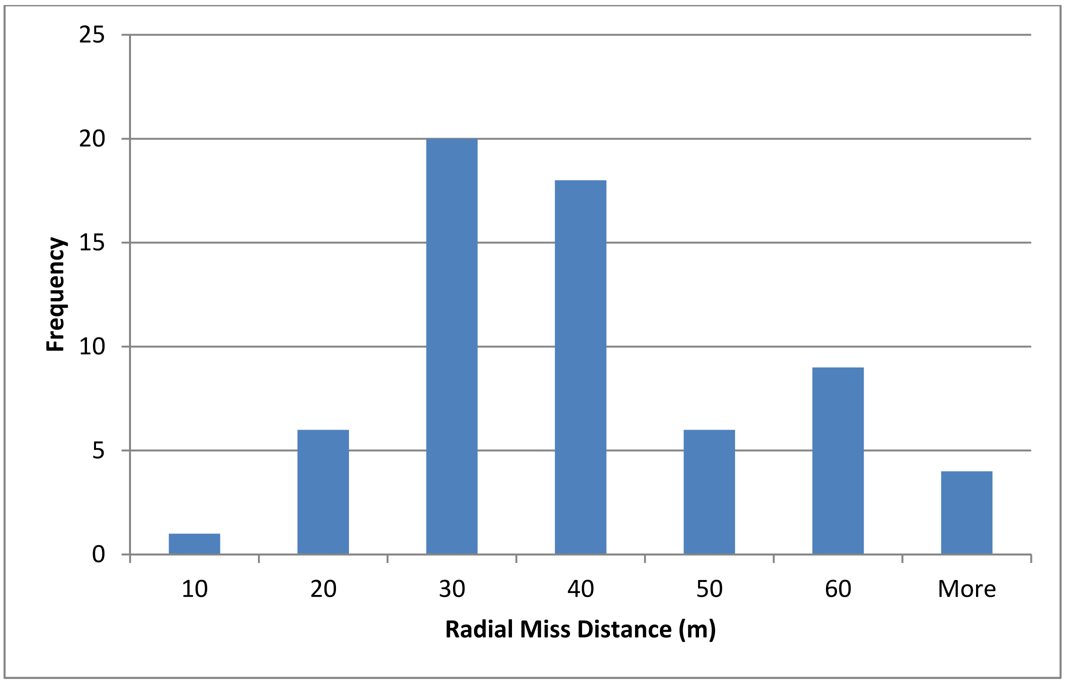

Figure 20. Real world GM Histogram

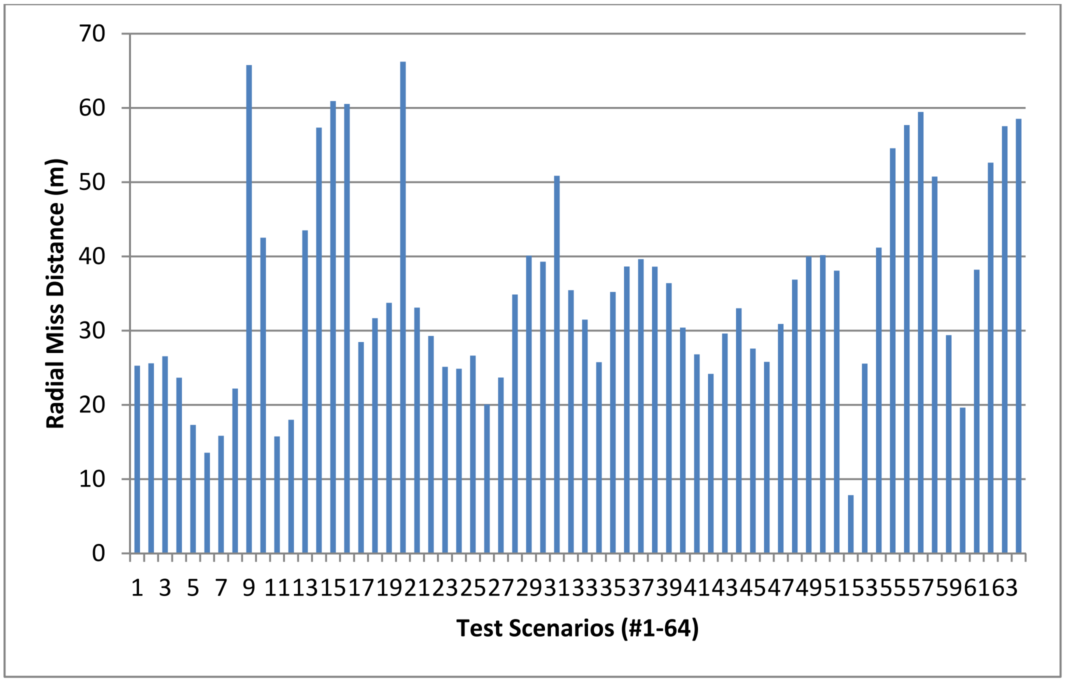

Figure 21. Real world GM by Test Case

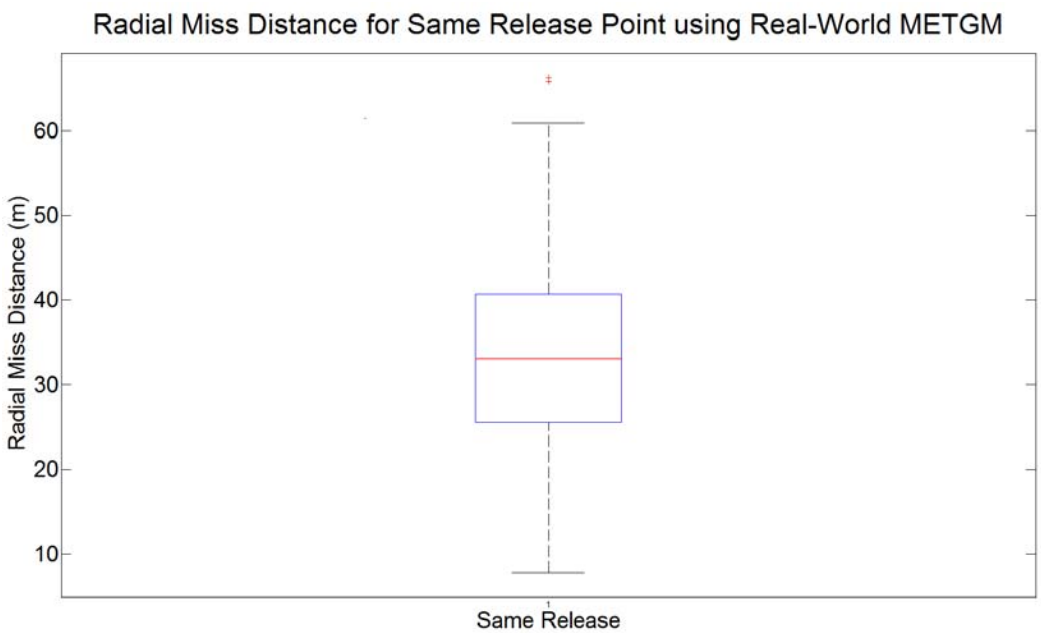

Figure 22. Real world GM Box Plot

Test Results Summary

The test results show that the majority of our test cases fall within 50 meters from JPADS with a few larger than expected differences. These differences were associated with those test cases run with high winds, where small differences in time of flight can yield large miss distances. The tests results indicate that the prototype produces similar solutions for release points and impact points when compared to JPADS under real-world drop conditions. Table 3 summarizes the statistics associated with the test results. When pooled, 68.75% of the test scenarios were within the 50 meter tolerance with an average radial distance of 44.8 meters. The testing only shows the distance between JPADS results and the prototype results.

Test Set	Type	# test cases	Minimum Radial Difference (meters)	Maximum Radial Difference (meters)	Average Radial Difference (meters)	% in Tolerance (+/- 50 meters)
1	Same Impact METCM	104	5.5	163.6	48.8	64
2	Same Release METCM	104	9.6	153.9	49.5	64
3	Same Release Real World METCM	64	7.1	82.6	40.1	75
4	Same Release Real World METGM	64	7.9	66.2	35.3	80
Overall					44.8	68.75

Table 3. Comparison to JPADS Test Results Summary

Recommended Improvements

There are several areas where PAD needs improvement.

1. The FCI data in the database files need to be re-evaluated after obtaining data from live drops. Since the FCIs were created based on data from JPADS, this causes an issue in identifying the source of error. Without test data we cannot tell if the FCI data is wrong, the technology is wrong, or if there are problems with the implementation of the technology; or all three.
2. There are no behavioral tests for the prototype. To be fielded for operational use, a set of behavioral tests would need to be created to test for invalid inputs.
3. The testing for the prototype only tests the end points of the trajectory not the points in between. To be fielded for operational use, testing may need to be done for each of the 5 phases of the trajectory.
4. Extraction parachutes are included in the prototype but not tested. To be fielded for operational use, the extraction parachutes should be tested fully.
5. The prototype only has a small number of test cases (440) due to time constraints. The prototype should have more tests in varied met conditions to increase the confidence in the software.
6. Testing should be done against actual drop data to further refine the software and for added confidence in the underling trajectory model and databases.

Way Forward

The testing shows that the prototype software generates reasonable solutions when compared to JPADS with the limited data set run. Without actual drop test data, it is not possible to determine which model actually produces a CARP that yields a more accurate impact. To determine which software is more accurate requires running both JPADS and the prototype in live drop tests with necessary data recorded. The data required to be collected are the initial conditions of the aircraft at time of drop initiation including speed, type, altitude, deck and ramp angles. Conditions for the pallet including size, weight, meteorological data and parachute types also need to be collected as well as location data for the aircraft and target. Radar tracking of the pallet and video from ground with timestamp showing extraction and parachute deployment events would be needed to correctly model the duration of phases from the technology. Improvements to the databases, along with actual drop test data, would be expected to greatly improve the accuracy of the prototype.

The objective of the prototype was to demonstrate that existing S4 ballistic software could be expanded to provide mission planning for ballistic air drops while providing an improvement in delivery accuracy over existing mission planning software through use of 4-D met forecasting technology. This prototype has room for expansion into other areas such as guided parachutes. The NABK currently supports GPS guided projectiles and this technology can be modified to support the guided parachute systems already in use in the field. Additional ballistic parachute systems can be easily added to the prototype through additional database files. No additional code would need to be altered to accommodate the additional systems. While the NABK is already used to calculate firing solutions for artillery and mortars, and has shown to be able to be modified to model air drop systems, additional modifications to calculate release points for aircraft bombing runs, the location of an ejected pilot, etc. could also be possible. The prototype currently uses a point mass trajectory model with 3 degrees of freedom (3-DoF) but could be expanded to include other forces and moments acting on the drop system during the flight to improve accuracy of drops through use of a 6 degree of freedom trajectory model (6-DoF).

Several NATO nations have expressed interest in continued development of this prototype and the building of mission planning software based on the S4 suite of products. The first step in continuing the work would be to conduct live testing with the aircraft and drop systems already included in the prototype software. This would establish the necessary set of data to support validation testing. The JPACWG has already expressed interest in conducting live drops with the prototype.

Summary and Conclusions

SG/2 supported S4 expansion of applicability beyond fire control into the airdrop domain, leveraging existing resources and software presently used by representative NATO fire control communities. An initial effort was conducted by a group of interested nations to establish the necessary technology, modify the appropriate components of the S4, and combine them to demonstrate an initial capability to produce a mission planning tool to computed air release points (CARPs) for unguided (ballistic) parachute systems while integrating a four-dimensional meteorological forecasting model in an effort to improve ballistic drop accuracy and eliminate the need for multiple passes over the drop zone.

The software developed from this effort uses a point mass (3-DoF) model to simulate all phases of the airdrop of material. The equations of motion were developed to simulate all phases of such missions, including movement of the pallet within the aircraft, extraction, parachute deployment, and descent to the target zone in order to produce an accurate CARP. Using existing S4 technology, this software has the ability to use high fidelity meteorological models and terrain mapping currently in use in NATO fire control systems to improve the accuracy of airdrops without the use of multiple aircraft passes over the drop zone, dropsonde data, or target zone surveys. This prototype software contains a limited database of extraction methods, ballistic parachutes, and cargo aircraft that has been developed using available reference materials from the USAF and through software testing against an established mission planning tool.

While the software is still in a prototype phase, the point mass model and airdrop methodology have been reviewed and approved by air drop experts in interested NATO nations and the software has been tested against a mission planning tool currently in operational use. A set of drop scenarios were established and run in the NATO airdrop prototype software and in U.S. Joint Precision Airdrop System (JPADS) and then compared. The results were used to calibrate database values and to identify a rough order of magnitude of the difference in the CARPs and impact points between the two models. Analysis of the trajectories of these scenarios with the final database values shows the potential for improvements in ballistic air drop accuracy by using the completely physics-based NABK software versus using JPADS, which uses look-up tables to estimate certain parameters.

It is the hope of SG/2 that this prototype software be further developed with the goal of it serving as a mission planning tool for use by interested NATO nations. In order to reach this goal, the software must be tested against live drops in order to verify that all significant forces have been captured in the model, and to further refine the database values driving the simulation. Once such testing has been completed, the software will be ready for further database expansion to include aircraft and air drop systems in use by the interested NATO nations. It is the hope that more interest can be generated by publication of this paper to the airdrop community to help move this prototype software to the next phases of development.

References

The following are documents referenced in the main sections of this paper. Some of the references unfortunately are not public release, and therefore not all requests for certain documents may be able to be fulfilled. Please contact the Firing Tables and Ballistics Division of the U.S. Army ARDEC to initiate the appropriate process to obtain references.

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Appendix – Detailed Test Case Description

Test	Aircraft	Altitude (m)	Run-in (deg)	Speed (m/s)	Main Chute	Pallet Mass (kg)	Met	Met Type	Calc Type	Target\CARP Lat	Target\CARP Long	Target Alt (m)	Impact or Release Time
test#1	C17	5334	90	130	26ft Ring-Slot	544.31	C	CM	CARP-OUT	57.5	-60	0	7/19/2012 11:29
test#2	C17	5334	90	140	26ft Ring-Slot	816.46	C	CM	CARP-OUT	57.5	-60	0	7/19/2012 11:29
test#3	C17	5334	270	130	26ft Ring-Slot	544.31	C	CM	CARP-OUT	57.5	-60	0	7/19/2012 11:29
test#4	C17	5334	270	140	26ft Ring-Slot	816.46	C	CM	CARP-OUT	57.5	-60	0	7/19/2012 11:29
test#5	C17	5334	180	130	26ft Ring-Slot	544.31	C	CM	CARP-OUT	57.5	-60	0	7/19/2012 11:29
test#6	C17	5334	180	140	26ft Ring-Slot	816.46	C	CM	CARP-OUT	57.5	-60	0	7/19/2012 11:29
test#7	C17	2438.4	90	130	G-12	544.31	C	CM	CARP-OUT	57.5	-60	0	7/19/2012 11:29
test#8	C17	2438.4	90	140	G-12	816.46	C	CM	CARP-OUT	57.5	-60	0	7/19/2012 11:29
test#9	C17	2438.4	270	130	G-12	544.31	C	CM	CARP-OUT	57.5	-60	0	7/19/2012 11:29
test#10	C17	2438.4	270	140	G-12	816.46	C	CM	CARP-OUT	57.5	-60	0	7/19/2012 11:29
test#11	C17	2438.4	180	130	G-12	544.31	C	CM	CARP-OUT	57.5	-60	0	7/19/2012 11:29
test#12	C17	2438.4	180	140	G-12	816.46	C	CM	CARP-OUT	57.5	-60	0	7/19/2012 11:29
test#13	C-130J	5334	90	130	26ft Ring-Slot	544.31	D	CM	CARP-OUT	-77	0	0	7/19/2012 11:29
test#14	C-130J	5334	90	140	26ft Ring-Slot	816.46	D	CM	CARP-OUT	-77	0	0	7/19/2012 11:29
test#15	C-130J	5334	270	130	26ft Ring-Slot	544.31	D	CM	CARP-OUT	-77	0	0	7/19/2012 11:29
test#16	C-130J	5334	270	140	26ft Ring-Slot	816.46	D	CM	CARP-OUT	-77	0	0	7/19/2012 11:29
test#17	C-130J	5334	180	130	26ft Ring-Slot	544.31	D	CM	CARP-OUT	-77	-0.00003	0	7/19/2012 11:29
test#18	C-130J	5334	180	140	26ft Ring-Slot	816.46	D	CM	CARP-OUT	-77	-0.00003	0	7/19/2012 11:29
test#19	C-130J	2438.4	90	130	G-12	544.31	D	CM	CARP-OUT	-77	0	0	7/19/2012 11:29
test#20	C-130J	2438.4	90	140	G-12	816.46	D	CM	CARP-OUT	-77	0	0	7/19/2012 11:29
test#21	C-130J	2438.4	270	130	G-12	544.31	D	CM	CARP-OUT	-77	0	0	7/19/2012 11:29
test#22	C-130J	2438.4	270	140	G-12	816.46	D	CM	CARP-OUT	-77	0	0	7/19/2012 11:29

Test	Aircraft	Altitude (m)	Run-in (deg)	Speed (m/s)	Main Chute	Pallet Mass (kg)	Met	Met Type	Calc Type	Target\CARP Lat	Target\CARP Long	Target Alt (m)	Impact or Release Time
test#23	C-130J	2438.4	180	130	G-12	544.31	D	CM	CARP-OUT	-77	-0.00002	0	7/19/2012 11:29
test#24	C-130J	2438.4	180	140	G-12	816.46	D	CM	CARP-OUT	-77	-0.00001	0	7/19/2012 11:29
test#25	C17	5334	45	130	26ft Ring-Slot	544.31	B	CM	CARP-OUT	-76	-44.99999	0	7/19/2012 11:29
test#26	C17	5334	45	140	26ft Ring-Slot	816.46	B	CM	CARP-OUT	-76	-44.99999	0	7/19/2012 11:29
test#27	C17	5334	225	130	26ft Ring-Slot	544.31	B	CM	CARP-OUT	-76	-45	0	7/19/2012 11:29
test#28	C17	5334	225	140	26ft Ring-Slot	816.46	B	CM	CARP-OUT	-76	-45	0	7/19/2012 11:29
test#29	C17	5334	135	130	26ft Ring-Slot	544.31	B	CM	CARP-OUT	-76	-45.00001	0	7/19/2012 11:29
test#30	C17	5334	135	140	26ft Ring-Slot	816.46	B	CM	CARP-OUT	-76	-45.00001	0	7/19/2012 11:29
test#31	C-130J	2438.4	45	130	G-12	544.31	B	CM	CARP-OUT	-76	-45	0	7/19/2012 11:29
test#32	C-130J	2438.4	45	140	G-12	816.46	B	CM	CARP-OUT	-76	-45	0	7/19/2012 11:29
test#33	C-130J	2438.4	225	130	G-12	544.31	B	CM	CARP-OUT	-76	-45	0	7/19/2012 11:29
test#34	C-130J	2438.4	225	140	G-12	816.46	B	CM	CARP-OUT	-76	-45	0	7/19/2012 11:29
test#35	C-130J	2438.4	135	130	G-12	544.31	B	CM	CARP-OUT	-76	-45	0	7/19/2012 11:29
test#36	C-130J	2438.4	135	140	G-12	816.46	B	CM	CARP-OUT	-76	-45	0	7/19/2012 11:29
test#37	C-130J	5334	0	140	G-12	544.31	A	CM	CARP-OUT	-75.00194	45	0	7/19/2012 11:29
test#38	C-130J	5334	0	140	G-12	816.46	A	CM	CARP-OUT	-75.00203	45	0	7/19/2012 11:29
test#39	C17	2438.4	0	130	26ft Ring-Slot	544.31	A	CM	CARP-OUT	-75.00079	45	0	7/19/2012 11:29
test#40	C17	2438.4	0	130	26ft Ring-Slot	816.46	A	CM	CARP-OUT	-75.00082	45	0	7/19/2012 11:29
test#41	C17	5334	118.125	130	26ft Ring-Slot	544.31	E	CM	CARP-OUT	-14	60	0	7/19/2012 11:29
test#42	C17	5334	118.125	140	26ft Ring-Slot	816.46	E	CM	CARP-OUT	-14	60	0	7/19/2012 11:29
test#43	C17	5334	298.125	130	26ft Ring-Slot	544.31	E	CM	CARP-OUT	-14	60	0	7/19/2012 11:29
test#44	C17	5334	298.125	140	26ft Ring-Slot	816.46	E	CM	CARP-OUT	-14	60	0	7/19/2012 11:29
test#45	C17	5334	208.125	130	26ft Ring-Slot	544.31	E	CM	CARP-OUT	-14	60	0	7/19/2012 11:29
test#46	C17	5334	208.125	140	26ft Ring-Slot	816.46	E	CM	CARP-OUT	-14	60	0	7/19/2012 11:29

Test	Aircraft	Altitude (m)	Run-in (deg)	Speed (m/s)	Main Chute	Pallet Mass (kg)	Met	Met Type	Calc Type	Target\CARP Lat	Target\CARP Long	Target Alt (m)	Impact or Release Time
test#47	C-130J	2438.4	118.125	130	G-12	544.31	E	CM	CARP-OUT	-14	60	0	7/19/2012 11:29
test#48	C-130J	2438.4	118.125	140	G-12	816.46	E	CM	CARP-OUT	-14	60	0	7/19/2012 11:29
test#49	C-130J	2438.4	298.125	130	G-12	544.31	E	CM	CARP-OUT	-14	60	0	7/19/2012 11:29
test#50	C-130J	2438.4	298.125	140	G-12	816.46	E	CM	CARP-OUT	-14	60	0	7/19/2012 11:29
test#51	C-130J	2438.4	208.125	130	G-12	544.31	E	CM	CARP-OUT	-14	60	0	7/19/2012 11:29
test#52	C-130J	2438.4	208.125	130	G-12	816.46	E	CM	CARP-OUT	-14	60	0	7/19/2012 11:29
test#1_gm	C17	5334	90	130	26ft Ring-Slot	544.31	C	GM	CARP-OUT	57.5	-60	0	7/19/2012 11:29
test#2_gm	C17	5334	90	140	26ft Ring-Slot	816.46	C	GM	CARP-OUT	57.5	-60	0	7/19/2012 11:29
test#3_gm	C17	5334	270	130	26ft Ring-Slot	544.31	C	GM	CARP-OUT	57.5	-60	0	7/19/2012 11:29
test#4_gm	C17	5334	270	140	26ft Ring-Slot	816.46	C	GM	CARP-OUT	57.5	-60	0	7/19/2012 11:29
test#5_gm	C17	5334	180	130	26ft Ring-Slot	544.31	C	GM	CARP-OUT	57.5	-60	0	7/19/2012 11:29
test#6_gm	C17	5334	180	140	26ft Ring-Slot	816.46	C	GM	CARP-OUT	57.5	-60	0	7/19/2012 11:29
test#7_gm	C17	2438.4	90	130	G-12	544.31	C	GM	CARP-OUT	57.5	-60	0	7/19/2012 11:29
test#8_gm	C17	2438.4	90	140	G-12	816.46	C	GM	CARP-OUT	57.5	-60	0	7/19/2012 11:29
test#9_gm	C17	2438.4	270	130	G-12	544.31	C	GM	CARP-OUT	57.5	-60	0	7/19/2012 11:29
test#10_gm	C17	2438.4	270	140	G-12	816.46	C	GM	CARP-OUT	57.5	-60	0	7/19/2012 11:29
test#11_gm	C17	2438.4	180	130	G-12	544.31	C	GM	CARP-OUT	57.5	-60	0	7/19/2012 11:29
test#12_gm	C17	2438.4	180	140	G-12	816.46	C	GM	CARP-OUT	57.5	-60	0	7/19/2012 11:29
test#13_gm	C-130J	5334	90	130	26ft Ring-Slot	544.31	D	GM	CARP-OUT	-77	0	0	7/19/2012 11:29
test#14_gm	C-130J	5334	90	140	26ft Ring-Slot	816.46	D	GM	CARP-OUT	-77	0	0	7/19/2012 11:29
test#15_gm	C-130J	5334	270	130	26ft Ring-Slot	544.31	D	GM	CARP-OUT	-77	0	0	7/19/2012 11:29
test#16_gm	C-130J	5334	270	140	26ft Ring-Slot	816.46	D	GM	CARP-OUT	-77	0	0	7/19/2012 11:29
test#17_gm	C-130J	5334	180	130	26ft Ring-Slot	544.31	D	GM	CARP-OUT	-77	-0.00003	0	7/19/2012 11:29
test#18_gm	C-130J	5334	180	140	26ft Ring-Slot	816.46	D	GM	CARP-OUT	-77	-0.00003	0	7/19/2012 11:29

Test	Aircraft	Altitude (m)	Run-in (deg)	Speed (m/s)	Main Chute	Pallet Mass (kg)	Met	Met Type	Calc Type	Target\CARP Lat	Target\CARP Long	Target Alt (m)	Impact or Release Time
test#20_gm	C-130J	2438.4	90	140	G-12	816.46	D	GM	CARP-OUT	-77	0	0	7/19/2012 11:29
test#21_gm	C-130J	2438.4	270	130	G-12	544.31	D	GM	CARP-OUT	-77	0	0	7/19/2012 11:29
test#22_gm	C-130J	2438.4	270	140	G-12	816.46	D	GM	CARP-OUT	-77	0	0	7/19/2012 11:29
test#23_gm	C-130J	2438.4	180	130	G-12	544.31	D	GM	CARP-OUT	-77	-0.00002	0	7/19/2012 11:29
test#24_gm	C-130J	2438.4	180	140	G-12	816.46	D	GM	CARP-OUT	-77	-0.00001	0	7/19/2012 11:29
test#25_gm	C17	5334	45	130	26ft Ring-Slot	544.31	B	GM	CARP-OUT	-76	-44.99999	0	7/19/2012 11:29
test#26_gm	C17	5334	45	140	26ft Ring-Slot	816.46	B	GM	CARP-OUT	-76	-44.99999	0	7/19/2012 11:29
test#27_gm	C17	5334	225	130	26ft Ring-Slot	544.31	B	GM	CARP-OUT	-76	-45	0	7/19/2012 11:29
test#28_gm	C17	5334	225	140	26ft Ring-Slot	816.46	B	GM	CARP-OUT	-76	-45	0	7/19/2012 11:29
test#29_gm	C17	5334	135	130	26ft Ring-Slot	544.31	B	GM	CARP-OUT	-76	-45.00001	0	7/19/2012 11:29
test#30_gm	C17	5334	135	140	26ft Ring-Slot	816.46	B	GM	CARP-OUT	-76	-45.00001	0	7/19/2012 11:29
test#31_gm	C-130J	2438.4	45	130	G-12	544.31	B	GM	CARP-OUT	-76	-45	0	7/19/2012 11:29
test#32_gm	C-130J	2438.4	45	140	G-12	816.46	B	GM	CARP-OUT	-76	-45	0	7/19/2012 11:29
test#33_gm	C-130J	2438.4	225	130	G-12	544.31	B	GM	CARP-OUT	-76	-45	0	7/19/2012 11:29
test#34_gm	C-130J	2438.4	225	140	G-12	816.46	B	GM	CARP-OUT	-76	-45	0	7/19/2012 11:29
test#35_gm	C-130J	2438.4	135	130	G-12	544.31	B	GM	CARP-OUT	-76	-45	0	7/19/2012 11:29
test#36_gm	C-130J	2438.4	135	140	G-12	816.46	B	GM	CARP-OUT	-76	-45	0	7/19/2012 11:29
test#37_gm	C-130J	5334	0	140	G-12	544.31	A	GM	CARP-OUT	-75.00194	45	0	7/19/2012 11:29
test#38_gm	C-130J	5334	0	140	G-12	816.46	A	GM	CARP-OUT	-75.00203	45	0	7/19/2012 11:29
test#39_gm	C17	2438.4	0	130	26ft Ring-Slot	544.31	A	GM	CARP-OUT	-75.00079	45	0	7/19/2012 11:29
test#40_gm	C17	2438.4	0	130	26ft Ring-Slot	816.46	A	GM	CARP-OUT	-75.00082	45	0	7/19/2012 11:29
test#41_gm	C17	5334	118.125	130	26ft Ring-Slot	544.31	E	GM	CARP-OUT	-14	60	0	7/19/2012 11:29
test#42_gm	C17	5334	118.125	140	26ft Ring-Slot	816.46	E	GM	CARP-OUT	-14	60	0	7/19/2012 11:29
test#43_gm	C17	5334	298.125	130	26ft Ring-Slot	544.31	E	GM	CARP-OUT	-14	60	0	7/19/2012 11:29

Test	Aircraft	Altitude (m)	Run-in (deg)	Speed (m/s)	Main Chute	Pallet Mass (kg)	Met	Met Type	Calc Type	Target\CARP Lat	Target\CARP Long	Target Alt (m)	Impact or Release Time
test#44_gm	C17	5334	298.125	140	26ft Ring-Slot	816.46	E	GM	CARP-OUT	-14	60	0	7/19/2012 11:29
test#45_gm	C17	5334	208.125	130	26ft Ring-Slot	544.31	E	GM	CARP-OUT	-14	60	0	7/19/2012 11:29
test#46_gm	C17	5334	208.125	140	26ft Ring-Slot	816.46	E	GM	CARP-OUT	-14	60	0	7/19/2012 11:29
test#47_gm	C-130J	2438.4	118.125	130	G-12	544.31	E	GM	CARP-OUT	-14	60	0	7/19/2012 11:29
test#48_gm	C-130J	2438.4	118.125	140	G-12	816.46	E	GM	CARP-OUT	-14	60	0	7/19/2012 11:29
test#49_gm	C-130J	2438.4	298.125	130	G-12	544.31	E	GM	CARP-OUT	-14	60	0	7/19/2012 11:29
test#50_gm	C-130J	2438.4	298.125	140	G-12	816.46	E	GM	CARP-OUT	-14	60	0	7/19/2012 11:29
test#51_gm	C-130J	2438.4	208.125	130	G-12	544.31	E	GM	CARP-OUT	-14	60	0	7/19/2012 11:29
test#52_gm	C-130J	2438.4	208.125	130	G-12	816.46	E	GM	CARP-OUT	-14	60	0	7/19/2012 11:29
JPADS_test#1	C17	5334	90	130	26ft Ring-Slot	544.31	C	CM	CARP-IN	57.50002	-60.10686	0	7/19/2012 11:29
JPADS_test#2	C17	5334	90	140	26ft Ring-Slot	816.46	C	CM	CARP-IN	57.50002	-60.09309	0	7/19/2012 11:29
JPADS_test#3	C17	5334	270	130	26ft Ring-Slot	544.31	C	CM	CARP-IN	57.50001	-60.07728	0	7/19/2012 11:29
JPADS_test#4	C17	5334	270	140	26ft Ring-Slot	816.46	C	CM	CARP-IN	57.50001	-60.0602	0	7/19/2012 11:29
JPADS_test#5	C17	5334	180	130	26ft Ring-Slot	544.31	C	CM	CARP-IN	57.50743	-60.08666	0	7/19/2012 11:29
JPADS_test#6	C17	5334	180	140	26ft Ring-Slot	816.46	C	CM	CARP-IN	57.50835	-60.07106	0	7/19/2012 11:29
JPADS_test#7	C17	2438.4	90	130	G-12	544.31	C	CM	CARP-IN	57.50001	-60.10818	0	7/19/2012 11:29
JPADS_test#8	C17	2438.4	90	140	G-12	816.46	C	CM	CARP-IN	57.50001	-60.09049	0	7/19/2012 11:29
JPADS_test#9	C17	2438.4	270	130	G-12	544.31	C	CM	CARP-IN	57.50001	-60.08378	0	7/19/2012 11:29
JPADS_test#10	C17	2438.4	270	140	G-12	816.46	C	CM	CARP-IN	57.50001	-60.06306	0	7/19/2012 11:29
JPADS_test#11	C17	2438.4	180	130	G-12	544.31	C	CM	CARP-IN	57.50631	-60.09246	0	7/19/2012 11:29
JPADS_test#12	C17	2438.4	180	140	G-12	816.46	C	CM	CARP-IN	57.50713	-60.07311	0	7/19/2012 11:29
JPADS_test#13	C-130J	5334	90	130	26ft Ring-Slot	544.31	D	CM	CARP-IN	-77.00002	-0.20896	0	7/19/2012 11:29
JPADS_test#14	C-130J	5334	90	140	26ft Ring-Slot	816.46	D	CM	CARP-IN	-77.00001	-0.18515	0	7/19/2012 11:29
JPADS_test#15	C-130J	5334	270	130	26ft Ring-Slot	544.31	D	CM	CARP-IN	-77.00002	-0.13545	0	7/19/2012 11:29

Test	Aircraft	Altitude (m)	Run-in (deg)	Speed (m/s)	Main Chute	Pallet Mass (kg)	Met	Met Type	Calc Type	Target\CARP Lat	Target\CARP Long	Target Alt (m)	Impact or Release Time
JPADS_test#16	C-130J	5334	270	140	26ft Ring-Slot	816.46	D	CM	CARP-IN	-77.00001	-0.10228	0	7/19/2012 11:29
JPADS_test#17	C-130J	5334	180	130	26ft Ring-Slot	544.31	D	CM	CARP-IN	-76.99207	-0.16201	0	7/19/2012 11:29
JPADS_test#18	C-130J	5334	180	140	26ft Ring-Slot	816.46	D	CM	CARP-IN	-76.991	-0.13304	0	7/19/2012 11:29
JPADS_test#19	C-130J	2438.4	90	130	G-12	544.31	D	CM	CARP-IN	-77.00001	-0.2159	0	7/19/2012 11:29
JPADS_test#20	C-130J	2438.4	90	140	G-12	816.46	D	CM	CARP-IN	-77.00001	-0.18435	0	7/19/2012 11:29
JPADS_test#21	C-130J	2438.4	270	130	G-12	544.31	D	CM	CARP-IN	-77.00001	-0.1531	0	7/19/2012 11:29
JPADS_test#22	C-130J	2438.4	270	140	G-12	816.46	D	CM	CARP-IN	-77.00001	-0.11388	0	7/19/2012 11:29
JPADS_test#23	C-130J	2438.4	180	130	G-12	544.31	D	CM	CARP-IN	-76.9931	-0.1779	0	7/19/2012 11:29
JPADS_test#24	C-130J	2438.4	180	140	G-12	816.46	D	CM	CARP-IN	-76.99223	-0.14222	0	7/19/2012 11:29
JPADS_test#25	C17	5334	45	130	26ft Ring-Slot	544.31	B	CM	CARP-IN	-76.00452	-45.06359	0	7/19/2012 11:29
JPADS_test#26	C17	5334	45	140	26ft Ring-Slot	816.46	B	CM	CARP-IN	-76.00535	-45.05945	0	7/19/2012 11:29
JPADS_test#27	C17	5334	225	130	26ft Ring-Slot	544.31	B	CM	CARP-IN	-75.99254	-45.01413	0	7/19/2012 11:29
JPADS_test#28	C17	5334	225	140	26ft Ring-Slot	816.46	B	CM	CARP-IN	-75.99201	-45.0044	0	7/19/2012 11:29
JPADS_test#29	C17	5334	135	130	26ft Ring-Slot	544.31	B	CM	CARP-IN	-75.99202	-45.06613	0	7/19/2012 11:29
JPADS_test#30	C17	5334	135	140	26ft Ring-Slot	816.46	B	CM	CARP-IN	-75.99148	-45.06207	0	7/19/2012 11:29
JPADS_test#31	C-130J	2438.4	45	130	G-12	544.31	B	CM	CARP-IN	-76.01665	-45.05392	0	7/19/2012 11:29
JPADS_test#32	C-130J	2438.4	45	140	G-12	816.46	B	CM	CARP-IN	-76.01506	-45.0491	0	7/19/2012 11:29
JPADS_test#33	C-130J	2438.4	225	130	G-12	544.31	B	CM	CARP-IN	-76.00732	-45.0154	0	7/19/2012 11:29
JPADS_test#34	C-130J	2438.4	225	140	G-12	816.46	B	CM	CARP-IN	-76.00458	-45.00585	0	7/19/2012 11:29
JPADS_test#35	C-130J	2438.4	135	130	G-12	544.31	B	CM	CARP-IN	-76.00672	-45.05352	0	7/19/2012 11:29
JPADS_test#36	C-130J	2438.4	135	140	G-12	816.46	B	CM	CARP-IN	-76.00396	-45.04867	0	7/19/2012 11:29
JPADS_test#37	C-130J	5334	0	140	G-12	544.31	A	CM	CARP-IN	-75.00815	45	0	7/19/2012 11:29
JPADS_test#38	C-130J	5334	0	140	G-12	816.46	A	CM	CARP-IN	-75.00853	45	0	7/19/2012 11:29
JPADS_test#39	C17	2438.4	0	130	26ft Ring-Slot	544.31	A	CM	CARP-IN	-75.00699	45	0	7/19/2012 11:29

Test	Aircraft	Altitude (m)	Run-in (deg)	Speed (m/s)	Main Chute	Pallet Mass (kg)	Met	Met Type	Calc Type	Target\CARP Lat	Target\CARP Long	Target Alt (m)	Impact or Release Time
JPADS_test#40	C17	2438.4	0	130	26ft Ring-Slot	816.46	A	CM	CARP-IN	-75.00729	44.99999	0	7/19/2012 11:29
JPADS_test#41	C17	5334	118.125	130	26ft Ring-Slot	544.31	E	CM	CARP-IN	-13.98501	59.97501	0	7/19/2012 11:29
JPADS_test#42	C17	5334	118.125	140	26ft Ring-Slot	816.46	E	CM	CARP-IN	-13.98639	59.97697	0	7/19/2012 11:29
JPADS_test#43	C17	5334	298.125	130	26ft Ring-Slot	544.31	E	CM	CARP-IN	-13.99286	59.99013	0	7/19/2012 11:29
JPADS_test#44	C17	5334	298.125	140	26ft Ring-Slot	816.46	E	CM	CARP-IN	-13.99513	59.99379	0	7/19/2012 11:29
JPADS_test#45	C17	5334	208.125	130	26ft Ring-Slot	544.31	E	CM	CARP-IN	-13.98223	59.98789	0	7/19/2012 11:29
JPADS_test#46	C17	5334	208.125	140	26ft Ring-Slot	816.46	E	CM	CARP-IN	-13.98324	59.9912	0	7/19/2012 11:29
JPADS_test#47	C-130J	2438.4	118.125	130	G-12	544.31	E	CM	CARP-IN	-13.98634	59.98048	0	7/19/2012 11:29
JPADS_test#48	C-130J	2438.4	118.125	140	G-12	816.46	E	CM	CARP-IN	-13.98803	59.98241	0	7/19/2012 11:29
JPADS_test#49	C-130J	2438.4	298.125	130	G-12	544.31	E	CM	CARP-IN	-13.99246	59.9922	0	7/19/2012 11:29
JPADS_test#50	C-130J	2438.4	298.125	140	G-12	816.46	E	CM	CARP-IN	-13.99487	59.99558	0	7/19/2012 11:29
JPADS_test#51	C-130J	2438.4	208.125	130	G-12	544.31	E	CM	CARP-IN	-13.98396	59.99002	0	7/19/2012 11:29
JPADS_test#52	C-130J	2438.4	208.125	130	G-12	816.46	E	CM	CARP-IN	-13.98579	59.99284	0	7/19/2012 11:29
France_test#1_gm	C17	5334	0	130	26ft Ring-Slot	544.31	FRA1	GM	CARP-IN	43.50665	6.4946	193	1/1/2012 0:00
France_test#1_cm	C17	5334	0	130	26ft Ring-Slot	544.31	FRA1	CM	CARP-IN	43.50665	6.4946	193	1/1/2012 0:00
France_test#2_gm	C17	5334	45	130	26ft Ring-Slot	544.31	FRA1	GM	CARP-IN	43.50855	6.48636	193	1/1/2012 0:00
France_test#2_cm	C17	5334	45	130	26ft Ring-Slot	544.31	FRA1	CM	CARP-IN	43.50855	6.48636	193	1/1/2012 0:00
France_test#3_gm	C17	5334	90	130	26ft Ring-Slot	544.31	FRA1	GM	CARP-IN	43.51455	6.48221	193	1/1/2012 0:00
France_test#3_cm	C17	5334	90	130	26ft Ring-Slot	544.31	FRA1	CM	CARP-IN	43.51455	6.48221	193	1/1/2012 0:00
France_test#4_gm	C17	5334	135	130	26ft Ring-Slot	544.31	FRA1	GM	CARP-IN	43.52102	6.48571	193	1/1/2012 0:00
France_test#4_cm	C17	5334	135	130	26ft Ring-Slot	544.31	FRA1	CM	CARP-IN	43.52102	6.48571	193	1/1/2012 0:00
France_test#5_gm	C17	5334	180	130	26ft Ring-Slot	544.31	FRA1	GM	CARP-IN	43.52335	6.49462	193	1/1/2012 0:00
France_test#5_cm	C17	5334	180	130	26ft Ring-Slot	544.31	FRA1	CM	CARP-IN	43.52335	6.49462	193	1/1/2012 0:00
France_test#6_gm	C17	5334	225	130	26ft Ring-Slot	544.31	FRA1	GM	CARP-IN	43.52034	6.50259	193	1/1/2012 0:00

Test	Aircraft	Altitude (m)	Run-in (deg)	Speed (m/s)	Main Chute	Pallet Mass (kg)	Met	Met Type	Calc Type	Target\CARP Lat	Target\CARP Long	Target Alt (m)	Impact or Release Time
France_test#6_cm	C17	5334	225	130	26ft Ring-Slot	544.31	FRA1	CM	CARP-IN	43.52034	6.50259	193	1/1/2012 0:00
France_test#7_gm	C17	5334	270	130	26ft Ring-Slot	544.31	FRA1	GM	CARP-IN	43.51455	6.50521	193	1/1/2012 0:00
France_test#7_cm	C17	5334	270	130	26ft Ring-Slot	544.31	FRA1	CM	CARP-IN	43.51455	6.50521	193	1/1/2012 0:00
France_test#8_gm	C17	5334	315	130	26ft Ring-Slot	544.31	FRA1	GM	CARP-IN	43.50918	6.50198	193	1/1/2012 0:00
France_test#8_cm	C17	5334	315	130	26ft Ring-Slot	544.31	FRA1	CM	CARP-IN	43.50918	6.50198	193	1/1/2012 0:00
France_test#9_gm	C17	5334	0	130	26ft Ring-Slot	544.31	FRA2	GM	CARP-IN	47.49515	7.46319	398	1/1/2012 3:00
France_test#9_cm	C17	5334	0	130	26ft Ring-Slot	544.31	FRA2	CM	CARP-IN	47.49515	7.46319	398	1/1/2012 3:00
France_test#10_gm	C17	5334	45	130	26ft Ring-Slot	544.31	FRA2	GM	CARP-IN	47.49664	7.4543	398	1/1/2012 3:00
France_test#10_cm	C17	5334	45	130	26ft Ring-Slot	544.31	FRA2	CM	CARP-IN	47.49664	7.4543	398	1/1/2012 3:00
France_test#11_gm	C17	5334	90	130	26ft Ring-Slot	544.31	FRA2	GM	CARP-IN	47.50267	7.44922	398	1/1/2012 3:00
France_test#11_cm	C17	5334	90	130	26ft Ring-Slot	544.31	FRA2	CM	CARP-IN	47.50267	7.44922	398	1/1/2012 3:00
France_test#12_gm	C17	5334	135	130	26ft Ring-Slot	544.31	FRA2	GM	CARP-IN	47.50953	7.45308	398	1/1/2012 3:00
France_test#12_cm	C17	5334	135	130	26ft Ring-Slot	544.31	FRA2	CM	CARP-IN	47.50953	7.45308	398	1/1/2012 3:00
France_test#13_gm	C17	5334	180	130	26ft Ring-Slot	544.31	FRA2	GM	CARP-IN	47.51173	7.46323	398	1/1/2012 3:00
France_test#13_cm	C17	5334	180	130	26ft Ring-Slot	544.31	FRA2	CM	CARP-IN	47.51173	7.46323	398	1/1/2012 3:00
France_test#14_gm	C17	5334	225	130	26ft Ring-Slot	544.31	FRA2	GM	CARP-IN	47.50832	7.47158	398	1/1/2012 3:00
France_test#14_cm	C17	5334	225	130	26ft Ring-Slot	544.31	FRA2	CM	CARP-IN	47.50832	7.47158	398	1/1/2012 3:00
France_test#15_gm	C17	5334	270	130	26ft Ring-Slot	544.31	FRA2	GM	CARP-IN	47.50266	7.47384	398	1/1/2012 3:00
France_test#15_cm	C17	5334	270	130	26ft Ring-Slot	544.31	FRA2	CM	CARP-IN	47.50266	7.47384	398	1/1/2012 3:00
France_test#16_gm	C17	5334	315	130	26ft Ring-Slot	544.31	FRA2	GM	CARP-IN	47.4977	7.47053	398	1/1/2012 3:00
France_test#16_cm	C17	5334	315	130	26ft Ring-Slot	544.31	FRA2	CM	CARP-IN	47.4977	7.47053	398	1/1/2012 3:00
France_test#17_gm	C17	5334	0	130	26ft Ring-Slot	544.31	FRA3	GM	CARP-IN	43.49227	6.49477	193	8/1/2012 6:00
France_test#17_cm	C17	5334	0	130	26ft Ring-Slot	544.31	FRA3	CM	CARP-IN	43.49227	6.49477	193	8/1/2012 6:00
France_test#18_gm	C17	5334	45	130	26ft Ring-Slot	544.31	FRA3	GM	CARP-IN	43.49417	6.486	193	8/1/2012 6:00

Test	Aircraft	Altitude (m)	Run-in (deg)	Speed (m/s)	Main Chute	Pallet Mass (kg)	Met	Met Type	Calc Type	Target\CARP Lat	Target\CARP Long	Target Alt (m)	Impact or Release Time
France_test#18_cm	C17	5334	45	130	26ft Ring-Slot	544.31	FRA3	CM	CARP-IN	43.49417	6.486	193	8/1/2012 6:00
France_test#19_gm	C17	5334	90	130	26ft Ring-Slot	544.31	FRA3	GM	CARP-IN	43.50055	6.48181	193	8/1/2012 6:00
France_test#19_cm	C17	5334	90	130	26ft Ring-Slot	544.31	FRA3	CM	CARP-IN	43.50055	6.48181	193	8/1/2012 6:00
France_test#20_gm	C17	5334	135	130	26ft Ring-Slot	544.31	FRA3	GM	CARP-IN	43.50708	6.48584	193	8/1/2012 6:00
France_test#20_cm	C17	5334	135	130	26ft Ring-Slot	544.31	FRA3	CM	CARP-IN	43.50708	6.48584	193	8/1/2012 6:00
France_test#21_gm	C17	5334	180	130	26ft Ring-Slot	544.31	FRA3	GM	CARP-IN	43.50909	6.49481	193	8/1/2012 6:00
France_test#21_cm	C17	5334	180	130	26ft Ring-Slot	544.31	FRA3	CM	CARP-IN	43.50909	6.49481	193	8/1/2012 6:00
France_test#22_gm	C17	5334	225	130	26ft Ring-Slot	544.31	FRA3	GM	CARP-IN	43.50609	6.50241	193	8/1/2012 6:00
France_test#22_cm	C17	5334	225	130	26ft Ring-Slot	544.31	FRA3	CM	CARP-IN	43.50609	6.50241	193	8/1/2012 6:00
France_test#23_gm	C17	5334	270	130	26ft Ring-Slot	544.31	FRA3	GM	CARP-IN	43.50055	6.50507	193	8/1/2012 6:00
France_test#23_cm	C17	5334	270	130	26ft Ring-Slot	544.31	FRA3	CM	CARP-IN	43.50055	6.50507	193	8/1/2012 6:00
France_test#24_gm	C17	5334	315	130	26ft Ring-Slot	544.31	FRA3	GM	CARP-IN	43.49514	6.50222	193	8/1/2012 6:00
France_test#24_cm	C17	5334	315	130	26ft Ring-Slot	544.31	FRA3	CM	CARP-IN	43.49514	6.50222	193	8/1/2012 6:00
France_test#25_gm	C17	5334	0	130	26ft Ring-Slot	544.31	FRA4	GM	CARP-IN	47.48282	7.48628	398	8/1/2012 9:00
France_test#25_cm	C17	5334	0	130	26ft Ring-Slot	544.31	FRA4	CM	CARP-IN	47.48282	7.48628	398	8/1/2012 9:00
France_test#26_gm	C17	5334	45	130	26ft Ring-Slot	544.31	FRA4	GM	CARP-IN	47.48517	7.47676	398	8/1/2012 9:00
France_test#26_cm	C17	5334	45	130	26ft Ring-Slot	544.31	FRA4	CM	CARP-IN	47.48517	7.47676	398	8/1/2012 9:00
France_test#27_gm	C17	5334	90	130	26ft Ring-Slot	544.31	FRA4	GM	CARP-IN	47.49163	7.47297	398	8/1/2012 9:00
France_test#27_cm	C17	5334	90	130	26ft Ring-Slot	544.31	FRA4	CM	CARP-IN	47.49163	7.47297	398	8/1/2012 9:00
France_test#28_gm	C17	5334	135	130	26ft Ring-Slot	544.31	FRA4	GM	CARP-IN	47.49771	7.47734	398	8/1/2012 9:00
France_test#28_cm	C17	5334	135	130	26ft Ring-Slot	544.31	FRA4	CM	CARP-IN	47.49771	7.47734	398	8/1/2012 9:00
France_test#29_gm	C17	5334	180	130	26ft Ring-Slot	544.31	FRA4	GM	CARP-IN	47.49972	7.4863	398	8/1/2012 9:00
France_test#29_cm	C17	5334	180	130	26ft Ring-Slot	544.31	FRA4	CM	CARP-IN	47.49972	7.4863	398	8/1/2012 9:00
France_test#30_gm	C17	5334	225	130	26ft Ring-Slot	544.31	FRA4	GM	CARP-IN	47.49715	7.49444	398	8/1/2012 9:00

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France_test#30_cm	C17	5334	225	130	26ft Ring-Slot	544.31	FRA4	CM	CARP-IN	47.49715	7.49444	398	8/1/2012 9:00
France_test#31_gm	C17	5334	270	130	26ft Ring-Slot	544.31	FRA4	GM	CARP-IN	47.49163	7.49792	398	8/1/2012 9:00
France_test#31_cm	C17	5334	270	130	26ft Ring-Slot	544.31	FRA4	CM	CARP-IN	47.49163	7.49792	398	8/1/2012 9:00
France_test#32_gm	C17	5334	315	130	26ft Ring-Slot	544.31	FRA4	GM	CARP-IN	47.48577	7.49493	398	8/1/2012 9:00
France_test#32_cm	C17	5334	315	130	26ft Ring-Slot	544.31	FRA4	CM	CARP-IN	47.48577	7.49493	398	8/1/2012 9:00
France_test#33_gm	C17	5334	0	130	26ft Ring-Slot	544.31	FRA5	GM	CARP-IN	43.4966	6.50938	193	11/15/2012 12:00
France_test#33_cm	C17	5334	0	130	26ft Ring-Slot	544.31	FRA5	CM	CARP-IN	43.4966	6.50938	193	11/15/2012 12:00
France_test#34_gm	C17	5334	45	130	26ft Ring-Slot	544.31	FRA5	GM	CARP-IN	43.4993	6.50176	193	11/15/2012 12:00
France_test#34_cm	C17	5334	45	130	26ft Ring-Slot	544.31	FRA5	CM	CARP-IN	43.4993	6.50176	193	11/15/2012 12:00
France_test#35_gm	C17	5334	90	130	26ft Ring-Slot	544.31	FRA5	GM	CARP-IN	43.50484	6.49871	193	11/15/2012 12:00
France_test#35_cm	C17	5334	90	130	26ft Ring-Slot	544.31	FRA5	CM	CARP-IN	43.50484	6.49871	193	11/15/2012 12:00
France_test#36_gm	C17	5334	135	130	26ft Ring-Slot	544.31	FRA5	GM	CARP-IN	43.51052	6.50155	193	11/15/2012 12:00
France_test#36_cm	C17	5334	135	130	26ft Ring-Slot	544.31	FRA5	CM	CARP-IN	43.51052	6.50155	193	11/15/2012 12:00
France_test#37_gm	C17	5334	180	130	26ft Ring-Slot	544.31	FRA5	GM	CARP-IN	43.51337	6.50936	193	11/15/2012 12:00
France_test#37_cm	C17	5334	180	130	26ft Ring-Slot	544.31	FRA5	CM	CARP-IN	43.51337	6.50936	193	11/15/2012 12:00
France_test#38_gm	C17	5334	225	130	26ft Ring-Slot	544.31	FRA5	GM	CARP-IN	43.51118	6.51808	193	11/15/2012 12:00
France_test#38_cm	C17	5334	225	130	26ft Ring-Slot	544.31	FRA5	CM	CARP-IN	43.51118	6.51808	193	11/15/2012 12:00
France_test#39_gm	C17	5334	270	130	26ft Ring-Slot	544.31	FRA5	GM	CARP-IN	43.50484	6.52182	193	11/15/2012 12:00
France_test#39_cm	C17	5334	270	130	26ft Ring-Slot	544.31	FRA5	CM	CARP-IN	43.50484	6.52182	193	11/15/2012 12:00
France_test#40_gm	C17	5334	315	130	26ft Ring-Slot	544.31	FRA5	GM	CARP-IN	43.49865	6.51787	193	11/15/2012 12:00
France_test#40_cm	C17	5334	315	130	26ft Ring-Slot	544.31	FRA5	CM	CARP-IN	43.49865	6.51787	193	11/15/2012 12:00
France_test#41_gm	C17	5334	0	130	26ft Ring-Slot	544.31	FRA6	GM	CARP-IN	47.49359	7.49376	398	11/15/2012 15:00
France_test#41_cm	C17	5334	0	130	26ft Ring-Slot	544.31	FRA6	CM	CARP-IN	47.49359	7.49376	398	11/15/2012 15:00
France_test#42_gm	C17	5334	45	130	26ft Ring-Slot	544.31	FRA6	GM	CARP-IN	47.49584	7.48488	398	11/15/2012 15:00

Test	Aircraft	Altitude (m)	Run-in (deg)	Speed (m/s)	Main Chute	Pallet Mass (kg)	Met	Met Type	Calc Type	Target\CARP Lat	Target\CARP Long	Target Alt (m)	Impact or Release Time
France_test#42_cm	C17	5334	45	130	26ft Ring-Slot	544.31	FRA6	CM	CARP-IN	47.49584	7.48488	398	11/15/2012 15:00
France_test#43_gm	C17	5334	90	130	26ft Ring-Slot	544.31	FRA6	GM	CARP-IN	47.50186	7.48093	398	11/15/2012 15:00
France_test#43_cm	C17	5334	90	130	26ft Ring-Slot	544.31	FRA6	CM	CARP-IN	47.50186	7.48093	398	11/15/2012 15:00
France_test#44_gm	C17	5334	135	130	26ft Ring-Slot	544.31	FRA6	GM	CARP-IN	47.50801	7.48468	398	11/15/2012 15:00
France_test#44_cm	C17	5334	135	130	26ft Ring-Slot	544.31	FRA6	CM	CARP-IN	47.50801	7.48468	398	11/15/2012 15:00
France_test#45_gm	C17	5334	180	130	26ft Ring-Slot	544.31	FRA6	GM	CARP-IN	47.51039	7.49377	398	11/15/2012 15:00
France_test#45_cm	C17	5334	180	130	26ft Ring-Slot	544.31	FRA6	CM	CARP-IN	47.51039	7.49377	398	11/15/2012 15:00
France_test#46_gm	C17	5334	225	130	26ft Ring-Slot	544.31	FRA6	GM	CARP-IN	47.50772	7.50242	398	11/15/2012 15:00
France_test#46_cm	C17	5334	225	130	26ft Ring-Slot	544.31	FRA6	CM	CARP-IN	47.50772	7.50242	398	11/15/2012 15:00
France_test#47_gm	C17	5334	270	130	26ft Ring-Slot	544.31	FRA6	GM	CARP-IN	47.50186	7.50574	398	11/15/2012 15:00
France_test#47_cm	C17	5334	270	130	26ft Ring-Slot	544.31	FRA6	CM	CARP-IN	47.50186	7.50574	398	11/15/2012 15:00
France_test#48_gm	C17	5334	315	130	26ft Ring-Slot	544.31	FRA6	GM	CARP-IN	47.49613	7.50222	398	11/15/2012 15:00
France_test#48_cm	C17	5334	315	130	26ft Ring-Slot	544.31	FRA6	CM	CARP-IN	47.49613	7.50222	398	11/15/2012 15:00
Iraq_test#1_gm	C17	5334	0	130	26ft Ring-Slot	544.31	IRQ	GM	CARP-IN	30.00621	44.98786	259	2/16/2005 6:00
Iraq_test#1_cm	C17	5334	0	130	26ft Ring-Slot	544.31	IRQ	CM	CARP-IN	30.00621	44.98786	259	2/16/2005 6:00
Iraq_test#2_gm	C17	5334	45	130	26ft Ring-Slot	544.31	IRQ	GM	CARP-IN	30.00737	44.98083	259	2/16/2005 6:00
Iraq_test#2_cm	C17	5334	45	130	26ft Ring-Slot	544.31	IRQ	CM	CARP-IN	30.00737	44.98083	259	2/16/2005 6:00
Iraq_test#3_gm	C17	5334	90	130	26ft Ring-Slot	544.31	IRQ	GM	CARP-IN	30.01348	44.97644	259	2/16/2005 6:00
Iraq_test#3_cm	C17	5334	90	130	26ft Ring-Slot	544.31	IRQ	CM	CARP-IN	30.01348	44.97644	259	2/16/2005 6:00
Iraq_test#4_gm	C17	5334	135	130	26ft Ring-Slot	544.31	IRQ	GM	CARP-IN	30.0207	44.97959	259	2/16/2005 6:00
Iraq_test#4_cm	C17	5334	135	130	26ft Ring-Slot	544.31	IRQ	CM	CARP-IN	30.0207	44.97959	259	2/16/2005 6:00
Iraq_test#5_gm	C17	5334	180	130	26ft Ring-Slot	544.31	IRQ	GM	CARP-IN	30.02271	44.9879	259	2/16/2005 6:00
Iraq_test#5_cm	C17	5334	180	130	26ft Ring-Slot	544.31	IRQ	CM	CARP-IN	30.02271	44.9879	259	2/16/2005 6:00
Iraq_test#6_gm	C17	5334	225	130	26ft Ring-Slot	544.31	IRQ	GM	CARP-IN	30.01897	44.99421	259	2/16/2005 6:00

Test	Aircraft	Altitude (m)	Run-in (deg)	Speed (m/s)	Main Chute	Pallet Mass (kg)	Met	Met Type	Calc Type	Target\CARP Lat	Target\CARP Long	Target Alt (m)	Impact or Release Time
Iraq_test#6_cm	C17	5334	225	130	26ft Ring-Slot	544.31	IRQ	CM	CARP-IN	30.01897	44.99421	259	2/16/2005 6:00
Iraq_test#7_gm	C17	5334	270	130	26ft Ring-Slot	544.31	IRQ	GM	CARP-IN	30.01348	44.99564	259	2/16/2005 6:00
Iraq_test#7_cm	C17	5334	270	130	26ft Ring-Slot	544.31	IRQ	CM	CARP-IN	30.01348	44.99564	259	2/16/2005 6:00
Iraq_test#8_gm	C17	5334	315	130	26ft Ring-Slot	544.31	IRQ	GM	CARP-IN	30.00883	44.99321	259	2/16/2005 6:00
Iraq_test#8_cm	C17	5334	315	130	26ft Ring-Slot	544.31	IRQ	CM	CARP-IN	30.00883	44.99321	259	2/16/2005 6:00
Afg_test#1_gm	C17	5334	0	130	26ft Ring-Slot	544.31	AFG	GM	CARP-IN	35.98419	65.98375	1273	2/4/2005 3:00
Afg_test#1_cm	C17	5334	0	130	26ft Ring-Slot	544.31	AFG	CM	CARP-IN	35.98419	65.98375	1273	2/4/2005 3:00
Afg_test#2_gm	C17	5334	45	130	26ft Ring-Slot	544.31	AFG	GM	CARP-IN	35.98606	65.97502	1273	2/4/2005 3:00
Afg_test#2_cm	C17	5334	45	130	26ft Ring-Slot	544.31	AFG	CM	CARP-IN	35.98606	65.97502	1273	2/4/2005 3:00
Afg_test#3_gm	C17	5334	90	130	26ft Ring-Slot	544.31	AFG	GM	CARP-IN	35.99317	65.9715	1273	2/4/2005 3:00
Afg_test#3_cm	C17	5334	90	130	26ft Ring-Slot	544.31	AFG	CM	CARP-IN	35.99317	65.9715	1273	2/4/2005 3:00
Afg_test#4_gm	C17	5334	135	130	26ft Ring-Slot	544.31	AFG	GM	CARP-IN	35.99941	65.97611	1273	2/4/2005 3:00
Afg_test#4_cm	C17	5334	135	130	26ft Ring-Slot	544.31	AFG	CM	CARP-IN	35.99941	65.97611	1273	2/4/2005 3:00
Afg_test#5_gm	C17	5334	180	130	26ft Ring-Slot	544.31	AFG	GM	CARP-IN	36.00064	65.9838	1273	2/4/2005 3:00
Afg_test#5_cm	C17	5334	180	130	26ft Ring-Slot	544.31	AFG	CM	CARP-IN	36.00064	65.9838	1273	2/4/2005 3:00
Afg_test#6_gm	C17	5334	225	130	26ft Ring-Slot	544.31	AFG	GM	CARP-IN	35.99789	65.98959	1273	2/4/2005 3:00
Afg_test#6_cm	C17	5334	225	130	26ft Ring-Slot	544.31	AFG	CM	CARP-IN	35.99789	65.98959	1273	2/4/2005 3:00
Afg_test#7_gm	C17	5334	270	130	26ft Ring-Slot	544.31	AFG	GM	CARP-IN	35.99317	65.99203	1273	2/4/2005 3:00
Afg_test#7_cm	C17	5334	270	130	26ft Ring-Slot	544.31	AFG	CM	CARP-IN	35.99317	65.99203	1273	2/4/2005 3:00
Afg_test#8_gm	C17	5334	315	130	26ft Ring-Slot	544.31	AFG	GM	CARP-IN	35.9878	65.99036	1273	2/4/2005 3:00
Afg_test#8_cm	C17	5334	315	130	26ft Ring-Slot	544.31	AFG	CM	CARP-IN	35.9878	65.99036	1273	2/4/2005 3:00