

PACD2008 : operational requirements fulfilled

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In Afghanistan, all allied nations are confronted with situations where engaging units deeper gives tactical or strategic advantages, but also strains the supply lines in a hostile environment. Logistic aircraft, including helicopters, get shot at on a weekly basis, not to mention land mines and ambush threats on ground convoys. High altitude airdrop is an alternative that proves economically viable if only one aircraft a year can be preserved – and its crew lives. The trouble is, altitude spoils the precision of conventional airdrop.

Precision Airdrop Capability Demonstration 2008 (PACD2008) focused on the lightweight precision airdrop technology (≤ 2 Klbs) that allows supporting paratrooper missions and re-supplying isolated special forces units or forward operation bases. The demonstration showed how Precision Aerial Delivery Systems (PADS) were developed at various cost and technology levels to address many possible cases in modern warfare. High velocity ballistic, guided round parachute, guided parafoil and hybrid systems, all state-of-the-art technologies were represented, as well as the accompanying mission planner and weather awareness technologies. Four organizing nations (Belgium, France, Germany and the United States of America) provided 5 aircraft to perform the airdrop part of the demonstration, with a most impressive show of interoperability between US systems and Belgian aircraft.

One of PACD2008 challenges was to land a system along a tree line, in the width of a road. A unit re-supplied at night can remain under cover until the supplies are down, and locate them on their way to another location with limited recovery time. A second challenge was to land supplies at a location offering the best terrain features, protecting both the supplies and the re-supplied unit. In addition to landing precision, these scenarios stressed the need for way-points, preferential axes and no-fly zones management in the navigation software.

In addition to an appraised operational approach and successful communication plan (including interest from the local TV news), PACD2008 also marked a step in the PADS development process with the best landing precision statistics ever for a precision airdrop demo. This shows the “Special Operations” product segment targeted by the French demo is, thanks to the anticipated US efforts in this field, mature today.

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Nomenclature

PACD	=	Precision Airdrop Capability Demonstration
AGL	=	Above Ground Level
CARP	=	Computed Air Release Point
CDS	=	cargo delivery system
DGA	=	Délégation Générale pour l'Armement (FR MoD procurement agency)
DZ	=	Dropzone
FOB	=	Forward Operation Base
HALO	=	High Altitude Low Opening
HV	=	High Velocity
IP	=	Intended Point of impact
JPACWG	=	Joint Precision Airdrop Capability Working Group
JPADS	=	Joint Precision Aerial Delivery System
LAR	=	Launch Acceptable Region, a.k.a. ARC, Aerial Release Circle in other publications
LCADS	=	Low Cost Aerial Delivery System
LV	=	Low Velocity
MP	=	Mission Planner
MSL	=	Mean Sea Level
NATO	=	North Atlantic Treaty Organization
PADS	=	Precision Aerial Delivery Systems
PI	=	actual Point of Impact
RoF	=	Rate of Fall
SOF	=	Special Operation Forces

I. Introduction

France was the lead nation of PACD 2008, the Ministry of Defense shared tasks between the Délégation Générale pour l'Armement (DGA) testing centers, for the technical direction of the demo (DGA is the national armament procurement agency), and the French Air Force, for operational support. Belgium, Germany and the United States of America were the other participating nations, contributing aircraft and the majority of demonstrated airdrop systems.

The general information about PACD demonstrations is documented in a former AIAA paper¹ and in PACD2008 final report². This document deals mainly with PACD2008 specific features.

The second PACD shares a common purpose with previous PACD¹ and PATCAD⁵ demonstrations: to bring together allied militaries, governments and industry to collaborate and become familiar with the latest airdrop technologies. These demonstrations provide a forum for the international community of industry and government agencies involved in the development and utilization of precision aerial delivery (PAD) technologies to share experience, communicate and collaborate on demonstration cases that show the potential for common technical requirements, and witness state-of-the-art and emerging capabilities in precision airdrop. In addition to this general purpose, PACD2008 was strongly influenced by a new background.

In the context of asymmetric warfare, it is common for North Atlantic Treaty Organization (NATO) forces not to have absolute ground control at every point of the logistic lines. In the recent years NATO authorities marked this as a key feature to adapt their fighting forces for missions of Defense Against Terrorism (DAT 5), the need to adapt led to a Program of Work that included action DAT 5: "Precision Air Drop Technology for Special Operations Forces".

PACD2008 was organized in the scope of DAT-5. This background oriented the definition of PACD2008 specific purpose and airdrop scenarios, and was compatible with the PACD specific limitations:

- Review the precision airdrop concepts that can support Special Operation Forces (SOF) and, in a larger measure, Forward Operation Bases (FOB) in a context of DAT (theater of operations with low infrastructure – variable level of ground control)
- Demonstrate the performance of current and emerging technology with drop cases based on scenarios that prove tactical adaptation of the systems in addition to technical performance
- Evaluate the stealth level of demonstrated systems
- Payloads up to 2,000 lbs

In addition, PACD 2008 included several drop cases aiming at a demonstration of interoperability, dropping the same system from different nations' planes to identify load conception and configuration or procedure related issues that will orient further work in the NATO Joint Precision Airdrop Capability Working Group (JPACWG) about interoperability.

II. The rationale for high altitude airdrop and the need for technical development

A. Concept rationale

Land mines and ambush threats on ground convoys have a weekly cost in lives and equipment. Yet some mission elements and FOBs have to be supported in remote areas. Aerial delivery in the broader sense is the natural alternative.

Aircraft vulnerability analyses show that a significant increase in survivability against ground to air threats is achieved by flying below 500 ft above ground level (AGL) or above 18,000 ft mean sea level (MSL). Yet the low speed of helicopters and the terrain features in mountainous regions dramatically spoil the advantage below 500 ft AGL, while making low altitude airdrop practically impossible, as experienced formerly in the Balkans, where many nations started developing high altitude airdrop solutions. In theaters where the majority of ground to air threats are small caliber weapons, high altitude airdrop from 3,000 AGL to up to 18,000 ft MSL provide many opportunities to improve aircraft and crew survivability with a range of technical options. Some of these options include guided parachute solutions that yield additional tactical advantages; allowing for the operation of smaller dropzones (DZs), providing horizontal stand-off in addition to vertical stand-off, promising further evolutions for the airdrop of sensitive stores, and adapting the airdrop system trajectory to the tactical situation and threats.

B. Technical developments

Let "Drift", the effect of wind on the movement of a parachute, be written in a simple form assuming the wind is uniform (or has been suitably averaged) and the rate of fall (RoF) is constant.

$$(1) \text{ Drift} = \text{Wind} \times \text{Altitude} / \text{RoF}$$

Mission planning includes computing this effect to have the right position of the air release point. Yet mission planning uses an expected value of the wind, which leads to an error in planning the drift

$$(2) \text{ Drift_error} = (\text{Wind} - \text{exp_Wind}) \times \text{Altitude} / \text{RoF}$$

exp_wind being the wind expected at mission planning stage
(either forecast or prior measurement)

This simple formula shows that for a given altitude, there are only two sources for drift error. In the 90's, the knowledge of wind conditions and the long time of descent of conventional parachutes made for poor airdrop precision at high altitude, limiting the benefit of the developing concept. Incremental improvements focused on minimizing the two sources of the loss of precision, the wind profile precision and the time of descent, with the use of enhanced wind forecast models, in situ wind profile measurement and high velocity ballistic systems.

The combination of such improvements and their real-time coordination led to the development of various communication chains and data processing software to calculate a Computed Aerial Release Point (CARP) in flight, with the best and latest wind data available, along with a variety of improved ballistic airdrop systems that now include High Velocity and High Altitude Low Opening (HV and HALO) Container Delivery Systems (CDS).

Radical developments include self-guided airdrop systems, mainly based on parafoil technology today, that emerged as another technical concept to enhance precision : to work on the consequence of airdrop imprecision (lateral translation capability) instead of its causes (wind profile accuracy and time of exposition).

New technical solutions may emerge for the same concepts, yet according to (2), no radically new concept shall emerge.

III. Precision Airdrop Concepts/Systems demonstrated

A. Wind and Weather systems

French units participating in the demo had weather information support from CMOE, "centre météorologique des opérations extérieures de l'armée de l'air", sending wind forecast information by fax and e-mail to the PACD operation's room at Cazaux (French Air Force Base). CMOE has various other data-links to feed en-user systems.

The US Joint Air Force Army Weather Information Network (JAAWIN) run by the US Air Force Weather Agency (AFWA) web interface gave access to simple 1D wind profiles while the JPADS-MP provided the US navigators with the more detailed 4D wind forecast from their national models and dropsonde data.



Figure 1: JAAWIN interface(Biscarosse : red circle) and JPADS-MP block III, including the drop sonde (below right).

In addition to US aircraft, the JPADS-MP was operated on the BE C-130 during the demonstration, showing the possibility to interface the systems and procedures of two nations.

B. Mission Planners

ASTRAL:

ASTRAL software, designed specifically for Centre d'Essais en Vol, Base de Toulouse (formerly known as CAP/Centre Aéroporté then CEVAP) was used again for PACD2008.

Made to support test and evaluation airdrop activities, it has a scientific-oriented structure and functionality that makes it unsuitable for operational use but highly versatile for experimental activities.

In the case of PACD2008, many systems were to be pushed beyond the standard limits in terms of Launch Acceptability Region (LAR). This was necessary for the interest of the demonstration and possible thanks to high quality upper air sounding wind data provided every 30 minutes by CELM, DGA's host center for the demonstration. ASTRAL's advanced Monte-Carlo and navigation simulation features not only allowed for the construction of a LAR based on a lift to drag ratio (L/D) and a predefined horizontal margin, but also the realistic simulation of the airborne guidance unit (AGU) behavior in non linear, random wind conditions. This additional capability allowed for a determination of a 99% success LAR for Microfly (Airborne Systems North America) with an offset roughly 30% superior to the standard provider offset function. This analysis was necessary to demonstrate Microfly could be dropped alongside Onyx500 (Atair Aerospace system already cleared by the provider for bigger offsets) and the US paratroopers, the most technically demanding drop case at PACD2008.

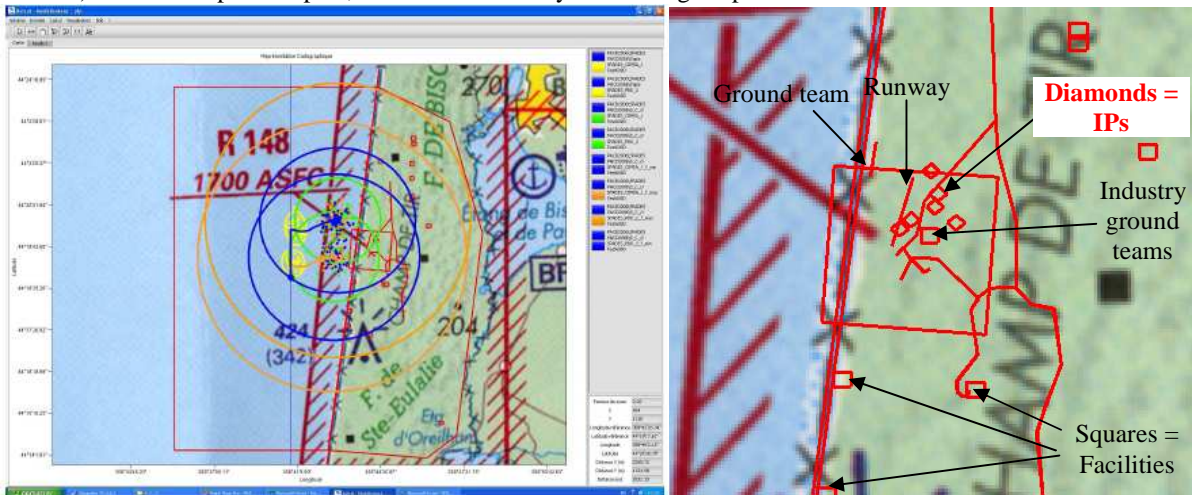


Figure 2: ASTRAL interface for CARP management(DGA/CEV software) and a detail of the DZ at CELM. The legend to the right of ASTRAL allow to identify the system and simulation case (accidental free fall is yellow, accidental max L/D orange, min L/D is blue, industry clearance is green.)

JPADS-MP:

Where ASTRAL allows the user to define any equation but is reserved for a few specialists to use, JPADS-MP (see Fig. 1) is a fully integrated, operational solution that covers all functions from wind data acquisition to AGU setup. Installed in a C-17 or C-130, it allows the navigator to select an airdrop system from a database and requires

only the input of update values such as the total rigged weight of each payload and the planned release conditions. NSRDEC masters the architecture of JPADS and contracts industry for separate product segments. JPADS-MP hardware was designed by Planning Systems Inc. (PSI). It has and will have continuous industry support to ensure it evolves with its environment, new standards for system interface and supports new PADS with minimum impact from the end user's perspective.

"Provider" mission planners:

Industry providers exhibited their own mission planners during the static display. These products are usually evolving rapidly, with new software or hardware plug-ins being easy to add to cover new functionality, though they do not all have the same demonstrated ruggedness and user friendliness as JPADS-MP. Some are more functional demonstrators of a firm's capability than military operable products designed on military standards. The main obstacle to their fielding could be the lack of information on (non-US or on any) military standards (such as electromagnetic compatibility standards) at the early stages of design. New militarized versions may have to be developed based on the same functionality..

Some industry leaders have already mastered the US military standards and/or have benefited from an early exposition to the JPADS program, and are more likely to provide equipment fit for fielding.

Yet many have the following features :

- User friendly information management, including the easy selection of PADS models, map background display, graphical user interface (GUI) with information trees, warning lights to check the correct setup of a drop.
- Interface to define a wind profile at several altitudes, with in some cases the possibility to load a standard format file.
- Visualization of the planned PADS trajectory on map background
- Accurate PADS navigation simulation to evaluate LAR margins based on the day's wind conditions and, in some cases, according to way-points imposed
- Wireless communication port to setup the AGU
- Wireless communication with the AGU for in-flight monitoring and control override.

The last feature is of importance during the demonstration, as a safety measure in addition to CELM safety analyses; for example, it allowed the Dutch Space SPADES system to prevent the drop of mishandled systems that reported in-flight status before the drop and made CEV confident in allowing the ParaLander to perform the first fully autonomous flights under the demonstrated configuration, as control override was possible at anytime in case of safety issues.

C. Airdrop Systems

LMTGH/OB: (paper presentation)

A French acronym for HALO-CDS, this French Army design was presented during the conference at the beginning of the demonstration to highlight the remaining potential of ballistic airdrop to provide low-cost systems with enhanced precision and standard landing shock level as compared to HV-CDS.

The design presented utilizes fielded cargo parachute extractors as a drogue, reformed personnel canopies in clusters as a main decelerator and a military free fall (MFF) safety actuator and pyro-cutters for the low opening function. Its fielding could be done at a tenth of the cost of an equivalent conventional CDS solution.

The general development of the concept, based on the use of fielded components or new low-cost components, and the development of reliable and cheap actuators for the low opening functions (50% of the system cost today), would benefit both industry and governments in the long term.

Static only:

500 class PADS : UTRI(Italy) and MARS (Czech Republic) presented Skyporter and DOP-1M

NavAids : EADS Defence&Security (Germany) and UTRI(Italy) presented ParaFinder and Skypath, both designed to be compatible with the firm's PADS.

Wireless Gate Release System : US Army presented WGRS, a programmable CDS release system.

By order of appearance, airdrop demonstration:

Planning Systems Inc. (PSI) Dropsondes and JPADS-MP

Stara Technology Inc. Mosquitos 1A, 1B, and 1D*

High Velocity – Low Cost Aerial Delivery System (HV-LCADS) (US Army)

MMIST Sherpa***

Airborne Systems North America (ASNA) Firefly^{***}/Microfly^{**}
 NAVOCAP SNCA^{**}
 Zodiac/Pioneer Panther 500^{*}
 EADS Defence & Security ParaLander^{***}
 Strong Enterprises Screamer^{***halo}
 Dutch Space SPADES 1000^{***}/Spades 300^{**}
 Atair Onyx 500^{**}/Onyx300^{halo}
 NanΩhmics + Rockwell GlideLine paratrooper NavAid
 Zodiac/Aerazur PBO French Air Force paratrooper suit
 G-12 Improved Container Delivery System (ICDS) (US Army)
 G-12 ICDS (BE)
 Capewell Affordable Guided Airdrop System (AGAS)

*UltraLight (<500)

**500 class parafoil SGS (mostly designed for paratrooper follow-on missions)

***2K class parafoil SGS (mostly adapted for SOF team equipment augmentation and FOB re-supply).

halo marks a high altitude, low opening system (opens a ballistic parachute close to the ground).

IV. Scenarios

In order to include SOF operational needs in the demonstration, NATO Supreme Headquarters Allied Power Europe (SHAPE) defined scenarios to be illustrated with drops. Five scenarios were focused on the direct support of SOF team insertion:

SOF 1: unmanned survey of unattended DZ acoustic/seismic sensors)

SOF 2: paratrooper follow-on PADS to support team insertion

SOF 3: reinforcement of SOF position with heavier equipment / resupply of multiple elements on 1 pass

SOF 4: discreet and easy to locate resupply of camouflaged SOF element near a tree line – landing on a road

SOF 5: resupply of engaged SOF element – IP covered by terrain and approach pattern avoids hostiles

Three were a general illustration of additional possibilities to support forward operations and bases with the same technology:

FOB 0: state-of-the-art low level ballistic airdrop as the reference of illustration

FOB 1: enhanced, high altitude airdrop: enhanced ballistic or basic self guided targeted to 1 DZ, altitude allowing avoiding threats.

FOB 2: advanced PADS Concept of Operation (CONOPS) using high gliding performance to optimize aircraft use (allows to drop many loads in one pass to a DZ much smaller than the airdrop run or to dispatch the same loads to several distant DZ, minimizing aircraft exposure and flight time).

Here is the summary of the most illustrative PACD drops.

A. Unmanned survey of unattended DZ

IP#2 had been defined close to a fork on the road crossing the DZ, a location suitable to survey a would-be paratrooper drop zone. Stara Mosquito 1A and 1B systems are designed to release a small, camouflaged payload that looks like a stone before gliding away from the IP to avoid disclosure of the actual payload. The concept allows for the deployment of seismic and/or acoustic sensors to check if the zone is unpopulated prior to a SOF team insertion.

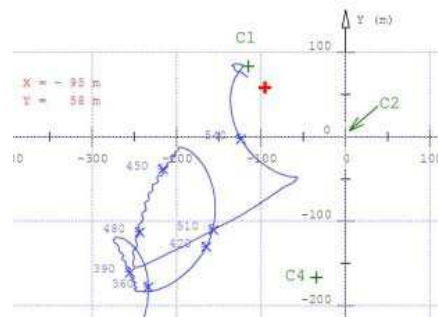


Figure 3: STARA Mosquito 1B trajectory on May, 29 2008

On May 29, STARA Mosquito1B was operated successfully from a US C-130. A few seconds after parachute inflation, the system headed roughly direct to the IP and reached its vicinity about 750 m above ground level. After circling twice to manage energy, it headed direct to the IP and dropped the payload 80 m before and 200 m above the IP. There from, with an estimated free fall of 6 s, CEV estimates the impetus of the payload allowed it to cover about 70m, landing really close (10m) to the target while the parachute and AGU took a divergent trajectory to a point 110 distant from the concealed payload.

The payload was so discreet that the CELM topography section, in charge of measuring the actual points of impact, could not locate it and only the estimate of the ballistics allow defining the approximate Point of Impact (PI).

B. Paratrooper follow-on

Class 500 systems allow the carrying of equipment that does not fit in a trooper's bag, or simply boost the total weight of equipment of a SOF element, while not exceeding the weight a few commandos can carry on foot.

IP#2 was also naturally the target for some systems illustrating this scenario, including Onyx 500 and Microfly that were dropped simultaneously with the US paratroopers. The clear weather conditions helped making this demonstration possible, yet in more realistic night jump conditions or with poor weather, integrated de-confliction features will be necessary. Indeed, though the riggers chose a heavy weight for the loads to remain below the paratroopers, the latter can spin down fast when above the DZ and cross the self guided systems (SGS) trajectory nevertheless.

Atair for example has developed collision avoidance (de-confliction) algorithms employing standard communication equipment to transmit locations of nearby systems to each other. Further development shall be made on all SGS so that the paratrooper navigation aids (NavAids) are included in the de-confliction functionality



Figure 4: *Onyx crosses Onyx in total confidence – GPS fixes are shared. Does the paratrooper above target 2 have the same situation awareness?*

All 500 class systems also fit for this mission today, as well as ParaLander that is designed to accompany paratroopers (equipped with ParaFinder NavAid) with much heavier payload and soft landing capability.

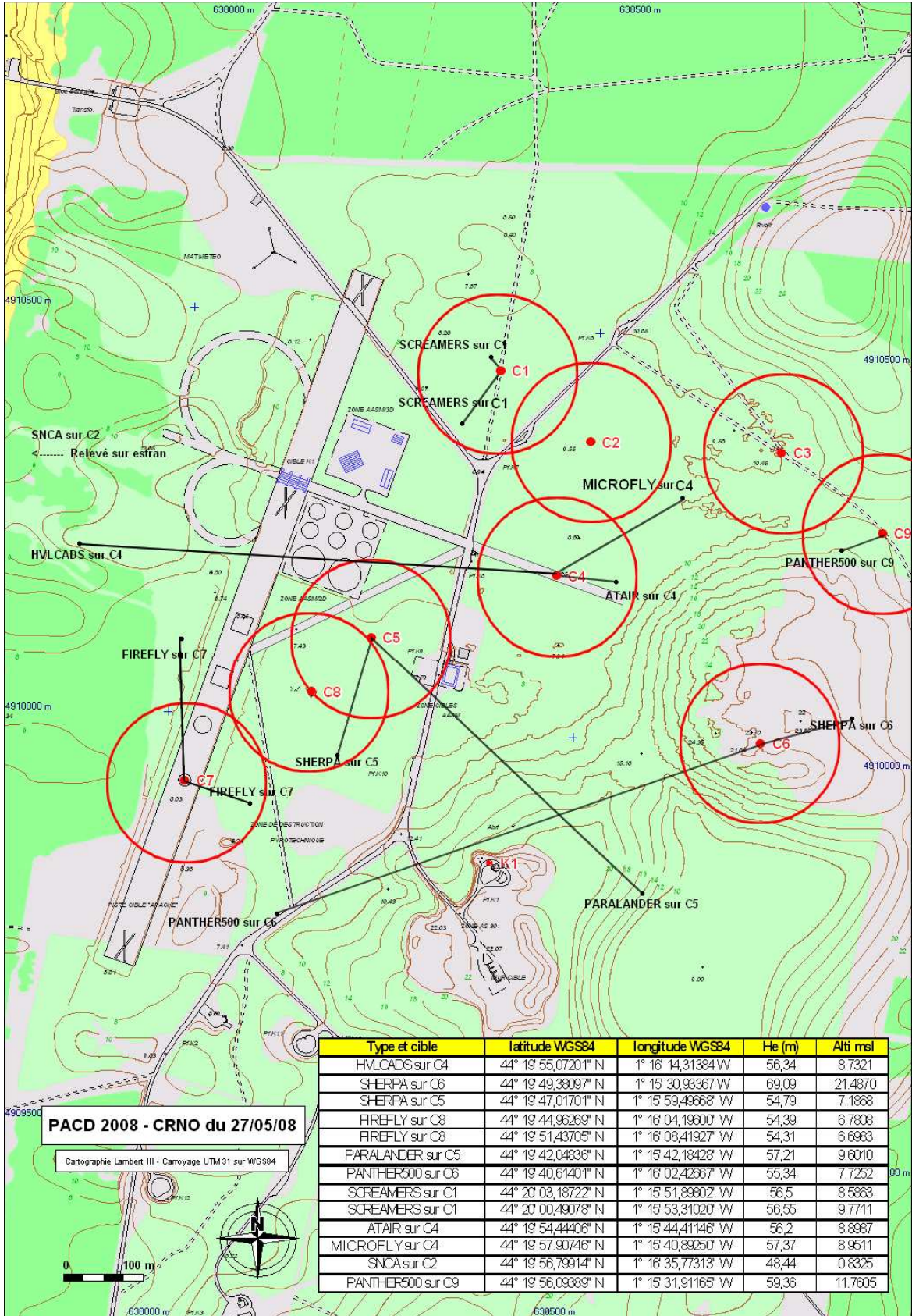
C. Resupply / 1 on N

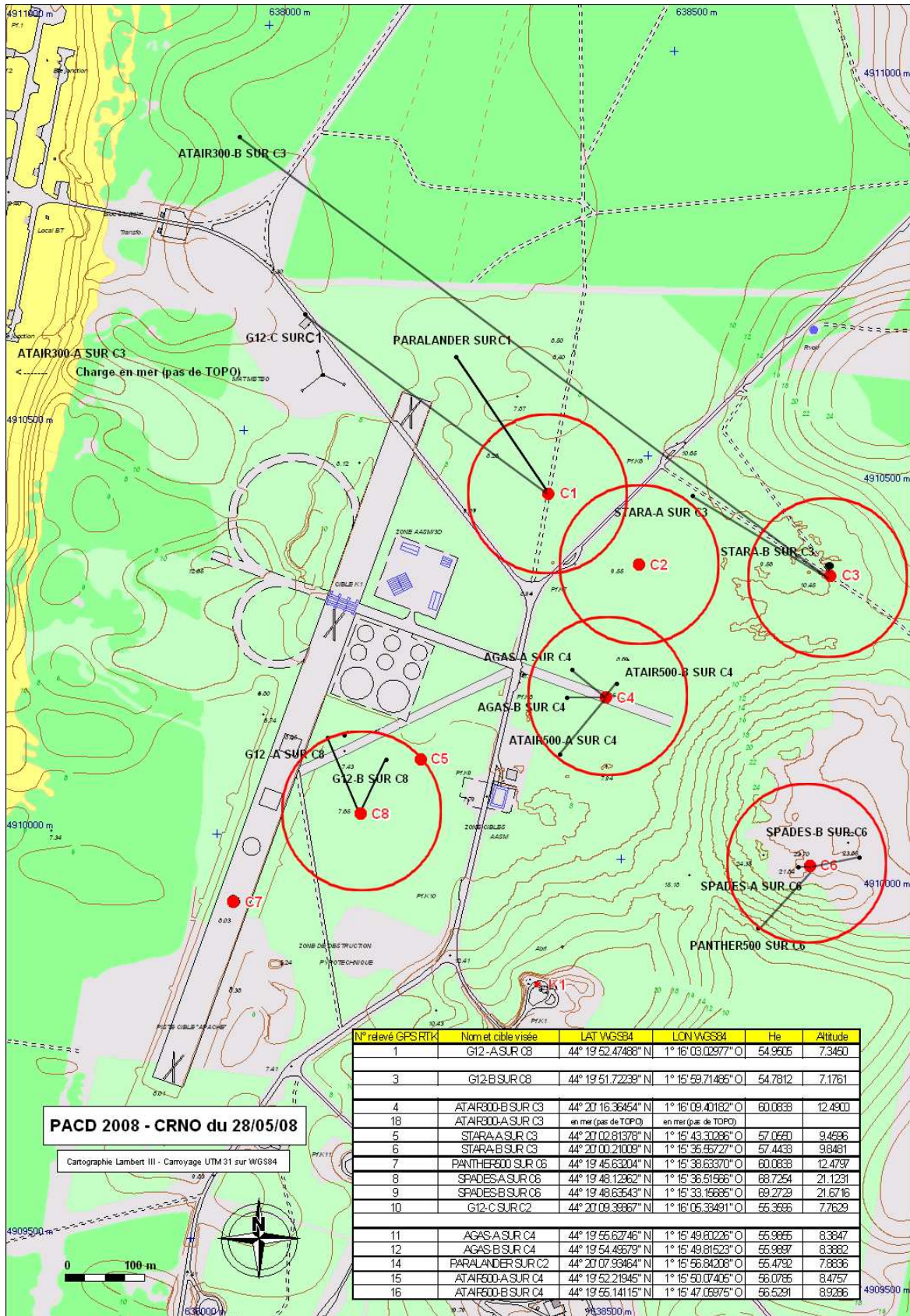
Though they need mobility initially to move from an unpopulated drop zone to a mission area, SOF teams may need larger or heavier equipment closer to their operational station and 2K class systems can become helpful. Yet for discretion's sake, the recovery point for the additional equipment may be a few kilometers away from the operational station. Also, the presence of the dropping aircraft in the mission area shall be set off at a certain distance and made short – including no permission to drop several times for several SOF elements on several sides of the mission area.

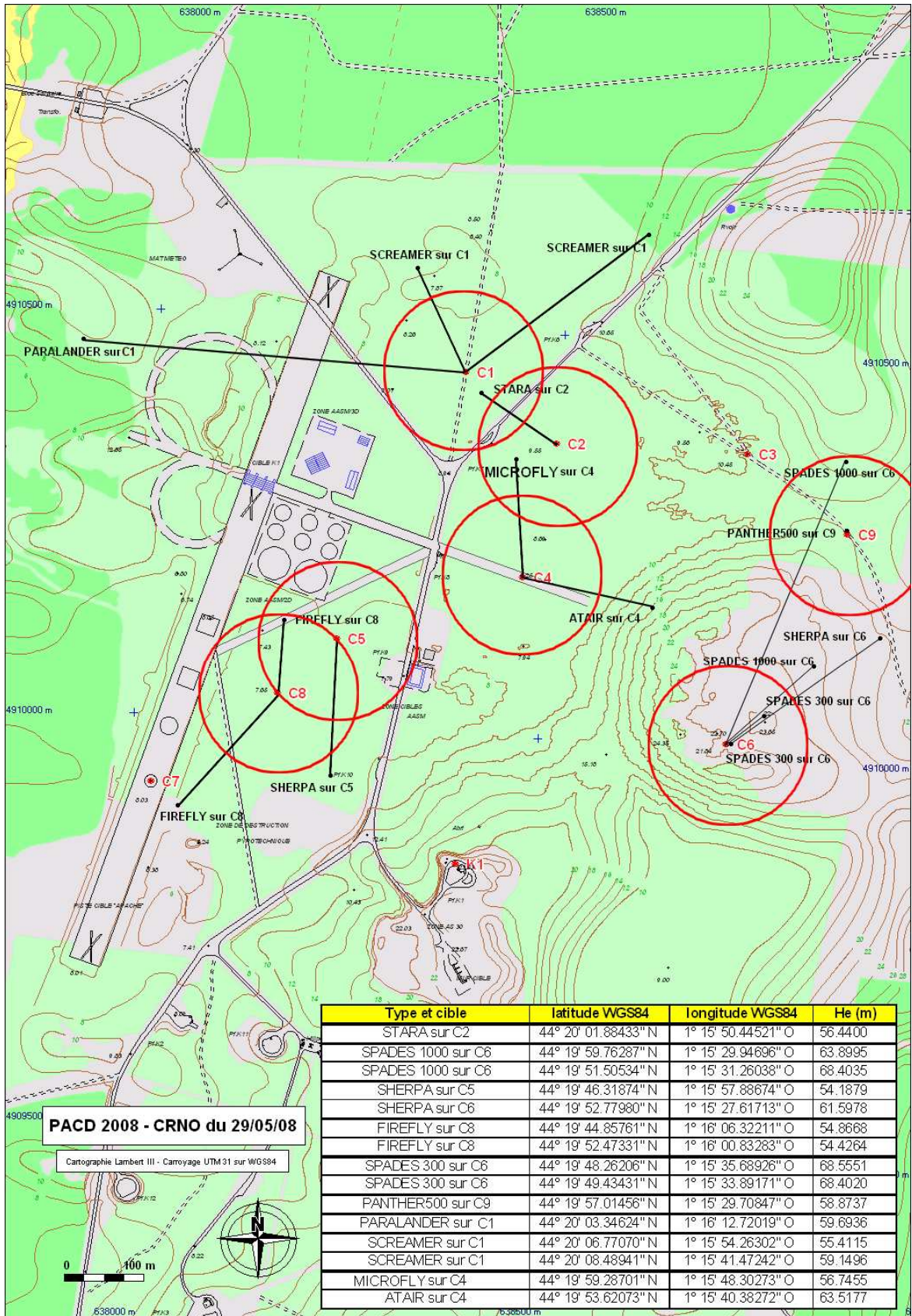
Parafoil based SGS, once again, provide a solution, as it was demonstrated at PACD2008 with consistent wind data, these system can be dropped with a planned offset around 66% of L/D (actual offset measured ranged from 40% to 82%). With most L/Ds of approximately 3/1, a parafoil SGS could be dropped 20,000 ft AGL, 10 km away from the mission area and re-supply SOF elements 6 km away from the mission area in calm wind conditions.

The Sherpa systems gave the basic illustration of this scenario, demonstrating how long this capability has been available.

Next pages : *Map detail of the DZ with IP/PI location and 100 m radius circles around IP.*







D. Along the Road

An additional challenge is to facilitate the retrieval of supplies at night without compromising the discretion of the mission. A possible solution could be the enhanced precision obtained when landing on a preferential axis, e.g. along a road. Indeed, though the longitudinal precision is not improved, the lateral precision can be less than 20m, giving the retrieving unit only a narrow band of terrain to scout to locate their supplies.



Figure 5: Firefly lands close to a “road”

Firefly was intended to land along the fake runway on IP#7. Yet the US Army operated PADS did not have the latest version of the guidance algorithm and were set to land headwind instead of the preferential direction. Nevertheless, 3 impacted less than 50m away from the would-be road and one 80 m away.

Panther 500, even when dropped to the target “behind the hill”, had a preferential landing course 120° that corresponds to a sand track passing at IP#9. Out of 3 successful drops on IP#9, the SGS landed once on the track, once 20 m south of the track and once 4m away from the IP.

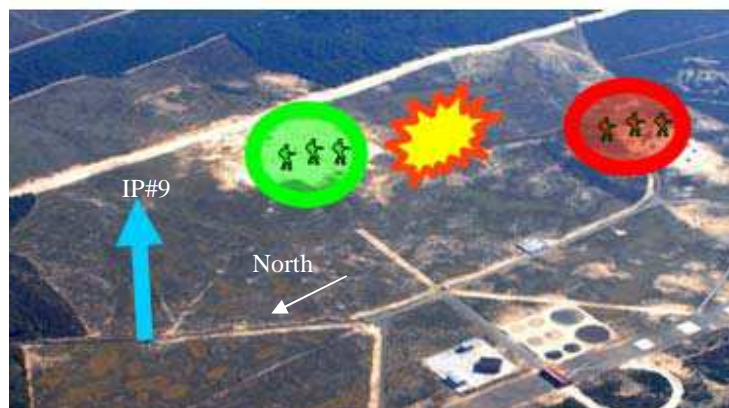


Figure 6: Panther drops on IP#9: the blue arrow covers a narrow sand track behind the sandhill.

E. Behind the hill

The last SOF scenario is exploratory, and illustrates the potential of SGS to adapt to specific tactical situations. The would-be enemy position was 1 km south of the sand hill. The would-be position of the SOF element is on top of the sand hill. IP#9 is behind the sand hill, which provides cover. It had been decided to perform one drop of the complete scenario on May 26. Though more drops on IP#9 occurred during the public airdrop session, they did not include the full constraints of the scenario: preserving SGS stealth and survivability. This was achieved by managing energy close to 1 km north of the sand hill and making a direct final approach to the IP, following a shallow depression in the terrain.

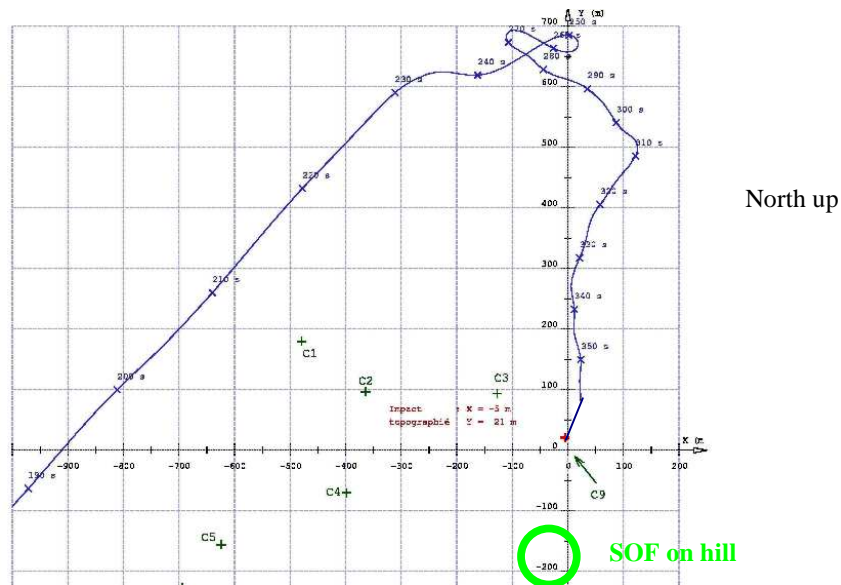


Figure 7: SPADES drops on IP#9: the system stays further than 2 km away from the “red” position (see fig.6) until it is time for a direct approach(compare with Fig 6).

Though the final was close to 700 m and 1 minute long, careful planning and efficient guidance yielded a precision of 22m.

F. Low altitude CDS

The US crews performed 2 CDS drops 600 ft AGL flying in formation to illustrate the reference airdrop technology.

G. Enhanced, high altitude airdrop

The US and BE crews performed several ballistic drops based on dropsonde data and JPADS-MP CARPs. HV-LCADS allow higher airdrop altitudes than G-12 thanks to the reduced time of descent. AGAS, operated like a ballistic system but with a lateral control capability, is an incremental improvement of traditional airdrop technologies.



Figure 8: The BE C-130 drops a CDS / a HV-LCADS / AGAS steering

H. Advanced PADS CONOPS

The use of parafoil-based SGS allows focusing a large number of containers that require more than 1,000 m to dispatch at airdrop altitude onto a small DZ. Such features make airdrop more flexible, reducing the number of rotations needed to re-supply small drop zones, saving fuel and flight potential.

V. PACD 2008 overall results and products

The overall result of PACD 2008 was positive. A large audience was gathered to witness the airdrop demonstrations of 44 drops (47 including the drops on may26) with very good real-time observations including

much better trajectory tracking than PACD 2006. The systems' performance was evaluated in the scope of supporting SOF operations, which they proved to be fit for. The general accuracy was greatly improved (70% of PI less than 200 m away from IP, vs. 40% at PATCAD 2007⁵) which proves that the 500 class and 2K class SGS segments are mature. The few airdrop failures were related to human factors and could have been avoided with formal training, which this event did not allow for.

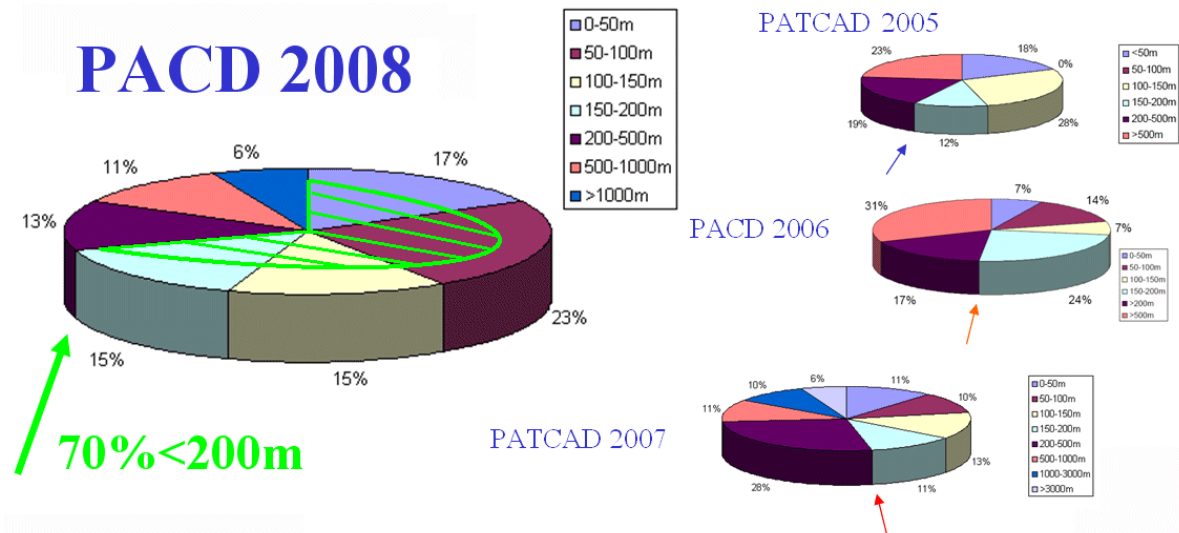


Figure 9: Recent PATCAD and PACD landing precision statistics (distance PI to IP, m)

In addition to a successful event, PACD 2008 also improved the French demonstration standard by producing a final report² quite similar to the PATCAD products, an official communication video and several measurement data packages made available to national specialists through NATO channels.

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