

C-27J Spartan : Paratroops and Loads Airdrop Qualification

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ABSTRACT

This paper covers the whole flight test activity performed to achieve the military certification, for paratroopers and loads airdrop, of the C-27J Spartan tactical transport aircraft.

As an Alenia G.222 derivative, the main target of this project was to obtain a considerable improvement of the former aircraft capabilities also with the introduction of new devices (e.g. CARP and tow-plate).

Detailed information are given about flight test instrumentation, preliminary steps, safety and hazard analysis for the more demanding tests, as well as semi-empirical methods used during this activity.

The testing was performed with the active co-operation of both the Italian Army – Paratroopers Brigade, which provided a dedicated software for trajectories analysis, and the Italian Air Force.

The whole campaign was carried out in three different phases for a total amount of more than 50 test flights, covering the airdrop of paratroopers (including preliminary airflow evaluation and the use of a great number of dummies) and loads (by gravity, extraction and LAPE techniques).

This presentation shows experiences and results achieved by the test team, focusing on the more uncommon tests such as external airflow measurements, maximum payload airdrop and LAPES operations.

A comparison with the G.222, showing the relevant increase obtained in terms of operational capabilities, is also outlined in the paper.

1. INTRODUCTION

The military certification of the C-27J tactical transport aircraft included the airdrop capabilities of paratroopers and various types of loads.

This paper deal with the flight test activity performed to achieve the task emphasising the tests performed, including some semi-empirical methods, in order to verify the theoretical predictions and to identify/solve the possible problems that could arise during the qualification phase.

The test were planned, performed and analysed with the active co-operation of Italian Army, Italian Air Force, civilian paratrooper and equipment suppliers.

The main task was to achieve the desired goals quickly and safely, in very short scheduled time windows.

The whole campaign was carried out in different steps, covering the period from 2002 up to 2005, with a total amount of more than 50 test flights, including those performed to satisfy dedicated Customer requirements.

This presentation shows experiences and results achieved, focusing on the more uncommon tests performed such as external airflow measurements, maximum payload airdrop and LAPE technique operations, as well as propaedeutical aerodynamics checks and emergency procedures validation.



2. AIRCRAFT DESCRIPTION

The C-27J was developed as a joint venture between Alenia and Lockheed Martin.

It is a multirole light-to-medium transport aircraft, specifically designed for rugged military operation, capable to perform logistic support and tactical missions to unprepared remote airstrips with STOL capability.

It is designed to perform cargo and troop transport, loads airdrop including LAPES, high and low altitude paratroops airdrop, medevac and aerial surveillance, in all-weather conditions and without need of ground support.

The aircraft, based on the Aeritalia G222 / C-27A airframe, is characterised by high wing with retractable tricycle landing gear, fully pressurised fuselage that features a large cargo compartment inter-operable with larger airlifts, rear ramp and cargo door for loading / unloading and aerial delivery plus two large lateral paratroops doors.

The landing gear incorporates a jacking system that provides capability of cargo height and attitude adjustment to facilitate aircraft loading / unloading operations.

With respect to the baseline aircraft, the Italian Air Force (AMI) variant includes a number of additional options such as an in-flight refuelling system, an on-board gas generation system to prevent tanks explosion and a self protection system inclusive of radar warning, laser warning, missile warning and chaff & flare dispenser.

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The aircraft is powered by two Allison AE2100 D2 turboprop engines with two six-blades all composite Dowty Rotor R391 propellers of 13.5 ft diameter (the same as C-130J).

The two crew flight station features a glass cockpit with full integrated avionics (using 1553 data bus), five colour multipurpose displays, two digital autopilot / flight director, colour weather radar with precision ground mapping capability, integrated displays for accurate navigation and airdrop as well as a digital map, dual GPS / INS systems, TCAS and GCAS.

It is a dark cockpit philosophy fully NVG compatible.

The Flight Management System besides flight plan management, world navigation data, take off and landing data, guidance, provides also a very precise Computed Airdrop Release Point (CARP) reference.

The AMI variant also includes an Head-up Display.



2.1 Cargo capability and airdrop missions details

The large cargo compartment can accommodate three full size standard 463L pallets, wheeled and tracked vehicles (including HMMWV and Iveco LMV), spare engines.

The ramp area can be used to support additional payload.

Two independent electrical retrieval winches are available to support loading / offloading, chute lines retrieve or 'hung up paratrooper' recovery as well as operation of the shearing knife to cut the restraining lanyard during A22 containers airdrop.

The basic aircraft is designed for seven typical mission profiles :

Loads transport	9000 kg payload (up to 11500 kg in 'logistic' mission)
Troop transport	up to 62 equipped troops seated on 2 or 3 rows
Medical evacuation	up to 36 wounded personnel plus 6 medical attendants
Loads airdrop	up to 9000 kg payload (using standardised loads) with a max single load of 6000 kg.
LAPES airdrop	up to 5000 kg payload (single or tandem platforms)
Paratroops airdrop	up to 46 equipped paratroops
Combat Offload	up to 6000 kg payload

3. TEST OBJECTIVES

The test activity had the objectives to :

- demonstrate safe airdrop characteristics of paratroopers, from both side and cargo doors, and loads from cargo door
- achieve the military qualification of the C-27J for paratroopers and loads airdrop, according to the System Specification target
- demonstrate a considerable expansion of the G.222 airdrop operational capabilities
- assess the CARP mechanization and performance
- supply to the customer an operational fully qualified system

These goals were intended to be obtained by the hereinafter described main steps.

3.1 Paratroopers

- preliminary comparison between G.222 and C-27J in terms of external airflow measurement and qualitative evaluation by experienced people
- propaedeutical phase including
 - parachute static lines length definition (in order to standardise equipment and materials with the C-130J already in service with the Italian Air Force)
 - airdrop of single and multiple dummies
 - testing of retrieval capabilities by winches
 - development of emergency procedures such as hung up paratroop recovery (up to a max. weight of 350 lbs)
- airdrop of paratroopers from side doors or cargo door

3.2 Loads (by gravity technique)

- airdrop of up to six 1000 kg A-22 containers

3.3 Loads (by extraction technique)

- airdrop of a single 6000 kg 12 ft standard platform
- airdrop of two 12 ft standard platforms up to a maximum of 9000 kg
- airdrop of three 8 ft standard platforms up to a maximum of 7500 kg

3.4 Loads (by tow-plate technique)

This technique was originally intended as propaedeutical to the LAPES campaign but later evolved to an operational commitment for procedure standardisation with C-130J.

- airdrop of a single 5000 kg 12 ft standard platform

3.5 Loads (by LAPE technique)

- preliminary testing and evaluation of operational and safety procedures
- airdrop of a single 5000 kg 12 ft standard platform
- airdrop of two 2500 kg 12 ft standard platforms

3.6 Combat Offload

- release of single and multiple pallets up to a maximum of 6000 kg

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4. THE TEST TEAM

To perform such an intensive flight test campaign several people were involved, from different Companies and Agencies.

Integrated teams were constituted, time by time, for each specific type of test including personnel of Alenia (as test responsible, it provided test pilots, test engineers and load masters), Italian Army – Brigata Paracadutisti “Folgore” (it supplied the paratroopers and supported loads preparation and logistic organization), Italian Air Force – 46a Brigata Aerea and Reparto Sperimentale Volo (test pilots and load masters).

An additional support was given by Capewell (LAPES rigging and personnel training), AAR (supplier of the aircraft cargo handling system) and civilian paratroopers in the preliminary phase.

5. RISK ASSESSMENT AND MANAGEMENT

A very careful approach and risk assessment was carried out before proceeding to the test.

Any critical event that could occur during airdrop was identified and analysed in order to reach the confidence level necessary to minimise the risk during test.

The operational procedures of Italian Air Force and Italian Army were used, when available, after being adapted to the C-27J.

For LAPES activity, which implies an high criticality, a dedicated team was tasked to identify and analyse the risk factor and level in order to minimise criticality during flight testing.

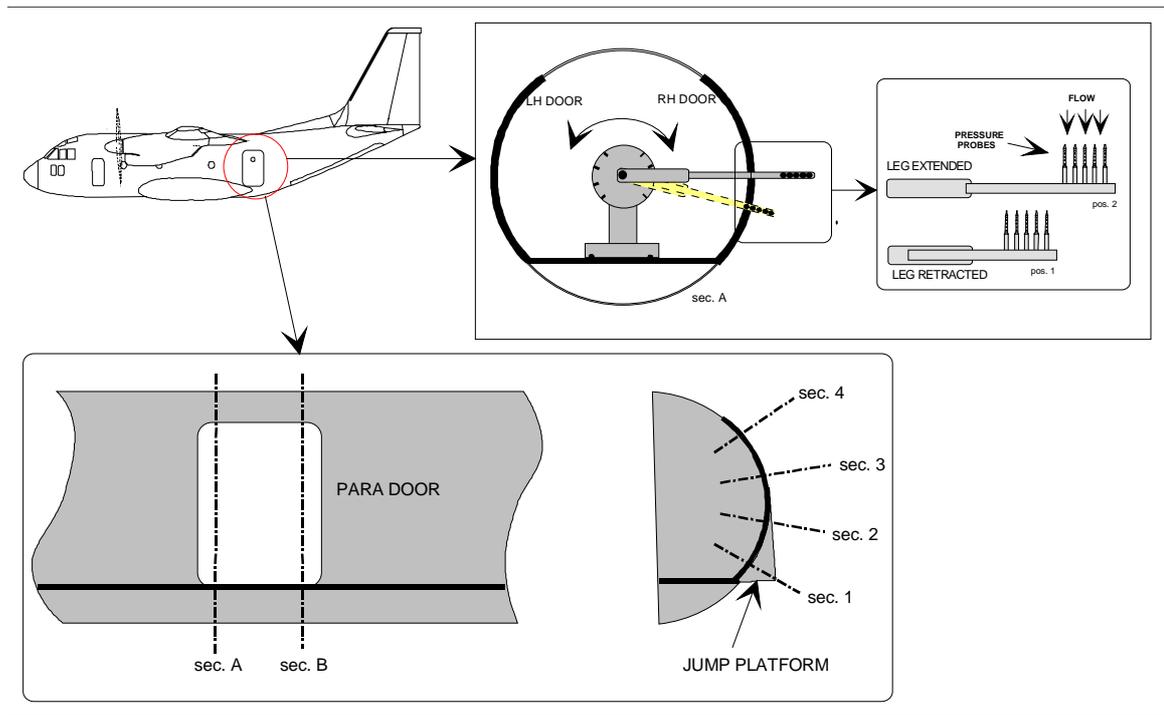
A number of critical events were processed to achieve the goal (e.g. airdrop systems failure, procedure misleading, aircraft failure during airdrop).

Following the analysis the risk reduction was obtained by means of theoretical analysis, flight simulator training, procedures optimisation and crew co-ordination assessment.

6. TEST AIRCRAFT & FLIGHT TEST INSTRUMENTATION

The aircraft used for test was a production standard C-27J.

It was equipped with the basic Flight Test Instrumentation (FTI), recorded on a PCM system, plus a number of dedicated equipments installed for the specific purpose.



In the earlier phase an “aerodynamic field measurement system” was flown, designed and manufactured in house, to map the airflow characteristics just outside the doors where the paratroops is firstly invested during jump.

The system consisted of a series of 5 pressure probes (with 5 holes each) inserted on a mobile arm measuring, by means of dedicated computer, flow velocity, angle of attack and yaw on different horizontal and vertical sections of the doors.

The same equipment was later installed in a G222 to compare the flow and evaluate any differences induced by the new six blades propellers.

Some tufting were also added to the arm to collect additional data and to visualise flow characteristics.

In addition, to provide a visual reference of the parachute bags movements, a black grid was painted in the rear part of the fuselage behind the side door.

The same grid was also implemented with the installation of a number of tufts in order to better visualize the local airflow.



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For the loads airdrop a couple of micro-switches were installed on the floor, to record platform movement and exit from cargo compartment, and correlated with 4 fixed videocameras providing left and right external sides, external bottom and internal cargo views.

The bottom camera images were also used to make trajectory analysis about para jumping from both side doors in order to give evidence about safe simultaneous left & right doors jumping.

The software used for this analysis had been developed by Italian Army “Folgore” Test Department.

During each airdrop test a G222 safety and photo chase flew in close formation with the C-27J.

In addition to the above instrumentation some hand held camcorders and photo cameras were used on board, on chase aircraft and on the ground.

7. TEST EXECUTION AND RESULTS

To achieve the program target a step by step approach was used, as detailed below together with the most important results obtained in terms of airdrop capabilities.

7.1 Airflow investigation and dummies testing

The initial investigation was dedicated to a comparison between G.222 and C-27J in order to define the most suitable airdrop envelope.

Firstly, an instrumented probe equipped with pressure transducers was extended outside the lateral doors thus allowing the external airflow measurement on both aircraft.

The results showed a deeper boundary layer along the fuselage and a better airflow entering through the doors. These characteristics were considered more favourable from a jumping point of view.

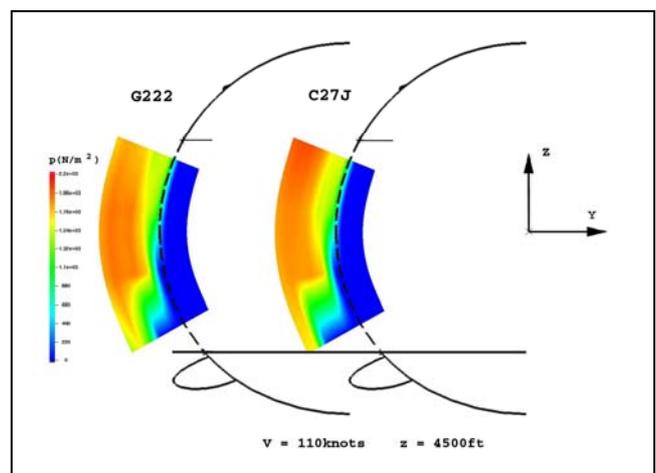
Additional information were provided by very experienced Italian Army Paratroopers Brigade “Folgore” instructors which qualitatively evaluated the airflow close to the doors.

A twenty knots window, in the low speed range, was identified as the best recommended jump condition from side doors whilst a larger range is still acceptable for axial door operations.

It is worth mentioning that a very preliminary assessment had already been conducted by a group of civilian instructors which gave the same conclusions.

Next step was the selection of the parachute static lines length, for both side doors and cargo door jumping operations, based on safety considerations and necessity of equipment standardisation with the Italian C-130J that was involved in its own airdrop qualification in the same period.

The final selection was for a 4.70 m line that satisfy both aircraft requirement.



Last item in the schedule was the release of dummies, simulating the physical structure of a real man with a weight up to 350 lbs, to evaluate potential safety problems for the subsequent paratroopers jumping, in particular during simultaneous drop from side doors.

A total of 72 dummies were dropped with different procedures :

- single from side door
- two simultaneously from side doors (one each from left and right)
- four simultaneously from side doors (two each from left and right)
- single from cargo door
- ten in sequence from cargo door

It was also demonstrated the capability to recover a bundle of bags (up to 26) on each side by a single retrieval winch.

Moreover, emergency procedures such as the recovery of an hung up paratrooper from both side and cargo doors were successfully developed and finalised.

This assessment was also carried out using the Hellenic Air Force peculiar recovery bar.

7.2 Paratroopers airdrop

When successfully completed, the propaedeutical phase gave the necessary clearances for the real paratroopers airdrop campaign in terms of flight envelope, equipment configuration, normal and emergency procedures.

The here detailed campaign consisted of more than 200 men jumping with static line technique plus 20 more using the free fall technique.

Different procedures and sequences were tested :

Static line technique

- single from side door
- two simultaneously from side doors (one each from left and right)
- four simultaneously from side doors (two each from left and right)
- ten simultaneously from side doors (five each from left and right)
- ten in sequence from a single side door
- single from cargo door
- ten in sequence from cargo door
- 46 in sequence from both side doors



Free fall technique

- six simultaneously from side doors (three each from left and right)
- six in sequence from cargo door
- six grouped from cargo door

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The conclusions were very satisfactory and confirmed the good results obtained during the preliminary activity.

The jumping qualities were judged very positively, in terms of airflow and capability to manoeuvre just outside the aircraft (the latter apply to free fall technique), far better than those of the G.222.

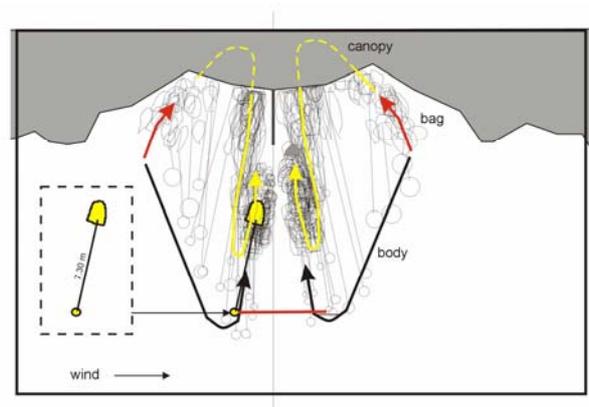
Furthermore, a trajectory analysis of sequential jumping from both side doors was performed by means of a dedicated software provided by Brigata "Folgore".

First step was the examination, frame by frame, of the ventral videocamera sequence to extract the body-bag-canopy positions for each paratrooper.

The analysis was performed for both left and right jumping lines simply defining the same couple of reference axis on the aircraft structure.

These information were processed by a vector imaging software which also gave the evidence that no collisions shall have occurred in a simultaneous two lines airdrop.

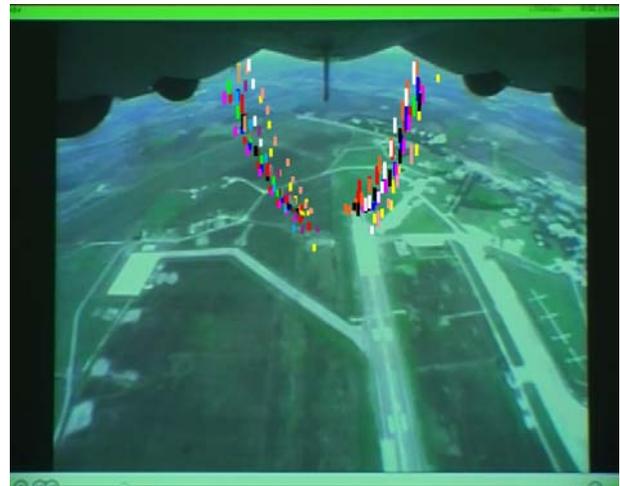
The first figure on the right shows an example of body-bag-canopy resulting trajectories, whilst the second one depicts the resulting path of the bodies for the whole sequences.



The relative distance measurement between left and right men bodies was determined using the following method.

The lateral opening sequence taken by chase allowed to determine the reference frame (i.e. when parachute suspension lines are fully deployed and perpendicular to the bottom videocamera axe of the test aircraft).

This is the moment, shown in the last picture, when the measured lengths are the same in both lateral and frontal view and, therefore, the corresponding frame of the test aircraft video gave the required information of distance.

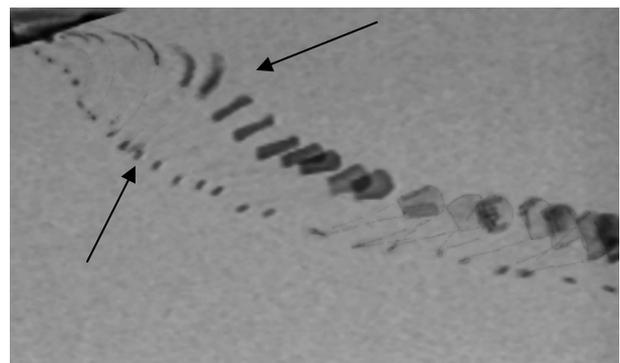


The results were very positive and gave the clearance for simultaneous jumping of paratroopers.

It has to be noted that some free fall jumpers left the aircraft well above the clouds level without visual reference of the drop zone but only relying on the CARP indications precision.

During the various demotour the aircraft was evaluated by several military paratroopers, including the famous US Army "Golden Knights".

All of them confirmed the good judgement derived by the test campaign.



7.3 Loads airdrop by gravity technique

The first phase of the loads airdrop testing concerned the release of A-22 CDS containers by gravity technique in both single and multiple shots.

The operational and emergency procedures were derived from those already used for the G.222.

The full sequence of tests, for a total of 15 loads, is hereinafter listed :

- one 500 kg A-22
- three 500 kg A-22 in single release
- five 500 kg A-22 in sequence
- six 1000 kg A-22 in sequence

The execution of the last test point required the installation of a totally new buffer stop in the cargo compartment; this modification allowed the storage of the sixth A-22, otherwise not possible with the original G.222 configuration.

The cleared airspeed envelope was 110 ÷ 140 kts.

The operational procedure used during these trials was to start the containers release sequence by means of the shearing knife, in accordance to the release point indication obtained by the CARP. It allowed to reach a very good precision in terms of loads dispersion around the target.

Compared to the G.222 capabilities, the C-27J shows a noticeable 20% increase of dropped weight (6000 kg versus 5000 kg) and one more container (six versus five).

Further analysis, based on good results obtained, showed the possibility of applying this technique up to twelve A-22 containers disposed in two parallel lines, giving the capability to airdrop the full payload of 9000 kg.

This solution will be investigated in the next future.



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7.4 Loads airdrop by extraction technique

The second step of the C-27J loads airdrop qualification was relevant to the extraction technique of medium to heavy weight loads embarked on standard 8 ft and 12 ft Type V platforms.

Also in this case the operational and emergency procedures were directly derived from those of G.222.

A preliminary test of a 15 ft extractor parachute, successfully accomplished, introduced the full drop sequence for a total amount of eleven single and double loads :

- one 2500 kg platform
- one 4000 kg platform (at two different speeds)
- two 2500 kg platforms
- two 4000 kg platforms
- one 5000 kg platform
- one 6000 kg platform
- two 3000 kg + 6000 kg platforms
- three 2500 kg platforms



The following table reports number and types of extractor & main parachutes used for different platform weight :

PLATFORM	EXTRACTOR PARACHUTE	MAIN PARACHUTES
2500 kg	15 ft	2 x G-11
4000 kg	15 ft	2 x G-11
5000 kg	22 ft	3 x G-11
6000 kg	22 ft	4 x G-11

A thirty knots speed range was certified.

The aircraft always showed a good behaviour in terms of attitude variation, load factor oscillation and pilot's controllability.

Again, the extraction sequence was started in accordance to the release point indicated by the CARP.

Since the beginning, the system showed a very careful mechanization always allowing to obtain significant scores with errors of just a few meters around the target.

Another important result was the demonstration of the capability to airdrop the full payload of the aircraft.

7.5 Loads airdrop by tow-plate technique

This experimental phase was originally intended as introductory to the next LAPES campaign and carried out in a logical build-up sequence :

- release of a 15 ft drogue
- release of a 15 ft drogue followed by a 22 ft extractor
- release of a 15 ft drogue followed by two 22 ft extractors
- airdrop of a 2500 kg platform with a 15 ft drogue and a 22 ft extractor
- airdrop of a 5000 kg platform with a 15 ft drogue and two 22 ft extractors

Normal and emergency procedures were specifically developed, before the beginning of the trials, jointly by Alenia and Italian Army as the tow-plate technique was a new item never used before with the G.222.

The A/C flight qualities when towing a 15 ft drogue were investigated, in the speed range from 120 kts to 130 kts, by controllability checks and altitude variations while simulating a LAPES approach.

The same test gave useful information about trim condition and power setting to be used.

The release of a drogue followed by single and double extractors allowed to verify the correct functionality of each component of the sequence.

At last, two complete airdrop demonstrations of a single 12 ft Type V platform guaranteed about the safety of the whole sequence, showed the operational applicability of this procedure to the C-27J and gave a good level of confidence for the next LAPES testing to begin soon afterward.

The configurations were characterised by :

<i>PLATFORM</i>	<i>DROGUE PARACHUTE</i>	<i>EXTRACTOR PARACHUTES</i>	<i>MAIN PARACHUTES</i>
<i>2500 kg</i>	<i>15 ft</i>	<i>22 ft</i>	<i>2 x G-11</i>
<i>5000 kg</i>	<i>15 ft</i>	<i>2 x 22 ft</i>	<i>3 x G-11</i>

The 5000 kg platform test demonstrated the uselessness of having a double extractor parachute as the single 22 ft extractor alone can provide the force necessary to safely complete the sequence also for the heaviest loads whilst the higher forces developed by the two parachutes could bring the platform to reach an abnormal attitude in the exit phase and cause a rupture of the platform to parachutes links.

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7.6 Loads airdrop by LAPE technique

At last, the Low Altitude Parachute Extraction System (LAPES) trial was a very demanding task in terms of prediction, safety analysis, organisation and crew co-ordination.

LAPES is considered one of the most difficult and dangerous airdrop operation as it involves the parachute extraction of heavy platforms whilst flying at only a few feet above the ground.

Although this technique has been today abandoned by the majority of the operators, it can still be a valid and very precise airdrop method for a tactical transport aircraft and this is the reason why Alenia decided to qualify the C-27J to do it.

LAPES had only been previously qualified on G.222 by Aeritalia in the 80's, but never officially adopted by the Italian Air Force as an operational procedure.

Alenia people made a big effort to analyse safety and hazard conditions, to provide equipment and technical assistance for loads preparation, to develop dedicated procedures.

A first step was the check of 15 ft drogue plus 22 ft extractor lines, not connected to any load, when operated in the airspeed and altitude range typical of LAPES mission.

Next to be performed were three complete demo :

- airdrop of a 2500 kg platform with a 15 ft drogue and a 22 ft extractor
- airdrop of a 5000 kg platform with a 15 ft drogue and two 22 ft extractors
- airdrop of two linked 2500 kg each platforms with a 15 ft drogue and two 22 ft extractors



The drop area was appropriately chosen in the middle of a military airfield, in order to have a large obstacle free space available in case of emergency.

The final approach trajectory, with drogue extended, was always characterised by a flight path angle of $1.5^{\circ} \div 2^{\circ}$ and power to maintain approach speed.

All releases were performed in an airspeed range of ten knots, at an altitude below 10 ft AGL.

The aircraft was always perfectly controllable and stable.

Each load was delivered intact with a ground run, from impact point to full stop, of less than 200 m, with noticeable precision as for prediction.

Further LAPES airdrop demonstration were performed during customer evaluations.

7.7 Combat offload

This testing campaign demonstrated the capability to operate release of single and multiple loads in wartime conditions, over limited available airstrips, simply accelerating the aircraft to allow the pallets to be unloaded on the ground.

The heaviest weight tested was 6000 kg.

The aircraft always performed well, with imperceptible transition phases, and was ready to take-off immediately after the completion of the release.

8. CONCLUSIONS

The airdrop flight test campaign was successfully completed in the scheduled time and achieving all the objectives required by the program.

The aircraft has been fully qualified for paratroopers and loads airdrop, demonstrating safe characteristics and very good CARP precision and mechanization.



Furthermore, evidences were achieved that C-27J is far better than G.222 in terms of airdrop capability with :

- twelve more paratroopers
- increase in loads airdrop capability up to 9000 kg (80% more !)
- different techniques that improve flexibility
- better handling qualities during airdrop, thanks to the new flight control system

SYMPOSIA DISCUSSION – PAPER NO: 1**Author's Name: M. Quadro****Discussor's Name: T. Jann****Question:**

What are the advantages and disadvantages of the drag chute and plate technique?

Author's Response:

This technique allows minimizing the extraction time of the platform reducing the problems induced by the big g.c. excursion on the aircraft controllability. The disadvantage is the rigging of the platform on the A/C which is more complex.

Discussor's Name: Capt. C. Delwarde**Question:**

How do you know the wind conditions to determine your CARP? Is it an operational system?

Author's Response:

The wind at the airdrop altitude is directly computed by the aircraft air data system. The wind on ground is measured by the ground patrol, broadcast to the pilot and manually entered into the CARP. This (CARP) is the operational system user by Italian Air Force C130J and C 27J.

Discussor's Name: T. Jann**Question:**

Clarification 9t = total payload weight? for A/C

Author's Response:

Yes, e.g. 3x3 t or 1x3t, 1 x 6t