“A design for the delivery of humanitarian food aid from an airborne platform”

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Introduction

The provision of food aid to remote locations can be achieved by the use of ground transport (human or mechanized) or delivered by air. Ground communications are probably the first to suffer during a natural disaster such as an earthquake which means that aid will take a long time to get through and may arrive too late to help those that need it quickly. The air delivery option is the fastest method but can be hazardous when hostile action is taken in the form of surface to air missiles.

An aircraft needs to be able to deliver supplies from at least 20,000' and do so with a fair degree of accuracy. Current systems spread the supplies over a vast area making it difficult for survivors to locate and retrieve them. There are several high-tech military platforms available for the delivery of vehicles but these are generally expensive and the landing sites are difficult to predict when deploying from 20k'.

My original brief was to produce a drift marker system that used a dummy ration pack that was tracked during decent and allowed the aircraft to reposition and deploy the rest of the packs. The requirement this time is for a system that will free fall and deploy at 1000'. To produce a suitable parachute release system for perhaps thousands of packs is uneconomic so the packs have to be bundled in some form of container which needs to open for delivery at a predetermined height. To avoid injury to ground personnel container itself has to be retarded to a rate of around 20 feet/sec.

Naturally there are costs involved in the production of each container and it makes sense to keep as much of the container intact to provide shelter material. My design features a container that will not disintegrate, can be reconfigured as a shelter and is protected by a waterproof coating.

Please note that all drawings are for illustration and conceptual purposes. However a sense of scale has been incorporated to make things more realistic. Final designs may appear very different.

The system

I do not as yet have a name for the system so for the purposes of this document it will be called the “drop box” and abbreviated to DBX.

The DBX is composed of 5 main parts:

- Container
- Toggles
- GPS & Telemetry
- Release mechanism
- Parachute storage and deployment

Container

The container is formed from Triwall cardboard packaging material. To survive handling, deployment and free fall the walls will be about 20mm thick. Naturally this is an estimate and the final thickness determined during testing. It is hoped that the DBX can be produced from a single sheet of Triwall, this will add to the overall strength. At present I do not know what the maximum size sheet Triwall can process.

Fig 1 shows the DBX as it would be supplied by Triwall. All drawings are to scale and the dimensions are : length 3m, width 1m, height 1m. These measurements are subject to change but it did simplify my drawing process to keep the sides & base the same size. The blue areas are fold up flaps that enable the DBX to take its form. Not shown in the pictures are two webbing straps embedded in the rear wall of the DBX.

Note pre-punched holes to accept toggle system.

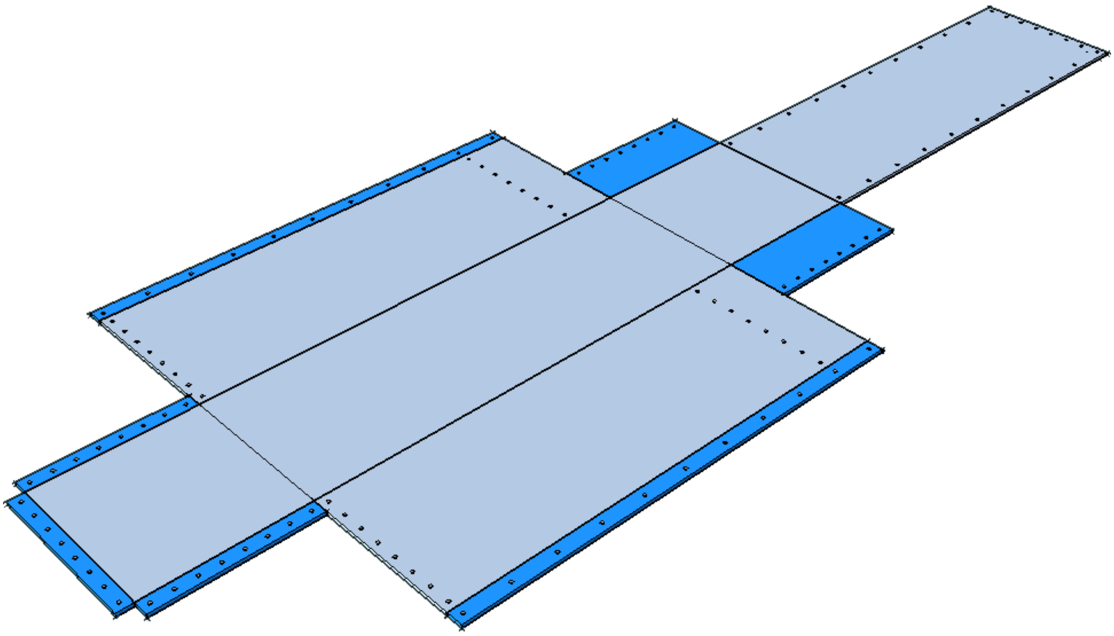


Fig 1

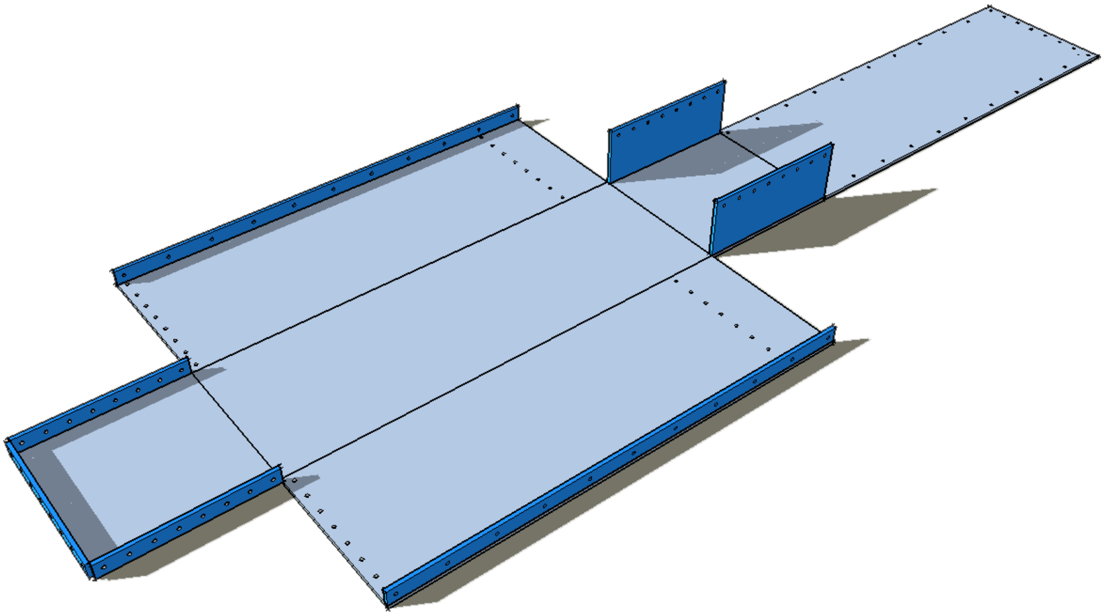


Fig 2

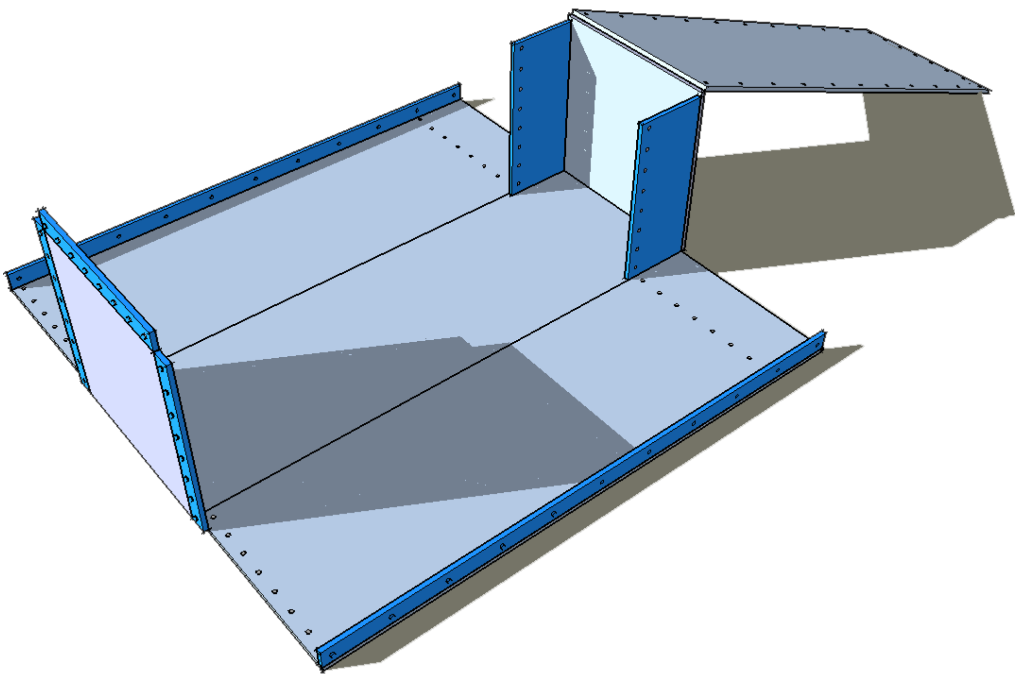


Fig 3

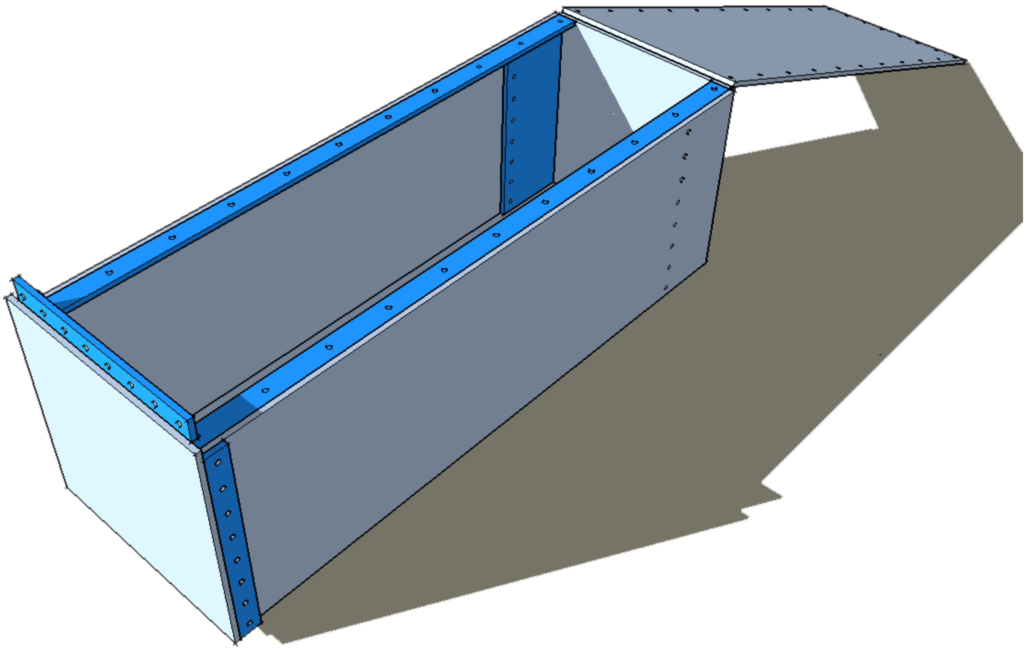


Fig 4

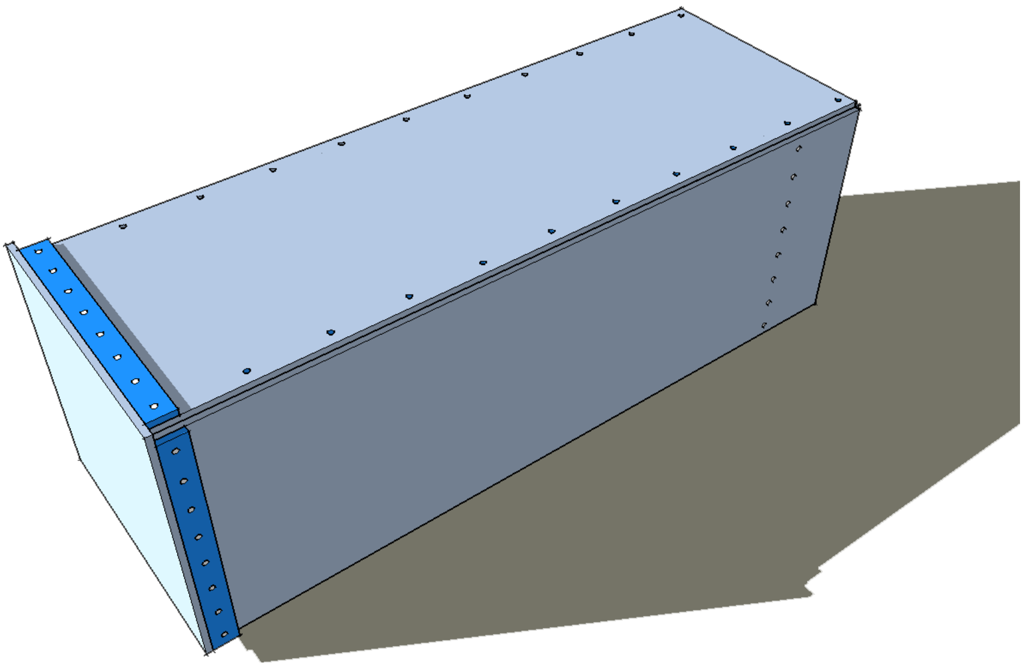


Fig 5

Aerodynamics and internal layout

There is no escaping the fact that the DBX does not have an aerodynamic shape. The internal contents will be packed in the lower 2/3rds of the DBX which will ensure the center of gravity is below the mid point. The flaps at the base of the DBX are designed to fold up on the outside of the two sides and lid. This ensures the air flows over the sides and base and does not try to pull the DBX to pieces.

The 1m square flat end may cause instability but it may be possible to secure some sort of curved profile to improve airflow. Should this be necessary, the profile could be manufactured from maize or similar and coated with a layer of some material to prevent disintegration in flight. I guess the more “bomb like” this can be the more stable the descent.

The dead space inside the top 1/3rd of the DBX needs to be filled with packing material and I know that an edible type similar to polystyrene chips does exist.

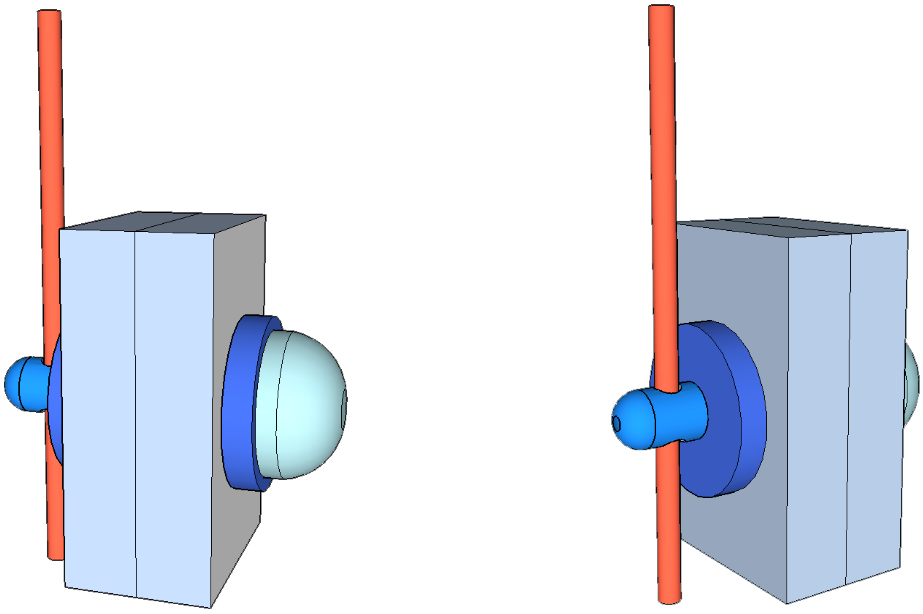
Toggles

The key to the DBX is the use of a toggle system that keeps the DBX together in flight and allows the contents to be ejected.

Fig shows the toggle assembly. There are three components: nylon washer, nylon pin and domed star fastener. The domed star fastener is similar to those used as retainers on plastic & steel shafts and can be found on modern printers, children's bikes etc. Once fitted, a star fastener is almost impossible to remove.

The domed star fastener is placed over the end of the nylon pin to form a peg. The peg has a 4mm hole drilled at the other end which will accept 3mm steel cable. A washer will be glued to the peg and the sub assembly pushed through and fixed to the appropriate side of the Triwall. The opposite side of the fixing point will have a washer secured to the Triwall. Once the peg is located, steel cable is threaded through the hole to secure the assembly and two layers of Triwall.

This construction method ensures that when the DBX cables are removed there is not a shower of loose components raining down on the ground.



The operation of the toggles and steel cable is crucial to the way the DBX functions. When fully assembled the DBX will be a strong structure but remove all the cables from the pegs and the box will collapse. The motive force for this will come from the main parachute deployment and various groups of toggles will be released in turn. When all cables are clear the parachute bridal will apply considerable tension to the web straps located on the rear of the DBX. At this point the DBX's velocity will be severely retarded and, as the DBX is not held together with anything, the contents should be ejected downwards.

Although there will be many toggles to release the actual force required will be quite small. Steel cable running in nylon with silicone grease will reduce friction to a minimum. A staggered release will also help matters but I am confident that the force available will be substantially more than required.

GPS & Telemetry

Successful deployment of this system is Dependant on releasing the toggles at the correct height and the subsequent dispersal of food packs. It may seem to be just a question of using a GPS to achieve this but a GPS will only give height information based on the distance between the receiver and MSL (mean sea level). It will not give height above the actual terrain.

As the earth is not a true sphere and is more like an oval, the GPS needs to use a system to determine exactly where sea level should be. Various standard models of the globe have been produced but the most common is called WGS-84. I would say that the majority of receivers base their calculations on this model.

It is vital that we obtain accurate terrain height to allow the system controller to release the toggles at 1000'. It is very important to ensure the DBX GPS and ground control GPS are using the same datum (WGS-84) else there will be inaccuracies and the system will not operate as planned.

The GPS module is hot of the production line and I have purchased direct from Taiwan. Although there are many different types available I needed one that would continue to function at any orientation. When the DB is ejected from the aircraft it will most likely tumble before stabilizing so any loss of tracking is not desirable.

The new design may help to solve another problem, namely lack of GPS signals inside the aircraft fuselage. For normal aircraft operation this is not an issue as there will be an externally mounted antenna with a clear view of the sky. The DBX will have the GPS mounted at the top of the unit and several DBX's will be together. The DBX's will be horizontal until deployed so providing the worst conditions.

During my original design stage for the Drift Marker I identified a system that will “repeat” the GPS signals inside the aircraft. This GPS will quite happily use these signals to give position information based on the location of the repeater aerial. These repeaters were extremely expensive at the time but, thanks to the explosion in car satnav systems, they are down to a few hundred pounds each. Various models are available and the most suitable will broadcast over a distance of about 30'. The repeater GPS antenna can be positioned anywhere in the aircraft so long as the collecting antenna and repeater antenna cannot “see” each other. The system does not have to be permanently mounted to the aircraft.

The control system will provide a series of indicators to show correct operation of the GPS and also a set of dial switches that will be set at the deployment height. The controller will determine the correct altitude for release based on this figure. Should the DBX system be successful, these switches will be replaced with a non contact method of setting the initial height.

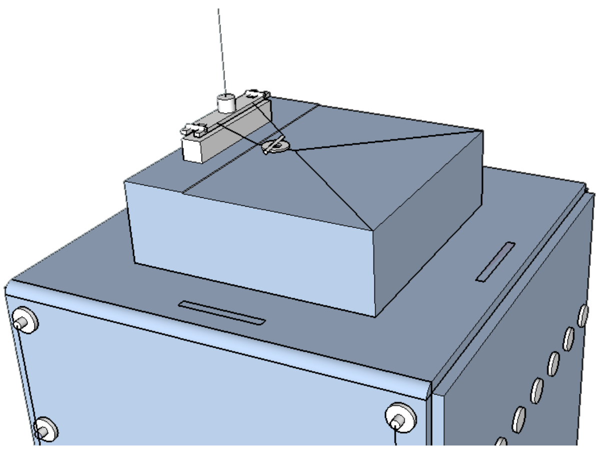
Telemetry

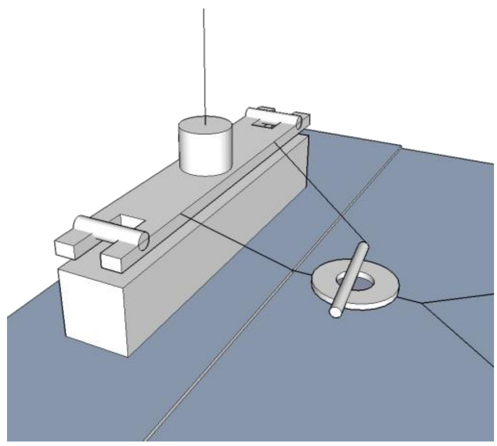
During the testing phase it will be vital to have various parameters transmitted to a ground based receiver to monitor the decent and deployment. This will be achieved using a radio modem. The link will be bi-directional so there will be a facility to send release commands in the unlikely event of the internal control system malfunctioning.

The radio modem operates at 2.4GHz. Other frequencies are available but that one is licensed for use in the UK. Although licensing is not of particular importance when deploying in a real situation I feel it is better to keep the DTI happy at this stage.

Release mechanism

My experience with release systems for sub sea work has provided several valuable lessons. Firstly a mechanical or electromechanical device is the most reliable. Second is the need to have a redundant system.





The above pictures show the release mechanism on the left hand side of the top unit. The close-up picture illustrates the double ended release bar. Should either end be triggered the bar will be released. Note the three cables attached to the release bar. The top one is connected to a streamer (or very small drogue chute), another to the parachute release pin and a third to the deployment bag located in the parachute storage pack.

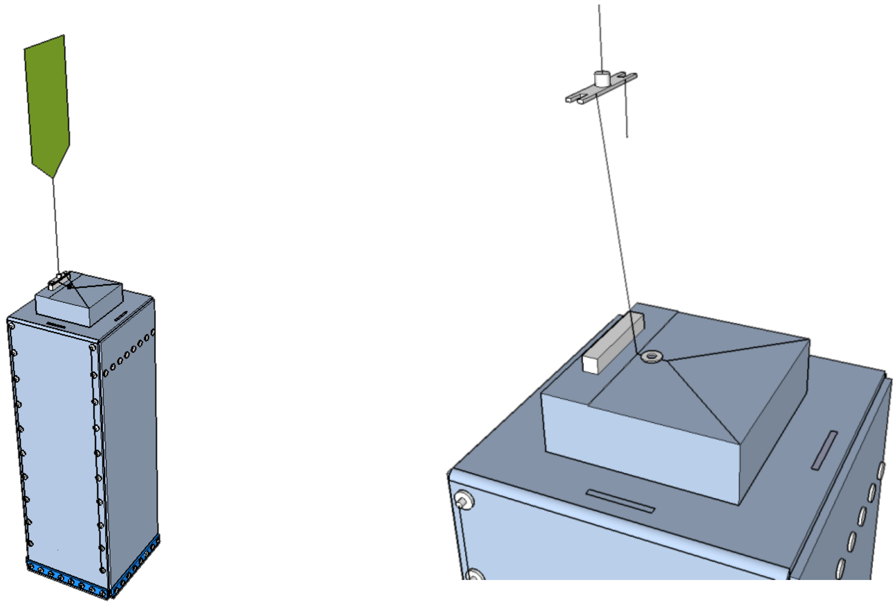


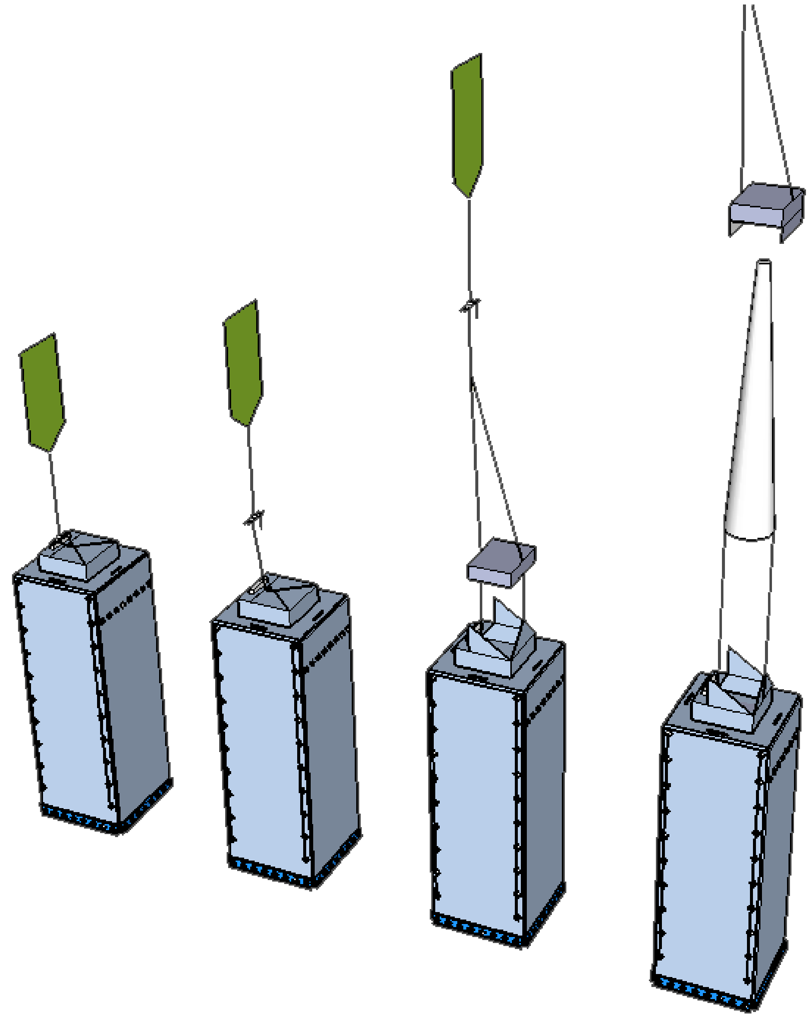
Illustration of the streamer and initial release.

Parachute storage & deployment

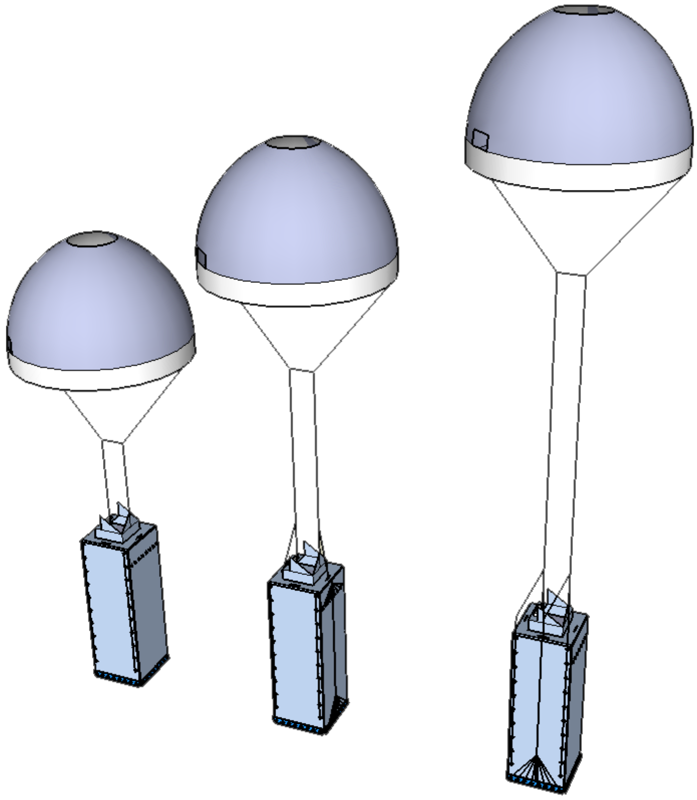
The parachute is contained in a “D Bag” which is in turn stored in a quick release container on the top of the DBX. This outer container has been designed to protect the parachute during ejection from the aircraft and will also prevent the parachute from opening prematurely. The “3 triangles” system is secured with a single release pin connected to the release bar.

During deployment the bar is released, the pin is withdrawn and the D Bag pulled from the container. The D Bag is released from the parachute and the parachute starts to inflate. At this time the parachute lines will release the toggles and the DBX will be ready for package ejection when the lines fully extend.

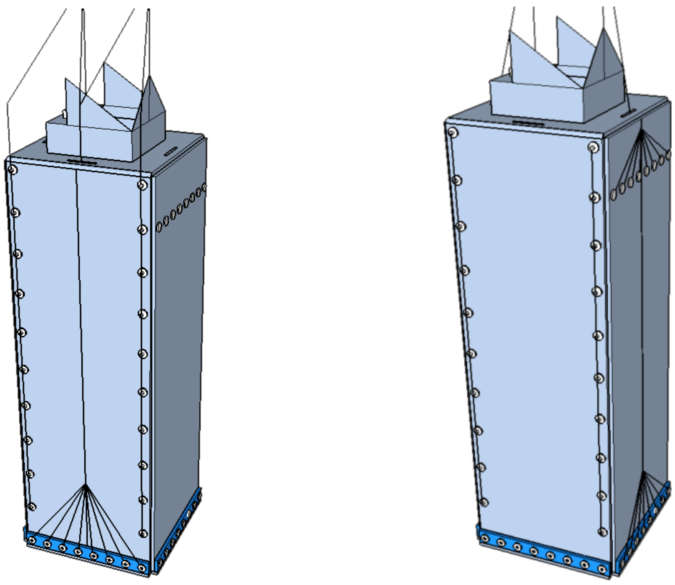
The following figures illustrate the deployment sequence.



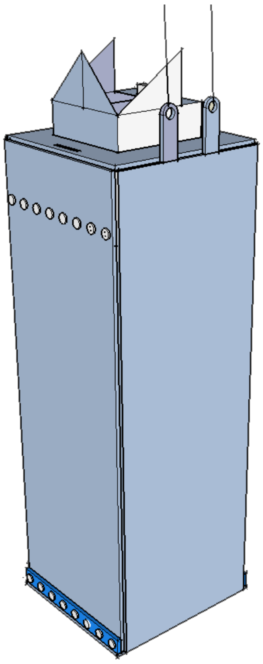
Stable descent
Release triggered + parachute pin removed
D Bag pulled from parachute box
Parachute ready to inflate



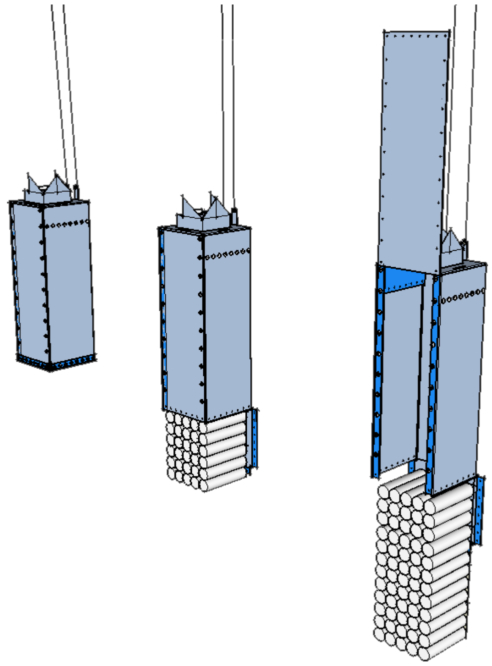
Parachute deployed
Both side toggles released
Front toggles released



Detail of front & side toggles. Side toggles are released from inside the DBX, wires shown for illustration. Cable exits from slot in top of DBX. Front toggles are released from outside the DB as it would be impossible to close the "lid" and secure the toggles from the inside.



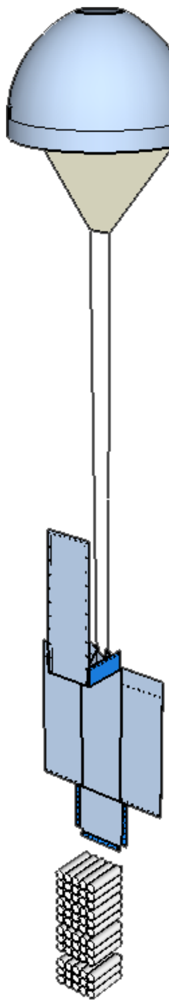
Rear of the DBX showing position of webbing straps, these carry the weight of the DBX during package ejection and transit to the ground.



Sequence as webbing straps take the load.

The DBX is no longer a container at this point and it is possible that the DBX will open up due to the descent velocity. This could well be in the order of 200mph so the illustrations are hypothetical.

The point at which the web straps take the load poses an interesting question. What weight will they have to take ?. Theoretically (if the DBX is still in the form of a container) there will be some load as the contents force open the base but I feel this will be minimal. I think the actual load will be the weight of the empty DBX + deceleration. I will incorporate a strain gauge in the webbing connections to measure this force.



Final stage of package delivery.

Deployment from aircraft

Ejection from the aircraft may be a problem but there are those in the group that are well qualified in this area. I note that the USAF use a 463L pallet system that has become a standard for several different aircraft : C-130, C-141,C-17 and C-5. I presume that the RAF also use the 463L or perhaps a UK variant that is still compatible.

The general method of ejection is to use a parachute to drag the pallets out of the aircraft but gravity can also be used. A 463L pallet complete with netting has a unit cost of around $2000 and each C-130 can accommodate 6 pallets. Once ejected they are not recoverable so this (plus the parachute) have to be regarded as “operating expenses”. I feel that we can make better use of $12,000+.

The following describes a system that addresses these problems.

Once again I do not have a name for this system so I will call it a “Roller Delivery Pallet” or RDP for short.

RDP

The 463L pallet has an overall dimension of 88” x 108” x 2.5”. The actual usable surface is 84”x 104”. The pallet is essentially two sheets of aluminum with a balsa core and weighs 290lb empty.

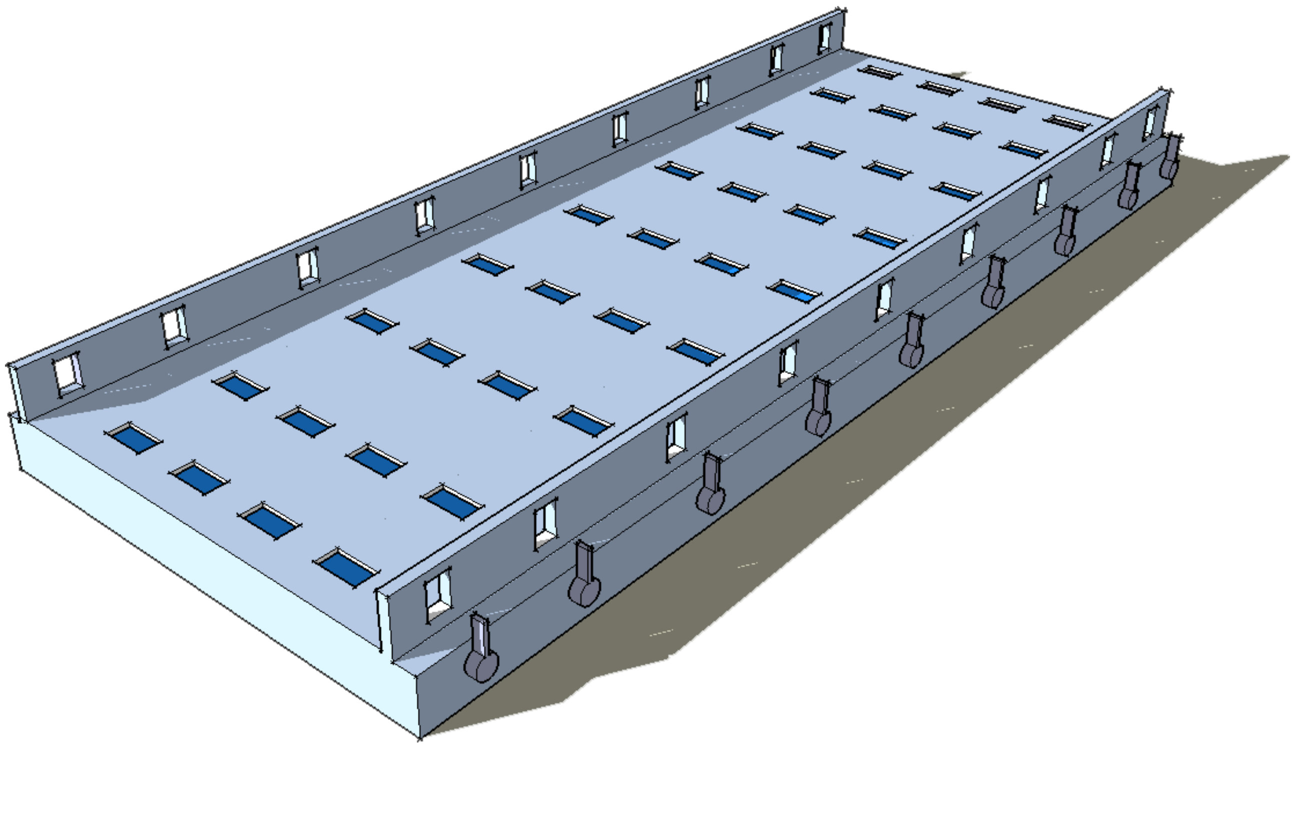
If the DBX dimensions are modified to suit then the DBX either becomes much smaller or the box is much wider than desired. I am still in favor of a long narrow format and believe this will assist the aerodynamics.

I see that it is possible to “marry” two 463L pallets and effectively create a single unit 88” x 216” long. This opens up the possibility of increasing both the DBX length, width and height and still maintain an “aerodynamic” format.

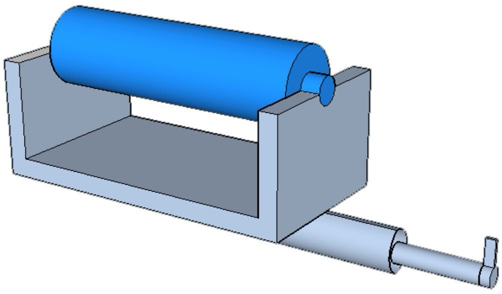
The main problem with making the DBX bigger is that it will be far more difficult to eject from the aircraft using gravity. The increase in weight and surface area will also increase friction so the DBX's cannot be slid along the pallets towards the rear door.

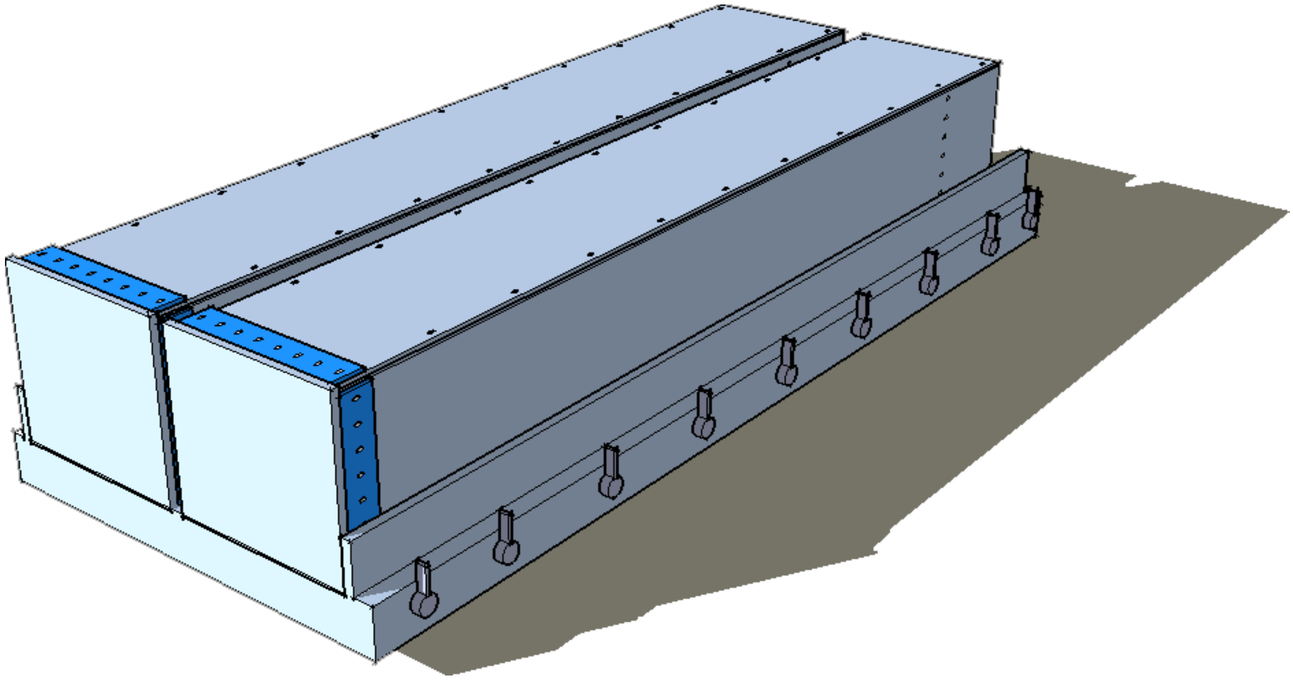
The next drawing shows a device that can be fitted to the top of two existing 463L pallets joined together. It is essentially a bed of rollers that can be lowered for transportation and raised to lift the DBX's off the surface thus reducing friction. Additional rollers are placed along each side which help to guide the DBX's.

The RDP can be a relatively lightweight unit but obviously strong enough to support the weight of two fully loaded DBX's.



Lever operates a cam shaft to raise & lower the rollers.





The RDP will be attached to the 463L pallet using existing tie points and the full range of 463L straps and nets can be used to secure the whole package during transportation. The roller cam levers will be operated in a fore to aft sequence with the final rollers raised just prior to ejection. Straps on the aft pallet will prevent the load moving prematurely.

It is possible to fit six 463L pallets in a C130, 13 in a C-41, 18 in a C-17 and 36 in a C5 !. The recommended maximum load is 7,500lbs an 250lbs/square ft. We will be well inside these limits even with a fully loaded RDP.

This system may have other applications.

Other considerations

Top plate

The top of the DBX may need to be strengthened with a thin ply panel to provide mounting points for the GPS/Modem, release system & parachute container. However none of these will be subject to any major loading so this is purely to make securing simpler.

Webbing

The webbing straps will probably have to be bonded between two layers of Triwall. This will serve to increase the rigidity of the back of the DBX. The back becomes the base when stored horizontally so additional strength would be useful anyway.

Power

I will probably use a small sealed lead acid battery as the power source for the electronics, GPS, modem & release systems. This removes the problems associated with air transportation of lithium based batteries. Weight is not an issue.

DBX weight

Naturally this is Dependant on the number of food packages packed into the DBX and the DBX tare wight. My initial calculations were based on a DBX of slightly different dimensions and it would appear that each DBX can carry the equivalent of four of the existing boxes. That means 360 food packs, around 430kg. Add another 30kg (estimate) for the DBX system and we have an all up weight of 460kg.

The overall weight can be reduced by creating a smaller DBX but there has to be a cost consideration. I doubt that the system would get funding if say the DBX was made ¼ its size but still had the same costs involved for release etc.

Parachute(s)

During the many hours researching this project on the Internet I discovered a source of ballistics grade parachutes used for amateur rocket recovery. These are guaranteed to operate up to 600mph which is well above my estimate that the DBX will reach terminal velocity at 200mph or thereabouts. These particular parachutes are inexpensive and lightweight.

The use of a streamer to provide the power to remove the D Bag and deploy the parachute may not be sufficient so a small drogue chute could be used. The streamer idea does have the advantage of not affecting the DBX drift during free fall whereas a drogue may do so. Also the forces applied to the release mechanism will be far greater for a drogue and complicate matters.

Conclusion

I hope that the ideas raised in this document will help the project to move forward and we can finally develop a system that will meet the requirements. Despite the fact that C-130 testing time may not be available until next year, it would be good to construct a scaled down version of the DBX that could be deployed from a helicopter or light aircraft.

Pat Cooper, August 2006