MRU Cardington Technical Note No. 5

The Southern England terrain experiment Aldermaston 1988

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A.J.Lapworth

August 1993

Met. Office Research Unit
RAF Cardington
Shortstown
Beds, MK42 0TH

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Foreword

The following notes are detachment operating instructions written prior to the Aldermaston detachment in 1988. This took place a few months after the Scillies detachment and the notes are influenced by the experiences there. It should be noted that the MB24 balloon with its disasterous tail design was still in use. However no strong wind flying was planned at Aldermaston and the decision to use it was reasonable. More serious in the event was the continued use of the defective cutdown device, although its deficiencies were still unrecognised at the time of this detachment. The dramatic malfunction of this device is described in a companion CTN and terminated the detachment.

1 Introduction

The purpose of this detachment is to obtain an estimate of a representative roughness for an area of inhomogeneous terrain. The Aldermaston area consists of a mixture of fields and woods. The topography consists of small hills and river valleys, with heights (depths) of about 30m.

The roughness lengths appropriate for large areas of woods or fields are reasonably well known and the roughness length associated with the hills and valleys can also be estimated. The problem is how to combine these various roughness lengths to obtain a representative estimate of the areal average roughness length appropriate for an area consisting of a mixture of fields, woods etc. This problem has recently been the subject of lively discussion in the literature and we hope to shed some light on the matter from an experimental point of view.

2 Notes on balloon operations

The balloon used for this detachment will be an Airborne MB24, with a volume of about 24,000 cu ft(680 cu m), a length of 75 ft(22·95 m), and a maximum diameter of 28 ft(8·45 m). It is manufactured from polyurethane coated nylon and can only be filled with Helium due to the static risk with Hydrogen.

2.1 General

For each flying period a forecast must be obtained.

No flying should take place when the wind is over 40 knots at any level, if it is gusting 25-30 knots at the ground, or if the lightning risk is 1 or 2. Overnight the balloon must be bedded if possible. If the wind is strong enough to prevent bedding, then it is preferable to attach navigation lights to the balloon cable and let the balloon up to 1000 feet. This should be high enough to clear surface turbulence and give enough cable to absorb shocks, while low enough to keep below the increased winds normally encountered at altitude. The 300 foot strop used on the Scillies detachment may be used but there will be increased turbulence at this low level over land, causing much greater oscillations of the balloon. After any flight, the cab recording tensiometer should be checked. If the cable tension is found to have exceeded 43 CWT, the cable should be changed before flying again.

2.2 Filling

The balloon should be filled to a net static lift of around 700 lbs. This assumes the following approximate weights:

Skin + rigging wires + tail guy	=	605 lbs
Valve	=	6.5 lbs
Bell crank	=	8.5 lbs
Heavyweight closehaul pennant complete	=	10.5 lbs
Handling guys	=	35 lbs
Air blower	=	6 lbs
Air relief valve	=	2 lbs
Two frames for air blower and relief valve	=	10 lbs
Cutdown device	=	15 lbs

This gives a total weight of 699 lbs (317 kilograms). To fill the balloon 88% full at sea level requires about 49 MRU bottles filled to 3000 psi, or about 58 bottles filled to 2500 psi or about 73 bottles filled to 2000 psi. Each bottle holds around 400 cu feet of gas at NTP when filled to 2700 psi., which should give an increase in lift of around 26 lbs per bottle when pure. The bottles are in two manifolded crates of 30 bottles per crate. Initial filling will thus use two crates. After this it is recommended to use bottles one at a time, opening each bottle onto the manifold in turn and CLOSING it after use, or using the next bottle will half refill the first one. Use in this way will reduce the effect of long term manifold leaks and makes accountancy of reserves easier. The alternative is to open all bottles onto the manifold. Used this way, the amount of gas used is proportional to the pressure drop. If all 30 bottles are opened onto the manifold then a drop in pressure of 100 psi is equivalent to about one bottle. One bottle filled to 3000 psi should give an increase in lift of about 26 lbs. Apart from the MRU bottles, there are several crates of manifolded Gas and Equipment twelve cylinder crates. These cylinders are supposed to be filled to 12 cu metres (427 cu ft).

3 Flying

The balloon will be filled 88% full for this detachment, which will give it a pressure height(at which gas is valved) of 4000 feet above sea level. This gives a static lift of around 680 lbs assuming a purity of 98% and that handling guys and blower are attached. A height of 4300 feet above sea level is theoretically attainable but this is inadvisable due to the large curvature in the cable giving a lieback of less than 30° to the horizontal at the pulley block in moderate winds when the purity gets low during the detachment (less than 95%). The large curvature will affect the accuracy of the balloon motion corrections. In strong winds the balloon can fly much higher than 4000 feet, but this must not be allowed to happen. The static lift is difficult to measure on detachment as even light winds increase the net lift (static+dynamic) by 50 to 100 lbs. If measuring the lift, check that the tail guy is free. It is best to overfill slightly and valve at pressure height. The static lift is constant with height provided that the internal temperature of the balloon is always the same as its surroundings and that pressure height is not reached.

Superheating by the sun can cause internal temperature excesses of 15° or more, increasing the lift by 50 lbs and also lowering the pressure height. This is a regular cause of Helium loss and may require one or two bottles of Helium a day to make good. The balloon has been shown to have a leakage rate when stored in the hangar giving rise to a loss of static lift of about 5 lbs per day. There is a loss of purity at the same time. This loss of lift and purity is mainly due to small leaks as diffussion through the fabric should only give a loss of 1 lb lift per day. Bedding trials over a few days showed that the background leakage rate was not significantly greater than in the hangar.

The balloon has a ballonet ceiling of 6500 feet above ground level. This should not affect operations, but if for any reason the balloon does exceed this height, the effect will only be noticable on the descent, near the ground.

The purity of the Helium is extremely critical in obtaining a good performance. If the purity drops to 90% then even if the balloon was filled with helium on the ground to an adequate static lift, by the time the balloon reached 1000 feet it would have valved off some of the gas due to the increased volume per unit lift of low purity gas.

4 Windspeed limits

The balloon has been recently rerigged to fly with zero pitch in low winds. The rerigging will probably reduce slightly the cable tensions from those previously measured although the reduction is not expected to be very great. The windspeed estimates given below take no account of this, but do take account of the tensions found on the Scillies trial. These tensions were significantly greater than expected, which may have been due to the distortion of the balloon envelope noticed below the nose. The pitch should increase to 15 - 20° at 40 knots. This means that dynamic lift and hence cable tensions increase as the cube of the windspeed. The tensions are maximum at the top of the cable, being reduced by several cwt at the winch. However, tests have shown that if the cable is stressed to over 50% of its minimum breaking load, there is a permanent weakening of the cable. In addition, if the cable is wound in or out, then it will start to break when the tension is around 65-70% of the minimum breaking load. This figure was determined from tests on KB65 cable using undercut 'U' groove capstans. The windspeed limits are extremely critical. In order to obtain maximum performance an OPERATIONAL WINDSPEED MAXIMUM OF 40 KNOTS has been agreed. At this windspeed the cable tensions at the balloon are around 30 cwt which gives a safety factor of 1·8 on moving KB85 cable and 2·8 on static KB85 cable. This cable BREAKS AT 85 CWT WITH A STATIC LOAD, usually at the ferrule. Extrapolations of experimental results indicate that a cable tension of 85 cwt is achieved at a windspeed around 55-60 KNOTS, DECREASING TO 45-50 KNOTS IN A 10 KNOT UPDRAUGHT. There is an uncertainty due to the lack of data on movement of the centre of pressure. This range is only 15-20 knots above the operating maximum, and a single gust could break the cable. Two further points should be noted. Firstly, if the cable is wound in or out, the cable will start to break up at a cable tension in the region of 57 cwt. This tension should occur at a windspeed of around 50 knots. Secondly, the maximum windspeed that the balloon has been tested to is around 48 knots. At this windspeed the envelope is observed to distort its shape badly and the rudder flutters, resulting in rapid fatigue of the fabric. Above this windspeed there may be unexpected drag increases due to either sharply increasing pitch or tail waggle. A CLOSE WATCH SHOULD BE KEPT ON THE TOP PROBE GILL READINGS WHEN OPERATING NEAR THE LIMITS. In addition the forecast winds at altitude should be regularly reviewed as, by the time the wind starts to increase it may be too late to make bedding possible. It should be noted that the highest tensions in the cable can be generated with the balloon near the ground if a gust catches the balloon sideways on. In this position the drag coefficient is around 10 times that in the nose on position and there is not sufficient cable to absorb shock loads.

5 Tail waggle

The rudder waggle, which has increased with the age of the balloon, appears to start at 25 knots with a period of about 1 second but decreases to a flutter at windspeeds above 45 knots. The waggle does not appear to affect the stability of the balloon but does vibrate the cable and possibly affects the probe measurements. In addition it results in fatigue of the fabric, causing the seams where the tail joins the hull to split.

6 Rates of ascent and descent

These are usually limited by the winch to around 200 feet/min. On ascent the speed should not exceed 150 feet/min in order to allow gas to escape from the valve restrictor plate when the balloon is above pressure altitude. This will also allow a reasonable profile to be taken. In high winds the descent rate should be restricted to 100 feet/min or less as the pitch angle of the balloon will be increased by the descent rate, increasing the cable tension (watch the cab tensiometer). Some approximate calculations suggest that the cable tension increases by around 6% for an updraught of 100 feet/minute.

7 Bedding

Full details on the balloon bedding procedure are given in appendices A and B but a short summary is given here.

The balloon can be fairly easily handled near the ground in windspeeds of up to 15 knots. Above this it becomes progressively more difficult until at speeds gusting 25 to 30 knots it may become very difficult or impossible. If bedding the balloon is impossible, then provided winds above 50-55 knots are not forecast, it is best to leave it flying on about 1000 feet of cable which should be above the turbulent surface air. With this length of cable there should be sufficient absorption of shock loads due to gusts.

If the balloon cannot be bedded and a wind significantly higher than 50 knots or a high lightning risk is forecast, consideration should be given to ripping the balloon which is done by giving a pull of greater than 20 lbs to the RED NYLON CORD ON THE STARBOARD SIDE OF THE BALLOON. This is not too awful an action to contemplate as there is a spare balloon and the ripped one is easily repairable. Only the gas is lost, together with some flying time while the second balloon is inflated.

The bedding operation involves setting the pulley (snatch) blocks onto the bed so that the balloon is pulled down facing into wind, pulling the balloon down and transfering it to a central strop, removing the radar reflector, running the handling guys through the pulleys and clipping them to the spider, pulling the balloon down on the spider until the ballonet blower and air relief valve can be removed, removing and pulling out the rigging leg with topping up hose attached, putting padding over the main rigging and then tensioning down with the ballonet sleeve undone and exhaust tube inserted. Be careful to ensure that it is the ballonet sleeve and NOT the neighbouring gas inflation sleeve which is colour coded RED. Finally the tail exhaust sleeves are undone and the tail folded and lashed down, AND THE RIP CORD TIED SECURELY TO ONE OF THE STAKE PLATES.

If possible lines should run from the main rigging patches under the balloon to the bed wires to stop the balloon twisting in a wind. The tensioning should be set to about two tonnes of the main cable when it has been taken off the flying cable (which has a limit of 4·25 tonnes) and transferred to the Tirfor. This should put a load of about 500 lbs on each of the patches, and may be increased from 2·0 tonnes to 2·5 tonnes in a high wind. The tension pressurises the balloon to withstand the wind, and should be in the range 10 to 20 mm water (i.e. 1 to 2 mb). The balloon can take up to around 60 mm water excess pressure although it will stretch greatly. However in the bedding position the main strain is on the patches, which stretch and eventually leave the fabric above them porous. As the balloon CANNOT VALVE GAS WHEN BEDDED (as the valve is not pressure but line operated) a check should be kept on the internal pressure and line tension, in particular when the sun falls on it first thing in the morning, causing the gas to expand.

Unbedding is the reverse of bedding (remembering to untie the rip line) except that the balloon must be inflated with air from a blower as it is raised. Otherwise in any wind the gas will surge around and the balloon will lie acrosswind rather than lining up with it. Another point to watch is the problems that arise if the wind is not in the same direction as when bedded. If the wind is greater than 15 knots it is probably best not to unbed in this latter case, but if unbedding is attempted the tail guy should be held on to until the handling guys have been unclipped and then released with care (there may be several hundred pounds force on it).

8 Air blower and exhaust valve

The balloon is not pressurised by the helium gas except insofar as the static lift exerts a pressure of 8mm water near the top of the balloon dropping to zero at the bottom. The main pressure is due to ram air entering through non-return flaps at the nose and tail air scoops. This is augmented by an airbooster giving a superpressure of 1·5 to 2·0 times the ram air pressure which should stop the nose dimpling in a steady air flow. The booster is highly desirable but not essential to operations and can be removed provided its duct is tied up. As the balloon rises the ballonet diaphragm expands downwards and the air displaced must be allowed to escape or the balloon will burst. This is accomplished by means of a metal can exhaust valve facing into wind, and set to open if the internal pressure exceeds the ram pressure by about 14 mm water(1·4 mb). This valve is important. If it is not attached to the balloon, its ducting must NOT be tied up. However in this case the balloon will not be able to maintain a high internal pressure and will dimple in gusts and high winds.

For reference, there follows a table of ram air pressures expected for given windspeeds near the ground:

VELOCITY (KNOTS)	PRESSURE (mm water)
10.	1·7
20.	6·6
30.	14·9
40.	26·6
50.	41·5
60.	59·7

9 Weather limits

The main factors affecting balloon flying are winds at all heights, turbulence near the ground, and lightning risk. The wind speed limits, which have already been noted, are 45 knots at altitude and 25 to 30 knots near the ground depending on turbulence. In strong turbulence lower limits should be considered. The other major risk to flying operations is that due to lightning strike. The balloon acts like a high level lightning conductor and can 'make its own strikes'. Many balloons have been lost due to this cause. In particular flying by night has the additional problem in that no local assessment of lightning risk by noting cloud thickness is possible.

Flying can take place in lightning risks of 4 or 5. With a lightning risk of three, convection above the freezing level is indicated and further advice may be sought from the forecaster. Usually flying is permitted below cloud base. There should be NO NORMAL FLYING IN LIGHTNING RISK VALUES OF 1 OR 2. If rain or dark clouds are noted during flying operations, the lightning risk should be queried. An important factor is thickness of convective cloud above the freezing level, a thickness of more than 5,000 to 10,000 feet giving a fair chance of lightning. Thus lightning is more likely in cold weather when the freezing level is lower.

If flying in marginal conditions it is well worth while asking the forecaster to check weather radar for strong echoes every hour or two.

10 Navigation

- Notify:

ATC supervisor FARNBOROUGH	0252-24461	Ext 3775	
ATC supervisor BOSCOMBE DOWN	0980-23331	Ext 2114	0830-1700 Mon-Thurs 0830-1600 Fri
Supervisor BRIZE RADAR	0993-842551	Ext 551	

at the start of flying operations and, when they are finished at the end of the day.

- Outside the above hours our number is Silchester 700309 (Grid ref SU 620642)
- By day drogues are flown at 500 foot intervals on the cable. By night, a pair of lights (white over red) are flown under the balloon and this pair is repeated every 1000 feet. At least one pair must be below cloud base. A triangle of flashing lights must be set out on the balloon bed.
- The balloon should also carry a radar reflector in the rigging.
- The area has been NOTAMed.
- The NOTAM gives a maximum height of 4500 ft AMSL., in an area 2·5 n.m. radius from N5122 W00108 which includes restricted area R101.
- The local air traffic includes both fixed wing aircraft and helicopters.
- If the balloon breaks away, first actuate the cutdown device. Then phone RAF West Drayton (0895-444077 or 0895-445566 Ext 6150 (distress and diversion) or Ext 6153) and give details.
- The police should also be informed.
- If the cable breaks near the pulley block when the balloon is at altitude then it will probably trail cable a considerable distance over the countryside shorting power cables and causing damage. If the break is near the balloon it will rise (nose up) and may or may not burst (watch for this if possible) If it does not burst it will reach an equilibrium ceiling of 20,000 to 30,000 feet and drift downwind into the airways.
- If the cutdown device works, the balloon should sink to the surface in a few minutes.

11 Cutdown device

In view of the possibility of loosing the balloon, efforts have been made to equip both the main balloon and the spare with cutdown devices. These work by using a coded transmission from the ground to detonate a ring of explosive on top of the balloon, cutting a hole in the envelope. The explosive is Cordtex-related and detonates with a loud noise. Care has to be taken not to kink the charge, and a stiffening panel is provided to keep the charge flat during balloon inflation. The receiver and battery are located in the balloon rigging above the point of attachment. The battery should last for about 48 hours. The device operates on a frequency of about 153·63 MHz which is close to that of our walkie-talkies. To test the receiver, the transmitter can be switched to 'TEST' and the button pressed. A light on the receiver should then come on. To fire the charge, the transmitter is switched to 'ARM' before pressing the transmit button. If there is some uncertainty as to whether the device has worked, the transmitter output power can temporarily be greatly enhanced by switching to the high power setting.

12 Weather forecasts

During the detachment weather forecasts will be provided by Brize Norton. They will be in our normal format. We will normally receive a main forecast at the start of the day plus an amendment half way through the forecast period. It is expected that Brize Norton will pass forecasts and some charts by DOCFAX.

- Telephone numbers:

Forecast room (ex-directory)	Carterton	(0993)	840114
Thro' Brize Norton exchange	"	"	842551 ext 535 or 536

- Forecasts will start when we request.

- Forecasts will be done on request for flying at night or weekends.

APPENDIX A

Balloon bedding procedures MB24 - April 1988

1. Lay out groundsheets on bed and also position tail sheets.
2. Attach carabiners and bedding pulley blocks to bed wires as directed by bed supervisor. (Those for the bow and numbers 1, 2 and 3 guys on the 22ft bed mooring circle and number 4 on the 30ft circle with extension strop).
3. Clear balloon bed of all obstacles.
4. Lay out spider in approximate position.
5. Winch the balloon down and remove the radar reflector and untie the handling guys.
6. Remove breakaway device battery and receiver pod. Tie off connector to rigging.
7. Attach 6ft strop from a separate shackle on centrepoint to bellcrank mooring strop.
8. Pay out flying cable so balloon is flying on mooring strop.
9. Have 1 person steady balloon into wind using tail guy loosely reeved round 60ft mooring circle.
10. Disconnect flying cable and remove it from flying block.
11. Remove flying block from bed (or drop it into centrepoint hole), and cover centrepoint and bed earth plates with protective mats.
12. Haul in flying cable under hand tension as directed by bed supervisor.
13. Move spider to correct position beneath bow of balloon and attach it to the flying cable.
14. Reeve handling guys through bed pulley blocks and attach to appropriate legs of spider.
15. Check all spider legs, handling guys and blocks are free and not twisted or tangled. Have 1 person each side to monitor their free movement during subsequent bedding operations, and stop proceedings if problem is noted.
16. Bed supervisor will now instruct winch driver to start pulling down the balloon on the handling guys. The person at the tail to keep some tension on the tail guy.
17. At appropriate height the bed supervisor will instruct winch driver to stop hauling in while he and the two from either side of the balloon go underneath to disconnect ripline and attach it to the 30ft mooring circle. They also disconnect topping up hose rigging wire from main rigging shackle and pull it out to the port side, then reconnect all the other rigging legs on the shackle and position the rigging in the centre point hole under the balloon.
18. Bed supervisor then instructs hauling in to continue, until halted for removal of blower and flap valve. Person at the tail is then instructed to tie off tail guy and undo rudder air sleeve.

19. Remove blower and valve from bed area and position protective mats over close haul rigging.
20. Personnel are then repositioned to port and starboard sides and third person prepares to take in on the tail guy.
21. Bed supervisor then instructs winch driver to restart pulling down the balloon, and another person to untie the ballonet sleeve on port side (not red helium gas sleeve.) and fit air deflation tube.
22. Pull in tail guy tight and tie off, undo fin deflation sleeves to release air more quickly.
23. As the balloon settles, the tensions on the guys are taken in and the spider is transferred to the winch chassis using the Tirfor winch and load cell to take the tension off the flying cable. The tension is normally kept at around 1000kg.
24. Fins and rudder are now tied down under balloon, to stop movement. Sandbags may be hung from side tag patches, but these patches must NOT be tied to the bed.
25. Check topping up hose safe under balloon and rip cord tied off and clear.
26. Check handling guy tensions are roughly equal.
27. In the interests of safety, people should not stand between ropes or rigging wires. Take great care when moving around the balloon bed.
28. The tension set by the Tirfor should be altered according to changes in temperature and pressure in the balloon, due to local weather conditions.

APPENDIX B

Balloon unbedding procedure MB24 - April 1988

1. Test air blower, switch it off and position it near rudder.
2. Undo securing lines around rudder and fins and retie fin deflation sleeves. Untie sandbags if used. Secure blower tube in rudder sleeve.
3. Connect spider to flying cable and take in tension so that Tirfor can be removed from spider.
4. When ready to raise balloon, start blower and as tension increases the winch driver will allow balloon to slowly ascend.
5. A person should stay at the tail to slacken tail guy as appropriate. One person either side of balloon should ensure free running of handling guys and bedding pulley blocks, and also check rip cord does not come under tension.
6. When accessible, tie off the ballonet sleeve.
7. Balloon is allowed to slowly rise until bottom is accessible. Bed supervisor may instruct person at tail to tie off tail guy and stop blower temporarily as ballonet inflates. Supervisor will stop the ascent whilst protective mats are removed from close haul rigging, air blower and flap valve are installed and the topping up hose leg is refitted to the main rigging. Shackles should be spiked up tight.
8. Bed supervisor will instruct person at tail when to restart blower. He then slackens tail guy as balloon rises further.
9. Rip line is untied from bed wire, re-clipped to rigging and tied onto bellcrank strop with a clove hitch.
10. Check air blower fan is rotating.
11. When sufficient air is in tail and ballonet, the bed supervisor will instruct person at tail to tie off tail guy, stop blower and remove pipe from rudder with assistance from others if necessary. Tie off rudder deflation sleeve.
12. Fit breakaway system pod to rigging and connect up cable to panel and battery.
13. Bed supervisor will advise winch operator to pay out cable to transfer balloon to the strop. He and person from each side of balloon will now pull the spider to slacken the handling guys and release them from the spider and bedding blocks. The person at the tail will WAIT UNTIL ALL HANDLING GUYS HAVE BEEN UNCLIPPED and then slip the tail guy and allow the balloon to come into the wind, steadying balloon without retying tail guy. This operation can be critical if wind is strong and different in direction to when balloon was bedded.
14. Refit flying cable to flying block and balloon bell crank.
15. Tie up handling guys.
16. Test breakaway system.
17. When ready to raise balloon, fit radar target and transfer to flying cable. Disconnect mooring strop.