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HIGH ALTITUDE CLOUD SAMPLING

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This joint statement follows discussions by the authors severally with the R.A.F. Task Force Officers and with [redacted] It is stimulated by the difficulties experienced during Grapple and Grapple-X and by the likelihood that the existing aircraft may come to the end of their useful life within the next three years.

1. Statement of the Problem

1.1 The requirement is to collect amounts of solid debris adequate for analysis from an atomic weapon cloud at altitudes in excess of 50,000 ft. It is possible that in the near future this might need to be extended to gaseous products, but, for the moment, to cohere ideas, we consider only the collection of particles lying roughly in the size range 0.1 to 30 microns.

The collection of this material has hitherto been made on cellulose filters in large ducts carried on the wing-tips of Canberra B.6 aircraft: the apparatus is described in [redacted]

The analysis of the collected material involves two main methods - one radiometric, where the material is identified and measured by the radiations emitted, the other mass-spectrometric, where the material is converted into a beam of ions which are subsequently separated into the various isotopes by a magnetic field, these isotopes being measured individually. Broadly it is the latter method which, as a result of low efficiencies at various stages of analysis, requires the major sample: comparatively speaking, radiometric analysis may be performed on much smaller amounts. (If minute amounts of activity - e.g. radiothorium - are being sought, the minimum amount required for a single analysis is about the same as that required for mass-spectrometry). Therefore, while the sensitivity of the radiometric measurements is not a cause of complacency, and efforts are being made to enhance these, the major savings must be made initially in the mass-spectrometric field. In part 2.3 of this memo, the possible improvements in this field are discussed, and it is believed that appreciable savings will be made not only by the introduction of new techniques, but also by the steady improvement of existing facilities. While it may be that these will come within a few months, it is nevertheless essential to consider the

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relative costs of improvements in the laboratory and of various suggested methods of sampling.

1.2 The sample size is best defined in terms of "fissions", which may be related to the total fission release of the weapon analysed. One megaton of energy is given by 10^{26} fissions, hence a sample of "10^{14} fissions" corresponds to one part in 10^{12} of the total cloud. This concept may also be defined in terms of some related property which may be measured by suitable radiac instruments: thus 10^{14} fissions give approximately 1 roentgen per hour dosage at a distance of 1 foot at 2 hours from burst; the dosage falls off with time approximately as $t^{-1.2}$ and with the inverse square of the distance. Such approximations are useful for identifying, within a factor of two, the number of "fissions" in any particular sample, the accurate number being determined by subsequent radiometric analysis.

Having established this concept, we now illustrate typical amounts collected, and specify target and minimum quantities for future collection on the understanding that, as analytical methods are improved, a downward revision may be made. The maximum collection made hitherto is about 2.10^{16} fissions during Buffalo-1 and Antler-3: still within this size range of weapon, we have had normally a few x 10^{15} fissions per aircraft sampling. In Grapple-1, about 5.10^{15} fissions were collected by the primary sampler, and much less by the secondary: Grapple-2 and -3 produced about 10^{15} fissions or rather less: Grapple-X produced totally, with three aircraft, just under 10^{15} fissions.

The target size of sample in any shot is 4.10^{15} fissions, the absolute minimum 4.10^{14} fissions. These are subject to two further criteria: they must be representative and must be adequately concentrated.

The first qualification arises from an effect, due probably to condensation processes and associated with particle size, whereby certain products may be concentrated or depleted in a particular sample: there is no satisfactory theory, but it is probable that the small particles which remain airborne for considerable times are quite representative, and those which are formed early, grow to relatively large size, and gravitate to the bottom of the cloud, are not representative.

The necessity for adequate concentration arises from the fact that, while the radioactive elements present in the cloud are a minor problem (with reservations regarding the longer-lived species), the naturally-occurring and stable elements are inevitably present as contamination in the collecting medium. This applies particularly to uranium, though it may be stated that, were such contamination altogether avoided, certain problems in diagnostic analysis would be more soluble. We consider only the uranium case here. The true uranium from the debris of a megaton weapon, associated with 10^{14} fissions, may lie between 10^{-7} and 10^{-8} gm. approximately. The uranium contamination associated with the type of paper used at present represents typically about 3.10^{-7} gm. per Mk. III filter duct. While corrections may be made, their efficacy varies with the particular isotopes, and

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further inaccuracies increase when the correction terms become comparable with the observations. In part 2.2 of this memo. we discuss possible improvements in this field.

1.3 We therefore specify for the immediate future (year 1958) that, per Mk. III sampling duct, the target sample is 10^{15} fissions, and the minimum sample 10^{14} fissions. This minimum sample would allow approx. a single mass-spectrometric assay of uranium, a single determination of detector material, if used, and a few determinations of salient fission products. It makes no allowance for spillage or other forms of loss. If more than one duct's worth is collected, it enables replicate analyses to be made which, in view of the minute amounts assayed, is imperative in establishing reliability.

We suggest two aircraft, each bearing two ducts in a typical case, and each collecting at least 10^{14} F/duct, are the minimum air requirement.

1.4 <u>Limitations of present aircraft sampling</u>: These may be stated baldly as follows: the aircraft cannot get high enough, and they cannot stay at maximum attainable altitude long enough in the radiation field there obtaining.

The tropopause at Christmas Island varies between 55,000 ft. and 59,000 ft.: this is in contrast to the tropopause at the Eniwetok (U.S. testing) area, which is more usually around 45,000 ft. and, under conditions of small, i.e. under two, megaton bursts may give quite different cloud concentrations. In the Eniwetok area, the mushroom tends to leave some cloud at the tropopause and then go on up to maximum height. The main body, being much higher, does not cause the problem of "shine" that is caused at Christmas Island, where the difference of 12,000 to 15,000 extra ft. in tropopause level tends to result in the upward rise of the cloud immediately after this level being slower, and the lateral spread immediate, thereby causing an embarrassing amount of "shine" to the cloud samples at 50,000 ft. This "shine" means that the aircrew are accepting radiation even while not actually collecting material - in common physical parlance, there is a poor "signal to noise ratio".

We have tended to find in past trials of high-yield airburst weapons that the area between the base of the cloud and the sea is, to all intents and purposes, free from significant radiation. The stem at 10,000 ft. and 20,000 ft. is also substantially free from fission products, which, in air samples, may start to be found at 30,000 ft. and upwards. With the bigger weapons (over two megatons) the same substantially holds, but even at 45,000 ft. the main body of the fission products will not be found, they are quite obviously in the region of 55,000 ft. to 60,000 ft. and above.

With surface megaton bursts, as in the U.S. "Castle" series, while the main cloud will get to the height dictated by the yield, much more is left in the stem and at the tropopause.

1.5 <u>Requirements for improved sampling</u>: If an aircraft can get to the tropopause, it will at least be able to guarantee sampling the material which is left behind there. Between this, which represents the effective base of the cloud, and the mean centre of the cloud, any increase in height will improve greatly the "signal to noise" ratio. Since the dose rate may be up also, it is necessary to

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icy sampling until the cloud has cooled off. (The alternative, of sampling for a shorter time, earlier on, is not applicable, because of "shine").

In section 6 we consider the technique of sampling.

2. Improvements in Equipment and Analysis

2.1 The filter ducts themselves, while not ideal, nevertheless are well-designed and effective, in that they offer a large frontal area with minimum effect on the particle size spectrum, and are easily fitted, serviced, and removed. Additionally, they represent an investment of some £45,000 in capital cost: there is no point in changing them unless, for mechanical or aerodynamic reasons, they cannot be used on other aircraft.

2.2 The type of filter element is under continuous review. To date, only two types of cellulose filter have been found useful, one called IPC paper, and made in U.S.A., the other EDTA - esparto, developed in U.K. There is little to choose between them as regards filtering properties and uranium content. While specialised methods could possibly be developed to reduce the amount of uranium "background", their introduction into manufacture even in the U.K. material under our control is another matter. In any case, such methods are generally specific, in the sense that, while one might reduce uranium, other possible irritants might not be touched and could be enhanced. Inorganic constituents, such as calcium and phosphate ions, are of much nuisance value in analysis, but may be circumvented if the amounts are not too great.

It is indeed possible that something might be done with porous, woven, or felted, plastic media. These, being made initially from gases, might a priori expect to be superior to natural products as regards purity. While probably inferior to cellulosic materials in normal air at low flow rates, there is some possibility that in the exceedingly dry air at extreme altitudes, with low air density, electrostatic attraction might enhance their value. Advise is being sought on suitable types of material. It is suggested that solubility in organic liquids would enable the dense, insoluble, and inorganic, debris sought to be removed simply, and that this should be a major criterion of suitability. Alternatively, stability to inorganic acids, whereby the debris might be preferentially dissolved, should be sought. Such investigations are essentially simple and cheap.

If substitutes can be found, flying in normal conditions will enable some comparison to be made with the present material using the normal radioactive background at high altitude: however, an operational comparison would eventually be needed.

2.3 The analytical technique involves a variety of steps, in certain of which losses may occur. These are principally as follows: chemical recovery, source utilisation, and detection technique. So far as the detection of radio-elements such as radiothorium is concerned, the overall efficiency is about 20%, and only marginal gains may be expected: the efficiencies involved in mass-spectrometric analysis are much lower.

/ (a) Chemical recovery:

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(a) Chemical recovery: With a clean sample, i.e. little interfering chemical contamination, the recovery in chemical processing may approach 100%: normally 50-70% is attainable, but in extreme cases only 15-20% may be obtained. This is a laboratory matter, demanding proven and standardised techniques: these are under almost continuous review, and are bound up to some degree with advances in filter technology.

(b) Source utilisation: With practically all solid-source machines currently manufactured, the fraction of the atoms deposited on the filament, which arrive as ions at the detector slit of the machine, is in the region 10^{-4}-10^{-5}. This depends principally on the ion optics of the source design, and most sources made to date are largely empirical: by careful theoretical design and model studies, a factor of ten might be squeezed. One should not altogether exclude sources employing a different principle, in which the efficiency of utilisation might reach several percent.

(c) Detection technique: Since the ions arrive at the detector end of an analyser in discrete groups, the two possible techniques are either simultaneous collection of each group, or so to vary the operating conditions that groups are swept past a fixed slit in turn. For practical reasons, only the latter has to date been employed. It is obvious that the efficiency may be expressed as the fraction of running time in which a particular isotope beam is being measured: this may be as little as 5%. Instrument modifications are continually being made so that this loss is minimised: the development of simultaneous collection as a long-term issue is being carried out

2.4 In short, in matters falling within the duties of [redacted] there is considerable room for improvement: it is fully recognised that pursuit of these offers the greatest scope for economy in the overall problem. The necessary development is being carried out as quickly as staff recruitment and training in an exceedingly specialised field permits: use is made of industry to the limited degree possible. The hold-up here is in experienced men. At [redacted] we are building up comparatively rapidly a strong team, whose contribution over the next two years may reasonably be expected to be at least one order of magnitude in sensitivity, at a cost of perhaps £50,000-£80,000.

3. Sampling by Means of Aircraft

The useful life of the present B.6 sampling aircraft is likely to continue until about 1960. There is adequate time to consider a replacement sampling vehicle. Unless more B.6 aircraft can be supplied, it appears that the choice of aircraft lies between the P.R.9 and the Javelin; alternatively, it may be that some rocket vehicle, with or without guidance, is feasible. We consider the position of these latter individually.

3.1 Manned vs. Unmanned: The advantage of using an unmanned sampling aircraft would be that the radiological hazard to crew which is now possibly a limiting factor under certain conditions, would be eliminated. The aircraft could either enter the cloud earlier or stay in it longer.

Disadvantages of such an aircraft are that its flexibility of manoeuvre and degree of control is not so great as one under direct human control, and in order

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To operate it and receive information on size of sample, a special ground-control system, involving great expense, would require to be set up at Christmas Island and/or Maralinga. Experience with the Jindivik suggests that the methods of control are not so perfected that one can guarantee the safe return of this aircraft to base, nor is there at the present time any ground-controlled aircraft of the Meteor/Canberra type in which the control is advanced enough to consider it for this rôle.

While such vehicles may be of use in low cloud sampling, they cannot climb higher than the existing B.6 and entry must be made at early times, when turbulence is likely to result in structural failure. This effectively limits early entry to rocket type.

The conclusion is that the manned aircraft, although suffering from the limitation imposed by allowable crew dosage is, at the present time, and in the foreseeable future, a better proposition that an unmanned aircraft.

3.2 Manned aircraft, jet and rocket-driven: Survey of position at 5th December, 1957.

The maximum operational ceiling of Canberra B.6 aircraft used for sampling is approx. 52,000' and, as stated in 1.4, this is not high enough. A requirement has been stated for a Canberra B.6 fitted with the double Napier "Scorpion" to sample at 62,000': work is in hand at present at Messrs. Napier, Luton, to modify a Task Force sampling Canberra with the intention that this height can be reached. The actual technique of sampling has yet to be established and is dependent on the flying characteristics of the modified aircraft, but in essence, it is thought that it will be to climb to approx. 62,000' and then to sample in a shallow dive through the cloud trapped at the tropopause. Two Canberras are at Napiers for modification: the first will not be ready to commence flight trials until 8th February, 1958, and the second until 5th March, 1958 - both these dates were stated at a meeting at Napiers on 3rd December, 1957 to be the earliest possible dates, with all overtime and all priority being applied. In the meantime, flight trials are progressing with a Canberra B.2 having similar configurations and characteristics to the B.6. Mark III sampling ducts on wing-tip tanks have been supplied to the firm and modified by them to include vortex generators to increase stability. These are being carried initially on the B.2 aircraft for test flying. The flight information to date indicates that, with Mk. III ducts fitted, there is likely to be an onset of buffetting, leading to loss of control at a Mach number lower than when tanks are not fitted; this means that it may not be possible due to control difficulties, to reach the height obtainable with "clean" aircraft. 60,000' has been attained, using this aircraft with Mk. III sampling ducts, and although there is difficulty in control at this altitude, the pilots who will be flying this aircraft during Grapple-Y are fairly confident that they can reach 60,000', and give a controlled sampling run. The rate of descent is probably fixed fairly closely at 800 f/minute: this has obvious repercussions on sampling technique. Some test-flying will be necessary after the 8th February to confirm B.2 results, if these have been accepted as satisfactory. The firm have been

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asked to continue preparations to modify the second B.6 aircraft, presupposing that B.2 results are satisfactory, and on the assumption that the flight trials of the first B.6 prove satisfactory.

On Grapple-Y, the operational intention is likely to be that two or three unmodified B.6 aircraft will sample the cloud under the conditions pertaining in Grapple and Grapple-X, i.e. at 50,000'-52,000', and the Scorpion-equipped Canberra will sample the cloud descending from 62,000' at 800 ft./minute.

3.3 P.R.9 & Javelin Prospects: The first production P.R.9 does not come into service until Spring, 1958 - it is unlikely that any could be made available for sampling purposes until some time after that: this aircraft without any auxilliary engine, such as the Scorpion, has a ceiling approx. 5,000 ft. greater than the B.6 - say, 57,000 ft. at Christmas, compared with 59-60,000 ft. over U.K. in fuel conditions allowing 30 minutes sampling time and ¾ hour thereafter.

On present performance, the Javelin is inferior to the B.6. However, if the Air Ministry state that the P.R.9 or Javelin is likely to be the ultimate replacement aircraft for the B.6 of the sampling force, then it is suggested that a design study be made forthwith for the aircraft to be used in the sampling role, both with and without Scorpions fitted, unless in the meanwhile the use of rockets with or without guidance has been accepted.

4. Sampling by Means of Rockets

In this field, recovery dominates all other problems. There is the undeniable advantage that sampling may be made at times when the dosage would be lethal, if the problems of heat, turbulence, and blast can be overcome. There are two possibilities, which we discuss separately: surface to air, and air to surface.

4.1 Surface to air rockets:

4.1.1 Present experience: We used standard 29 lb. heads, with a 3" rocket, fired from a land-mattress, in "Hurricane", "Totem", and "Buffalo". These have a range of some 28,000 ft. and a maximum height of 6,000 ft., and are therefore suitable only for kiloton weapon sampling, where the use of manned aircraft in any case is far more effective (though also far more expensive).

It has proved possible to send them through the cloud at times from 1 second upwards, the limiting factors being, on the one hand, destruction of the filter element and, on the other, rise of the cloud beyond reach.

By the use of quartz wool filter elements, samples of a few x 10^{13} fissions have been collected, and the major elements sought have not been too severely fractionated: since the entry port was only some ¼" i.d., no doubt a greater cross-section could be used, with consequent gain in sample size.

Turbulence has not proved a limiting factor: the rounds fell at the predicted MPI and with a scatter not appreciably worse than in practice firings. The major difficulty has been with last-minute wind changes blowing the cloud off-line, and this entails either guidance or siting the projector so close in as to wreck it, but also to ensure a hit. Another major problem

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is recovery. While we have successfully recovered every round at Maralinga and Emu, they were buried very deeply and had to be winched out with a 3-ton truck: the small hole made location difficult, except by close search over a staked area: it is not possible to guarantee recovery of any particular rocket within less than 24 hours.

This type of round may also be fired from air to ground, and will be considered in para. 4.2.1.

It is probable that any rocket for sampling megaton shots would need to penetrate at heights of 30-50,000 ft. (~ ½-1 min. from burst) to avoid difficulties due to heat and turbulence.

4.1.2 Recovery systems: In RAE TN GW 439 a system for the 'over sea' recovery of guided missiles has been described. This uses a two-stage parachute to slow the vehicle (RTV 2) to 50 f/sec. on impact and incorporates a flotation system which keeps the nose of the round above water, after plunging to about 30 feet depth. A similar type of system has been developed for the General Purpose Vehicle (GPV), discussed below. These could presumably be adapted to the other rounds discussed, which are of comparable weight.

Whether the contaminated round entire would be worth salvaging after immersion is a separate question.

It is possible to sever the round with explosives and to recover only a section: flasher lights or 'Sarah' could be installed. Recovery of the filter elements only would be more certain than collection of the whole round and would facilitate pickup by helicopter: conditions off Christmas Island may be worse than, e.g. at Aberporth.

4.1.3 Rounds available:

(a) RTV-2. This round is some 27' long and 27" max. dia. and, if the homing head were not used, it might be possible to develop a filter unit which would not detract from performance, and could be opened in flight and sealed completely during descent.

The boosted but unmotored round has a maximum range of about 20,000 ft. and a maximum altitude of 6,500 ft. The sustainer is HTP-kerosene, but the data on performance is not readily available. It should be stated, however, that this round is not now under current development, and hence any proposals involving its use would demand fresh production.

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(b) A related type is the General Purpose Test Vehicle (GPTV), developed by R.A.E. with Short & Harland (GW/HR/5). This exists in several variants, but the basic round is very similar to the R.T.V.2. It is liquid fuelled, with solid boosts, but there is some possibility of making the sustainer solid also. The parachute and flotation system is similar to the RTV2, and the problems of designing and installing a filter head would be expected to be identical. With such an installation, the homing head would have to be removed.

The maximum range of this round is 90,000 ft. (17 miles), but the maximum altitude is then only about 40,000 ft. A height of 60,000 ft. could be achieved, but the throw would shorten to 56,000 ft. (10½ miles). It could operate subsonically above 40,000 ft. for 30 seconds if little or no lateral demands were made.

The cost of this vehicle is approx. £30,000 each. We are given to understand that Short & Harland would welcome work of this nature, in view of their reduced commitments on other work.

(c) <u>Red Duster</u> (Bloodhound) is being developed by the Bristol Aeroplane Co. This is driven by twin ram-jets, on stub wings on either side of the fuselage, with orthogonal aerodynamic wings. It has a maximum ceiling of 50,000 ft. and a propulsion range of 85 miles, limited by guidance to about 23 miles. There are four solid boosts. There is a warhead section of about 20" x 20", which could presumably be adapted for filter heads.

(d) <u>Red Shoes</u> (Thunderbird), being developed by English Electric Co., is of roughly the same dimensions as Bloodhound, but is propelled by a solid motor and boosts. The maximum altitude with guidance is again 50,000 ft. and the range 20-25 miles. However, a controlled round (i.e. without guidance) has gone to close on 100,000 ft.

4.1.4 <u>General conditions</u>: The centre of the cloud from a shot of, say, 3 MT will rise with time according to the following table:

TABLE

Time (minutes)	1	2	3	5	10
Altitude of centre (thou. feet)	24	35	45	60	70

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The round must intercept a point above G.Z. at as late a time as possible to avoid difficulties due to heat and turbulence, it would appear necessary to fire from the land and recover from the sea. It will be seen that only 'Bloodhound' has sufficient range for it to be fired from, say, JCC, where blast damage would be expected to be small. However, the possible effect on the ramjet engines of meeting a shock-wave not quite head-on would need careful assessment.

With regard to the others, it would appear that the launcher could be, say, 8 miles away, with the rocket in position. At this distance, the blast would take about 30 seconds to arrive, and last about 5 seconds; the vehicle would then take a further 25 seconds to reach the cloud. The peak overpressure at this distance would be ~ $1\frac{1}{2}$ psi. Since the launcher is rugged (designed to stand a 90-knot wind with the vehicle in position) it may be that firing from a suitably prepared position would be possible without serious damage.

These figures are taken for Red Shoes as illustration, but it is probable that any of the rounds quoted would be suitable at such ranges. The most rewarding method might be to fire at a high Q.E. to attain maximum elevation, then to use sequence control to bring the round into approximately level flight before burn-out.

4.1.5 <u>Ground support</u>: This compares very favourably with that needed to support, say, a Canberra squadron. The equipment for a launcher control post would be the equivalent of a 3-ton truck load: the assembly and test area a space of about 16' x 30' x 12' high. A few maintenance personnel would be necessary, and a minimum operating crew of six could fire up to four rockets.

4.1.6 <u>Conclusions on surface-air rockets</u>: The individual techniques required are largely established. Modification to incorporate a self-opening and self-sealing filter has not yet been considered, but the internal space is certainly quite adequate in any of the above rounds. It is thought that Red Shoes, being a production item, would be cheapest (~£15,000). Although the rounds themselves might be written off, there could be a saving in operating crew and facilities, compared with manned aircraft, which would largely offset the capital cost.

4.2 <u>Air-surface Missiles</u>

4.2.1 The type of rocket discussed in 4.1.1 may be fired from beneath the wings of such aircraft as the 'Hunter' or the 'Javelin'. (The former - Mk. 6 and above - can carry 24 rockets, and the latter the same number if special pylon adapters are fitted). At 45° Q.E. a gain in height of 15,000 ft. is obtained, and hence the apex is at about 60,000 feet; this corresponds to a maximum throw of 30 miles, with a dispersion of about 1 mile. According to S.W.P., the aircraft, unless specially painted and possibly strengthened, would have to be a minimum of 12 n.m. slant range, if heading towards G.Z., to withstand the incident thermal dose, and possibly up to 50% more. (It would be

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necessary for the aircraft to be climbing to screen the pilot by the fuselage). The minimum safe range for blast damage is around 10 n.m. at the time of blast arrival, and the wave takes about 1 minute to arrive at this range.

Now the velocity of the rocket is about 650 f/sec. (7.5 miles/min.) after the propellant has burnt, hence, to intercept at 50,000 ft. at one minute from burst, the aircraft must at time zero be ~8 miles away, i.e. a slant range of ~12 miles, and climbing at 30-45°.

The aircraft would be only marginally safe from thermals: the pilot would have to fire and turn away immediately, so as to retreat before the blast wave, which is travelling only a little faster than he is.

Thus, there is a very slim chance that this technique could be successful, but it would demand a prior detailed assessment by R.A.E. and R.A.F. and the closest control in the field.

On the recovery side, while the round would bury itself deeply, there is not the same urgency of recovery as attaches to the aircraft sampling, and, provided that two or three rounds could be successfully recovered and available in U.K. by, say, a week from burst, the method could prove a good insurance policy. There is a reasonable impact area on the island S.E. from grid reference 9198.

This scheme, which appears very unattractive from most points of view, nevertheless has the merit that a single rocket could well collect as much as a Mk. III duct flown later.

4.2.2 English Electric have considered (SD/D/t/002) a fairly cheap (£2,500) rocket bomb test vehicle (RBTV) with a weight of 1800 lb., and which may be dropped from a Canberra B.2. For a maximum release altitude of 40,000 ft., and with the boost motor functioning, a maximum throw of 30,000 ft. may be obtained with ignition at 30 seconds, and of ~ 80,000 ft. with ignition at ~5 seconds. Recovery is by a triple stage parachute which slows from Mach 2 to 60 f/sec.: impact produces 10 g. deceleration. While land recovery is more probable than for the round just mentioned, the range is so short as possibly to preclude its use. It is possible also to recover this round from the sea, but details are not known at date of writing.

We are informed, however, by AD/GW(E) that English Electric are so heavily loaded with G.W. work that it is unlikely development of our interests could be undertaken without high-level pressure.

5. Auxilliary Equipment

There have been a number of modifications to aircraft requested both by SR/CR and other Branches, which need critical examination. A mechanism for this is suggested in a later paragraph. There are three, however, arising within SR/CR, which should be discussed.

5.1 Filter monitoring: In low-yield shots, which do not go to great height, it has proved practicable to relate the cumulative dose to the crew to the size

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of sample picked up: this becomes far from linear in conditions where "shine" is obtained. We have, therefore, initiated action with SLE and SRHP to have designed and manufactured in time for Grapple-Y, an instrument which will assess the activity picked up. For installation reasons, this will use a secondary duct mounted externally on the bomb-doors, with a calibration factor applied. It will be a differential instrument, in which the contribution from "shine" is automatically subtracted from the signal from the filter. This instrument measures rate, since the integration of pick-up is made by the filter which will then give a known dose-rate at a known time from a known number of fissions. An engraved cursor, with a suitable logarithmic scale, will enable time correction to be readily made.

It is hoped to have one instrument per aircraft made by 8th February, 1958.

5.2 Gas Sampling: With weapons where a substantial yield comes from fusion, the products are largely gaseous. The alternatives to direct measurement are either to infer the fusion contribution from radiometric measurements or to use the difference between fission yield and total yield measured independently. We have developed analytical methods for T, C-14, A-37, and the fission Kr and Xe species. The difficulty is in knowing the value of this work, and at the moment we are largely feeling our way with a staff of two men. The principal obstacle to date has been in collection, and this we discuss below: it may be that the results, when obtained and correlated, will be insufficient to justify continued effort, but we must develop the necessary techniques before any conclusion as to the ultimate value can be reached.

Broadly, the choice of equipment lies between collection for a short time (~10 seconds) or a long time (~3 minutes). So far, we have concentrated on the former, using the air delivered from the 12-th stage engine compressor to boost the pressure over ambient. There are three different marks. Mk. 1 used an inflatable rubber bag, the contents of which are pumped into a metal transit bottle, on return to the ground: this has given unreliable results, due to adsorption and condensation of some species. Mk. II uses a rigid metal bottle, of much smaller size, and gives reproducible results: Mk. III is identical, except for the use of a different actuating system. All three need an external calibrated duct to relate gaseous products to the solid material and the correlation cannot be better than ± 20%. The latter marks have the disadvantage of being very bulky (4' x 2') for civil air transport.

An alternative is to take ambient air through a filter and compress it into a small bottle. (While admittedly the filtration efficiency must be considered, it is not likely to be worse than the external filter: a direct comparison is then possible). On present ideas, each rig would need a wing tank to itself, and would not allow a Mk. III solids duct to be used: the cost per unit would be £1,000-£1,500, plus installation costs. Unless the present proposed installations can be modified so that the system can be incorporated in the present Mk. III

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solids duct, the consequent increase in flying effort alone would be so costly as to preclude its use.

5.3 Proposals are being made in a separate memo. for reorientation of the work carried on by [redacted] under SR/CR auspices. Briefly, it is now proposed that they should concentrate on mechanisms connected with particle formation and growth, using a few typical shots. It may be that present airborne equipment will be adequate, but some modifications may be necessary. The essential difference of this work is that it requires a small but very representative sample, whereas the radiochemistry requires the maximum sample provided it is fairly representative.

6. The technique of sampling

We have jointly evolved the technique of sampling, whereby aircraft are directed by an airborne controller: we feel that this is essentially the best way to ensure good sampling, with minimum hazard to aircrew. The instrument referred to in para. 5.1 should greatly aid this operation. It is now necessary, in our view, to establish a rota of R.A.F. officers, with a strong physics background, to continue this work.

The dose rate from fission products falls off as $t^{-1.2}$ in the following way (we neglect activities induced in uranium by non-fission processes since the gamma-energies are low).

Time from burst (minutes)	15	20	25	30	40	50	60	80	100
Dose (relative) r/min.	1	0.7	0.55	0.44	0.31	0.23	0.20	0.14	0.11

In non-turbulent conditions, the growth of the cloud is slow, and one gains by waiting (if the cloud is visible and accessible) until relatively late times, say, in the bracket 30-120 minutes. However, in turbulent conditions, sampling may be carried out much earlier in this bracket, since the dispersion of the cloud reduces the dose rate even faster than is given by these figures. Stewart (TRN 104/57) has calculated the following doses at 15 minutes for a 2.5 minute sampling run, in which the cloud is modelled on Grapple-2.

Base of cloud	Aircraft Ht.	Dosage/2.5 min.
50	50	60r
60	50	6r
60	60	120r

These compare with a dose rate of 300 r/hr. (= 12r/2.5 mins.) measured at Grapple-X in an aircraft at 48,000 ft. at 15 minutes. Since there is a steep dependence on vertical separation, the agreement is reasonably close.

It is probable that sampling runs can be made as Grapple-X, but that the Scorpion-driven Canberra(s) should not attempt a passage until at least an hour has passed. Since the rate of descent is fixed for the latter at 800 f/min., we must ensure that the aircraft never gets into an area of excessive radiation. He cannot climb and dare not descend faster. Operating procedures must be cast-iron in this respect.

[redacted]

/7. Organisation

[redacted]

7. Organisation

7.1 There is a need for a rota of R.A.F. officers to undertake the preparation of the sampling aircraft, and to unload and dispatch the material. Hitherto this has been done by two officers only, from RAF/AWRE, with assistance in the field by N.C.O's. They have also organised on behalf of [redacted] the modification of aircraft, procurement of individual items, and flight tests. It is felt that, coupled with their regular duties, insufficient continuity can be given to the various projects in U.K. and that an additional officer should be established at [redacted] to assist them.

7.2 The co-ordination of the activities involving aircraft in sampling and equivalent operations was managed successfully during the build-up for Mosaic and Buffalo by an air measurements committee. This was allowed to lapse during 1957 and it is apparent to us that the co-ordination is now somewhat haphazard: to state a case, the demands on aircraft power supplies are now so great that there is a deficit which can be met only by careful sequence of operation, yet demands are still made for more. The situation with regard to space inside the aircraft cabin for instrument mounts is equally bad.

The solution to this is to have a standing committee, run either by RAF/AWRE, or by SR/CR, as the principal users. This should include representatives of SSTD and SRHP, with such outside assistance as necessary from time to time. Since the personnel of the task force changes regularly, such a committee would maintain the essential continuity, without reference to any particular trial.

[redacted]

9th January, 1958

c.c. Task Force Grapple (6 copies)

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