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REPORT 26-03-R-006

DESIGN OF THE WES CENTRIFUGE

(PHASES 3A & 3B)

FINAL TECHNICAL REPORT

by

A N Schofield and R S Steedman

31 March 1993

United States Army

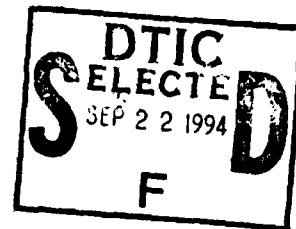
EUROPEAN RESEARCH OFFICE OF THE U.S. ARMY

London England

CONTRACT NUMBER DAJA45-92-C-0021

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A N Schofield

R S Steedman

31 March 1993

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SUMMARY

The detailed design of the WES centrifuge and the outline design of the containment structure are now complete. ANS&A has worked closely with the designers of the centrifuge, Acutronic SA of France, and with the different Laboratories of the US Army Corps of Engineers to ensure that the new capabilities that will be established by the commissioning of the centrifuge meet as far as possible the research goals set out in the WES Broad Agency Announcement of December 1988.

ANS&A's programme of Quality Assurance has provided a smooth interface between the future users of the facility and the design and specification of the centrifuge and its associated appurtenances. The involvement of all of the Research Laboratories of the Corps of Engineers in the centrifuge project has led to a broadening of the research goals set out in ANS&A's response to the WES BAA and ANS&A's Quality Assurance activities have also widened in their scope to accommodate this welcome development.

ANS&A recommend that the design of the centrifuge, as presented at the Final Design Review meeting in France in November 1992, should be accepted. A number of key changes have been made to the original conceptual design to meet the performance specification. The swinging platform will be supported on either side by three straps, with six pins in total connecting the straps to the platform slab. The magnitude of the forces passing through the hinges into the booms has led to the necessity of increasing the boom diameter near the ends, to provide an adequate bearing surface. Although both of these changes will impact on the user to a degree, this will be minimal in practice.

ANS&A recommend that the operating envelope of the centrifuge as designed be revised in the 150 to 350g range to fully benefit from the high load capacity of the swinging platform design. The operating envelope, which at present is limited in the mid-range by the limiting out-of-balance condition, can be pushed outwards without compromising the safety of the facility provided that the user can guarantee the integrity of the package under all failure conditions.

ANS&A have considered carefully the usage of the control building, connecting walkway and containment structure. ANS&A recommend that an integrated package transport system be adopted, based on floor movement of heavy packages, rather than crane transportation.

The integration of the centrifuge, the containment structure and the appurtenances is critical to the successful completion of the project. ANS&A recommend that the Quality Assurance Programme should embrace all aspects of the facility development, including also personnel training, marketing and the development of research programmes. This will be the subject of a further proposal under the BAA.

LIST OF KEYWORDS

centrifuge
test
model
capabilities
research
quality
assurance
containment
buildings
equipment
appurtenances
instrumentation
safety

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1.0 DESIGN OF THE WES CENTRIFUGE

1.1 BACKGROUND

This report is one of a series of reports prepared by Andrew N Schofield & Associates Ltd (ANS&A) addressing the development and commissioning of new capabilities for physical modeling research at the Waterways Experiment Station (WES), through the acquisition of a powerful centrifuge facility. The research described herein forms Phase 3a and 3b of the programme of work first proposed under ANS&A's response (of 17 April 1989) to the WES Broad Agency Announcement (BAA) of December 1988.

Phase 1 of this project, entitled "Safety Factor Analysis for Centrifuge Systems", addressed the specification, Quality Assurance (QA) procedures and safety of operations that would be required to successfully commission a new centrifuge center at WES. In the Final Technical Report under Phase 1 (Contract Number DAJA45-90-C-018), ANS&A (1992), it was recommended that WES should buy the Acutronic 684-1 centrifuge subject to the implementation of QA procedures designed to ensure the swift integration of the new facility into the research activities of WES.

Phase 2 of this project (Contract number DAJA45-91-C-0012) entitled "Development of a WES Centrifuge" initiated the Quality Assurance process under which ANS&A worked with the Laboratories of the US Army Corps of Engineers through the Centrifuge Coordinating Committee to prepare specifications for appurtenances and data acquisition equipment that would be needed during the commissioning of capabilities. During this Phase the detailed design of the Acutronic 684-1 centrifuge was undertaken in Europe by Acutronic France SA and close interaction between ANS&A and Acutronic's engineers provided feedback and technical review of the design progress. In October 1992 a final design review meeting was held at which a number of key decisions were taken including the design of the platform slab and hanger arrangement. During 1992/93 the first appurtenance contracts were also undertaken, providing WES with an initial package of equipment and data acquisition systems to meet the needs of the different Laboratories involved in the commissioning of capabilities.

Phase 3a entitled "Centrifuge facility design and development of capabilities" (Contract number DAJA45-91-C-0025) and 3b "Report on Quality Assurance for the WES Centrifuge" (Contract number DAJA45-92-C-0021) addressed the continuing role of ANS&A in providing advice and guidance during the design phase of the WES Centrifuge by Acutronic France SA.

1.2 REVIEW OF ANS&A'S QA PROGRAMME

In January 1992 WES contracted with Acutronic USA to supply and install a powerful centrifuge capable of providing novel capabilities in research for all of the Corps Laboratories. The wide range of capabilities sought by the Corps of Engineers for their new centrifuge is made clear in the WES Miscellaneous Paper GL-91-12 "Large Centrifuge: a critical Army capability for the future" dated May 1991 and published in January 1992. ANS&A's QA programme has therefore developed to embrace these new capabilities and to work with all of the USAE Laboratories involved with the centrifuge project. ANS&A has also been involved in commenting on the control building and on the location, arrangement and design of the centrifuge containment structure. However, during this phase of the centrifuge development, ANS&A's primary role has been to

work with Acutronic France and with the WES to ensure that the design of the centrifuge will be capable of accommodating the majority of the technical demands placed upon it over the foreseeable future. This work has been documented in a series of meeting notes which form the basis of this report and are attached at Appendix A. These notes date from the first documented meeting with WES and Acutronic on 9 January 1992 to the Final Design Review meeting on 18, 19 November 1992.

2.0 THE ACUTRONIC 684-1 CENTRIFUGE

2.1 DESIGN

Significant changes to the design of the centrifuge have taken place in the platform and hanger arrangements. The nature of the loading at high g has required that a welded box structure be adopted for the platform slab and that the two hangers supporting the platform should each comprise three straps (instead of two), connected to the slab by a total of six pins. Discussions have been held with Acutronic over the necessity of ready access to the slab structure for inspection of welds internally and over the finite element analysis of the load transfer from the slab to the straps.

The redesign of the bushings to locate the pins has significantly reduced stress concentrations in the slab (meeting reference 25-03-ROM-028) and should prove quite adequate for its purpose. The requirement for three straps on each hanger is necessary because of the high loads being transferred to the boom at high gravities but will limit visual access to the model volume. The flared ends to the booms were necessary to reduce stresses in the hinge locations.

In all other respects the design as completed and presented at the Final Design Review Meeting is very similar to that envisaged at the outset of the project. It is recommended that this design is accepted.

The opportunity to extend the capability of the centrifuge at low g by reviewing the catastrophic imbalance condition and working instead to a limiting stress condition arising from the loading from the package onto the platform is an important benefit. This is discussed in detail below.

The design book, including mechanical drawings and sample calculations, will need to be finalised by Acutronic for delivery to WES at an early date.

2.2 FABRICATION

The detailed design will be completed and the fabrication of the centrifuge will commence over the next year. (Manufacture of some components, such as the booms, has already started.) This will be overseen by ANS&A and its Associates in France and the UK. The centrifuge will be significantly heavier than originally envisaged (by around 20%), due to the heavier platform and hanger arrangement and its impact on the rest of the machine.

Acutronic will need to collate and assemble for WES all documentation concerning specifications and certificates of conformity as materials and components are ordered and delivered. The special nature of the materials used, for example the use of high strength steels, and the unique design of the facility places a particular emphasis on the

quality of the documentation accompanying the machine.

The French Welding Institute, the Institute de Soudure, will have an important role in their review of the design of the welded platform and the welding procedures proposed for its fabrication. It is essential that the welders are appropriately qualified and that full inspection and non-destructive testing of all welds is carried out before factory acceptance.

2.3 COMMISSIONING

The commissioning of the centrifuge facility will take place in three stages. During the first stage Acutronic will prove the mechanical performance of the centrifuge itself. In the second stage ANS&A will confirm that user interfaces supplied with the kit of appurtenances are operating satisfactorily. Finally, during the third stage, commissioning of capabilities by ANS&A will commence with research work leading to demonstration experiments in different Laboratory areas.

During the mechanical commissioning Acutronic will be required to demonstrate that the new centrifuge meets the agreed specification. In certain areas, such as the Safety Management Systems, this will be straightforward and Acutronic's standard commissioning procedures will be adequate. However in other areas, such as the definition of dynamic loading on the centrifuge or the deflection of the platform slab in flight Acutronic will need to give careful consideration to the nature of the acceptance tests. The platform slab will be instrumented with strain gauges, for example, and these could form the basis of a validation of the design calculation. The finite element model of one-quarter of the platform slab used for design should be available to potential users to confirm that irregular arrangements of load on the platform are not going to lead to overstressing. This model, which has been developed using the commercially available structural analysis finite element code ANSYS, should be incorporated into a user-friendly interface available on-site during and following the commissioning period.

Demonstrations will also be required that the installed centrifuge has met its predicted dynamic behaviour in flight. The nature of the dynamic loading that can be applied to the platform is still to be defined by Acutronic; this should be addressed urgently as it will have an important bearing on the design of appurtenances such as a future earthquake shaker.

ANS&A anticipate that during each of the commissioning stages trained WES mechanical, electrical and electronic engineers will be available to work alongside representatives of ANS&A in the commissioning of the centrifuge and its capabilities. These engineers should be identified at the earliest practical date and training programmes initiated to familiarise them with centrifuge testing in general and the Acutronic 684-1 in particular.

2.4 OPERATING ENVELOPE

An important development during the design process for the Acutronic 684-1 centrifuge has been the extension of the operating envelope in the low to mid range of g levels. This has arisen because of the design of the platform slab to meet the specified safety factors and because the quality of the forging of the steel booms has enabled WES to benefit from a slightly extended boom length, permitting an increase in the range of the

fixed counterweights.

The operating envelope for the centrifuge is determined by a range of factors depending on g level, Figure 1. At one extreme, at high g, the centrifuge performance is limited by motor power. At the low g end, the performance is limited by the counterweight capacity. In the transition between these criteria of maximum payload and maximum g level the envelope is defined by two conditions: the limiting out-of-balance criterion and the platform stress limit. Unlike the peak power or maximum counterweight capability this section of the operating envelope is capable of being exceeded by a careless or irresponsible user and it is therefore important that the definition of this non-linear boundary is well-understood. The following numbers are broadly accurate but are for illustrative purposes only. Actual values will be defined in the Acutronic user manual.

The limiting out-of-balance (ultimate limit state) was defined at the outset (based on past practice) as equivalent to the loss of the payload in flight. Assuming the maximum payload at maximum g level defines this limit then at 350g the loss of 2 tonnes would be equivalent to an out-of-balance force of about $350 \times 2 \times 10 = 7000 \text{ KN}$. At 250g the limiting payload could be increased on this basis to about 2.8 tonnes; at 140g, 5 tonnes etc.

For optimum design the platform stress limit should closely match the out-of-balance force criterion. However the platform, with its associated hangers and connections to the boom is the most highly stressed component of the centrifuge during normal operations and, as with the limiting out-of-balance force, this stress limit is also associated with operations with a maximum payload at 350g. The stressing of the platform derives mainly from the self-weight of the payload and the slab; at 350g this is a total radial force of approximately 14 MN (or 1400 tonnes). At 140g, however, the platform slab only exerts a radial force of around 2.8 MN. To fully utilise the design strength of the platform some increase in payload is then possible. On this basis the new payload limit could be up to around 8 tonnes before the design stress limit is again reached.

To make maximum use of this stress-based envelope requires a partial relaxation of the out-of-balance force criterion. It is recommended that this approach is adopted. On this basis, provided it is fully understood that the limiting (catastrophic) out-of-balance is no longer the loss of the entire payload but the partial loss of the payload, the centrifuge envelope can be extended to bring together the two limiting criteria at 140g. However, the limiting out-of-balance criterion is then equivalent to the loss of no more than approximately 60% of the maximum payload mass (of 8 tonnes) at that g level. The loss of more than this mass from the platform in flight would exceed the design ultimate limit state condition (which assumes the centrifuge loses its entire design fatigue life in stopping) and the centrifuge could not be assured of even coming to rest intact. This is a departure from previous practice and has been adopted to maximise the capability of the new Acutronic 684-1.

However, designers of model tests intending to operate in the 140 - 350g range must take careful account of the liability this condition imposes. For a package operating at maximum mass, the loss of just 60% of that payload, for whatever reason, would result in the centrifuge reaching its ultimate limit state condition and would lead to substantial damage. The loss of more than 60% of the payload would be likely to lead to the destruction of the facility.

3.0 CONTAINMENT AND TESTING

3.1 CONTROL BUILDING

The control building has been constructed and is being used temporarily by another research group. The building, which will be connected to the centrifuge facility by a covered walkway, will require some modification before it will be suitable for use for centrifuge work. The crane will need to be upgraded and the control room area rearranged in consultation with Acutronic to accommodate the control panels and data acquisition equipment. More windows would be desirable, and some of the present rooms should be retained as office accommodation and an electronics workshop and stores. Early occupation of the building, prior to the arrival of the centrifuge, will be necessary to allow ANS&A to store papers and equipment. Restroom facilities for both men and women should be provided.

3.2 CONTAINMENT STRUCTURE

Conceptual design of the containment structure has led to a number of options being considered both for the location of the centrifuge and for the arrangements for loading and model preparation. Level separation between the centrifuge and the control building is necessary for safety reasons and therefore there will need to be a lift arrangement connecting the control building level to the centrifuge chamber level. The proposed arrangement, with a covered walkway connecting the two buildings supporting a crane rail and a large model preparation room next to the centrifuge chamber, will provide good access whilst meeting safety considerations.

Only one door in the wall is necessary for access to the centrifuge chamber. This will provide for both pedestrian access and for carriage of models and equipment. Sealing of the door, particularly at floor level where a drain must be provided against the chamber wall, will need to be carefully considered by Acutronic. Recommendations for lifts and other facilities for model transportation are discussed below.

Provision of services to the centrifuge control building, model preparation room and the motor chamber should be carefully considered at an early date. For example hydraulic power packs will be necessary for user services; these could be located in the motor chamber. Additional conduits should be installed from the preparation room to the motor room to carry cables or hydraulic lines. Power and signal routes will need to be determined in consultation with Acutronic and WES as soon as possible. It is anticipated that a duplicate termination panel will be available in the model preparation room; the location of this will need to be agreed with WES.

Appurtenances and equipment will need to be stored and serviced in a secure environment such as the proposed control building. Power, water, hydraulic and pneumatic lines will be needed in the control building together with provision for the storage of tools, soil and materials for model building.

3.3 PACKAGE HANDLING

The production line style of a busy centrifuge center requires an efficient and easy to use system of transportation for containers, equipment and models from the control building

to the model preparation room, onto the centrifuge and back again. Within the control building and model preparation room packages will need to be moved around, assembled and disassembled. In some cases these packages will be very heavy, weighing many tonnes. However in most cases loads will be broken down for safety and convenience and loads of upto 1 to 2 tonnes may be typical.

Certain types of model, once assembled, may be highly sensitive to vibration or shock loading and will need to be handled with particular care. Transportation systems should be available at least in the model preparation room which can handle such models with the minimum of disturbance.

The loading of models onto the centrifuge must also be considered carefully. The flared booms at the hinge location will restrict access by fork lift and effectively prevent loading by overhead crane.

It is recommended that a floor-mounted transportation system is adopted for the centrifuge center. Packages should be designed to be stored either on pallets or using removable "legs". Air bearings or skates, together with fork lift trucks, can then readily move equipment anywhere in the laboratory with minimum disturbance.

The most effective and safe means of loading a package onto and off the centrifuge will be to bring a model alongside the platform slab and to slide it on. Ideally this would be achieved from a hydraulic lift fitted flush with the floor of the chamber which could rise up and lock onto the platform. This lift will need to have a capacity of eight tonnes.

It will also be necessary for the model preparation room to be equipped with a fork lift truck and at least one fixed crane. *The model preparation room will not need a rail mounted crane.*

The covered walkway and the model preparation room should be connected by a hydraulic lift capable of elevating packages upto eight tonnes mass.

The control building has a rail mounted crane which will be extended along the covered walkway to a gallery above the model preparation room. This crane should be designed to have a capacity of eight tonnes.

3.4 DATA ACQUISITION AND CONTROL SYSTEMS

It is planned to adopt a phased approach to the development of data acquisition and control systems. The first phase, to be delivered in October 1993 will comprise a portable data acquisition system that will provide an initial capability in instrumentation, data capture and processing. The system will be capable of being used either as a stand-alone unit or in the control room or elsewhere to remotely interrogate and log signals from a basic instrumentation network.

Phase 2 (anticipated during 1994/95) will include the provision of on-board data acquisition and remote control capabilities using a ruggedised military specification computer with solid state memory controlled remotely by the operator through a terminal in the control room. This more advanced system will be mounted in new purpose built cabinets in the centre of the arm. A limited dynamic capability will be provided to demonstrate an initial capability in blast or earthquake data acquisition.

Future phases will develop special needs such as the development of further dynamic channels and special power supplies, capacitors, control systems and instrumentation.

4.0 APPURTENANCES

4.1 LABORATORY NEEDS

The initial set of appurtenances, to be delivered in October 1993, will provide the first of the new research capabilities once they have been commissioned on the Acutronic centrifuge. Further kits of equipment are planned to follow in future years and these will build up the capabilities and permit the completion of the demonstration tests currently being discussed with each Laboratory.

ANS&A has worked closely with the different Laboratories to identify the opportunities and capabilities that they should be developed over the coming years and this work has been documented in the meeting notes attached at Appendix A to this report. Demonstration experiments have been planned in outline with most Laboratories and these have assisted in the definition of equipment and services that will need to be provided for users once the centrifuge has been installed. However considerable further work will be necessary to finalise the demonstration experiments and to ensure that each Laboratory can realise a new research capability.

ANS&A proposes to identify Associates to work closely with the different Laboratories prior to the arrival of the centrifuge and to assist researchers with their demonstration experiment during the commissioning of capabilities.

4.2 SERVICES

The routing of cables for power, hydraulic and signal lines both on board the centrifuge and from the slip rings to the control room or motor chamber needs to be determined at an early date. Termination panels will be needed on board the centrifuge for user systems to interface with models; their design and location should be determined following discussion with Acutronic.

It is recommended that high flow rates of water, if required, are provided by an on-board recirculating system rather than by modification to the Acutronic hydraulic rotary joint.

5.0 TRAINING AND MANAGEMENT

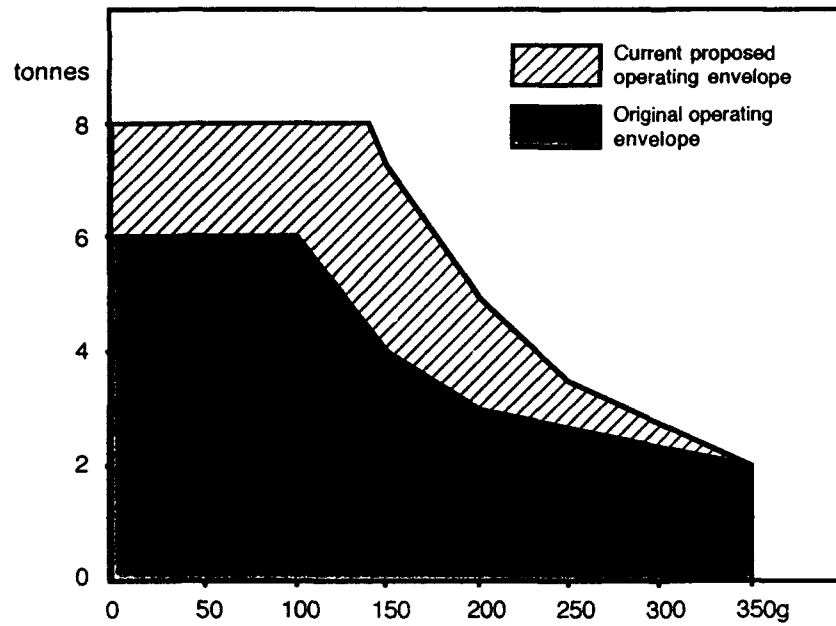
Earlier reports (ANS&A, 1991, 1992) have stressed the importance of training of future users, technicians and operators at the earliest possible date. In particular it is essential that mechanical and electrical engineers are identified who can become familiar with the new machine, its design and operation, before installation and commissioning. These staff, who will form the core of the new full-time centrifuge management team, will also need to fully understand the design and operation of the appurtenances and data acquisition and control systems now being manufactured.

Researchers who will use the centrifuge as a part of their research programs need to be trained in centrifuge techniques and assisted to develop proposals which make use of the new facilities wherever possible.

It was originally envisaged that training under ANS&A's Quality Assurance role would take place in Cambridge for a selected group of staff and potential users. This has not transpired, primarily due to restrictions on overseas travel for WES personnel and alternative plans are therefore being developed which will be the subject of further proposals under the BAA. These include ANS&A Associates being resident in Vicksburg for a period before and after commissioning to ensure the full potential of the new centrifuge center as a world class research facility is realised.

REFERENCES

- Schofield, A.N. and Steedman, R.S. (1992) Development of a WES Centrifuge, Final Technical Report, ANS&A Report 26-02-R-004 for US Army European Research Office, London (Contract No. DAJA45-91-C-0012).
- Schofield, A.N. and Steedman, R.S. (1991) Safety Factor Analysis for Centrifuge Systems, Final Technical Report, ANS&A Report 26-01-R-001 for US Army European Research Office, London (Contract No. DAJA45-90-C-018).



**Figure 1 Proposed operating envelope
for the Acutronic 684-1 centrifuge following the Final Design Review
(after Acutronic France SA)**

ANS&A Report 26-03-R-006
Revision: 0

APPENDIX A

Records of meetings

RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-001
Present:	R Whalin, W Marcuson	Date:	9 Jan 92
	RH Ledbetter,	Time:	9.00
	Committee of Users	Prepared:	RSS
	ANS, RP, RSS	Notes:	
Subject:	Meeting of Coordinating Committee		

Robert Whalin introduced the meeting, and outlined the objectives of the Committee in the area of the initial tasks and equipment development; the priority being to identify essential items of equipment for a program of testing that was expected to begin in around three years time. The contract with Acutronic was near signing and the project on the verge of becoming a reality. Marcuson acknowledged the support of the many authors of the WES report.

Richard Ledbetter outlined the role of the Committee to coordinate activities, users and applications from both within and outside the Corps. ANS&A, having been successful in their response to the BAA, would have a key role throughout the design and development of the centrifuge and its associated appurtenances and in assisting with the necessary training that was envisaged. This would result in a presence in Vicksburg for one or two years after the centrifuge came on line for training and equipment development.

ANS discussed the history of centrifuge developments in the US and the UK and the development of ANS&A with its structure of Associates. The facility at WES would be novel and was based on an excellent specification; it would be important at an early stage to review capabilities and to consider the development of equipment, instrumentation and expertise. There was a possibility of accepting a reduced specification to avoid a major cost overrun. Through its Quality Assurance activities ANS&A would be closely involved with the design and manufacture of the centrifuge and would oversee the project through commissioning and beyond. However the achievement of research objectives was seen as critical to the success of the facility; here ANS&A's role was to encourage users from different laboratories by discussing the opportunities that presented themselves on the centrifuge facility.

The meeting then concentrated on individual laboratories: their interests and expectations.

IT Lab (Wayne Jones) clearly interested in construction practice: projects involving pile driving, in flight construction, CPT/SPT, materials handling, tunneling, effect of rising water table etc. Need to verify assumptions on ground pressures. Possible link here with Colorado but also Gainesville or RPI for other specialist techniques.

Coastal Lab (Lyn Hales) described problems of waves on structures, movement of sediments. Considered 250 m x 250 m wave tank perhaps looking at wind generated waves and effects on structures. Need for Professors Hideo Sekiguchi (Disaster Prevention Research Institute) and Ryan Phillips to interact with Steven Hughes and Lyn Hales. Possible contact with Navy.

Environment (John Ingram) discussed soil-water interactions and leaching processes. Need for probes which could detect concentrations. Probably initially resistivity probes but possibly future optical probes available. Interested in work on dredge disposal: wave effects on capped deposits. Consider link with Zimmie at RPI on dewatering/consolidation of paper sludge.

Hydraulics (Marden Boyd and Stephen Maynard) interested in adequate flow rate and length of channel. May need up to 1 - 2 cubic feet per second (typically a 4 - 6" pipe); possible pump on board or alternative scoop from trough. Problems of flow through a rockfill dyke Reynolds numbers are low and it is difficult to model at 1g.

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Height may be 30 - 40' in the field; would like to model at between 20 - 50 g. Side slopes typically 1:2, 1:3 or 1:4. Just about manageable at 50g, probably requiring an overhanging container. Could use an instrumented (conducting) V notch to accurately measure flow. Also problems in fluid-structure interaction - have used brass to model steel at 1g but interested in opportunities at high g. Need link with hydraulics research perhaps at Colorado, Davis or Maryland with Deborah Goodings? Could consider transient problem, eg. water barrel passing through rip-rap. Site specific problems are supported by the Districts.

Structures (Kim Davis) interested in location of cameras for aerial view and mirror view of surface. Concerned about mounting equipment on booms; probably use on board capacitors. Research priorities have shifted rather than changed altogether. Ammunition storage facilities currently of interest; program funded by Navy to consider buried explosions where lithostatic pressures are substantial. Possible tests at LCPC or Bordeaux; should establish link with Schmidt.

Geotech (Paul Gilbert) described their interests in environmental chambers to simulate conditions on other planets. Also problem of overtopping dams: need to capture eroded material and to maintain pool level. Could use long weir constantly being overflowed or a piston/float system. Concern over identification of technician support.

Cold Regions (Stephen Ketcham); expected to see basic research eg in foundations to provide seed money to develop capabilities. Interested in geotechnical problems: frost penetration, permafrost. Also sea and river ice - possible links with Navy and Coastguard in ice breaking or ice vessel interaction. Most likely to see developments in geotechnical area looking at freezing ground for frost penetration and frost heave. Not so clear that the centrifuge will be useful for permafrost. Should consider identifying capabilities in weapons effects. Considering techniques of achieving cold packages, insulation, chilled brine, cold water at base, cold gas at surface etc. Need to control boundary temperatures on walls and base of models as well as surface temperature. Looking for control to $\pm 0.5^{\circ}\text{C}$ with capability of cycling temperatures at top and base (or at least step changes). Clearly needs cold room facilities at Centrifuge Center. Probable collaboration with Cambridge and Deborah Goodings. RPI also interested in frozen landfill capping. Valuable reference in R D Miller "Freezing phenomena in soils" Chapter 11 pp 254-299.

RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-002
Present:	RH Ledbetter, ANS, RSS	Date:	9 Jan 92
		Time:	pm
		Prepared:	RSS
		Notes:	
Subject:	Status of centrifuge contract		

a. Appointment of contract officer's representative

Probably Ledbetter, but not yet appointed.

b. Definition of milestones

Expect quarterly progress reports. Acutronic to provide monthly expenditure schedule, work schedule and commissioning test schedule. For example it will not be satisfactory simply to use a single billet for the test. The importance of inspection/testing was discussed.

c. Review of Specification dated September 1991

A number of errors were identified in the Acutronic Specification which required correction or clarification, for example "concrete masonry", page 2, "enlarged platform", page 6, "air conditioning", page 10, "SG/s", page 15. The minimum temperature for fluid passage was quoted as 10° C, which seemed high. A safety factor of 1/2.7 to the elastic limit was quoted but concern remains over the nature of residual stresses in the platform and the degradation of stiffness that might be observed as failure was approached.

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Signed:

RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-003
Present:	RH Ledbetter, G Hale, B Landes, B Logue ANS, RSS, RP	Date:	10 Jan 92
		Time:	9.00
		Prepared:	RSS
		Notes:	
Subject:	Status of centrifuge contract		

ANS&A performing a technical audit; there is a need for milestones and for ANS&A's role to be defined. The flow of payments is authorised by the Contracting Officer's Representative (COR); ANS&A has no authority in this area.

Communications will be from ANS&A to WES (COR). Assurance was given that WES's intention was for Acutronic to communicate with ANS&A and at all times to try to resolve issues directly without recourse to WES unless a difficulty cannot be overcome.

There is a need for the COR to inform Acutronic that ANS&A will be US Government Representatives and will be involved in technical assessment and QA. Left open in the Contract in case other Gov. Reps were to be used.

There is a need for a public statement following signing.

Communications from third parties to WES should be copied to ANS&A.

Role of RP in Vicksburg. Contract through ANS&A for simplicity. Comati should have no difficulty here. Need to proceed with proposal preparation.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-004
Present:	RH Ledbetter, G Hale, W Landes, B Logue ANS, RSS, RP J Perdriat, H Voss, Nicholas-Font	Date:	10 Jan 92
		Time:	9.30
		Prepared:	RSS
Subject:	Centrifuge contract	Notes:	

The meeting commenced by addressing the problem of communications between parties. HV explained that he had no contractual relationship with WES and therefore no mechanism to communicate with ANS&A. This would disappear once both parties were under contract to WES.

GH noted the high technical specification of the centrifuge. He stressed the importance of meeting budget targets and program deadlines; RDT&E military funds demand that close cost control is met: schedule and expenditure were critical.

WL described ANS&A's role as carrying out QA for WES. ANS&A and Acutronic were to try and sort out matters between themselves. The information flow will be parallel from Acutronic to ANS&A and to WES. HV stressed the importance of expeditious processing of information and eg. calculation approval to meet cost schedule.

ANS discussed the nature of technical achievements and milestones that would be necessary to complete a technical audit. This would be a novel facility: it may be preferable to compromise between additional cost and a reduction in specification. However the centrifuge was only one aspect of the technical achievement; the achievement of research data in addition to the supply of the centrifuge made this contract unique. RSS added that ANS&A's responsibility lay in assuring this research objective: a technical role.

JP emphasised the importance of reviewing the physical specification for the centrifuge, separating the accessories (which could be easily interchanged during the life of the machine). Acutronic were responsible for the design but there was a need for outside review of calculations: a cross-check perhaps by a bureau of calculations; no budget at present had been included for recalculation. RHL agreed that a third party check would be useful. It would be important during the design phase to prepare a detailed definition of the manufacturing process and the control processes. This would be a part of Acutronic's Quality Plan. A QA Manager (QAM) would be appointed and would have authority on timings as well; this would be computerised and open to ANS&A. Acutronic's responsibility was to design and submit; supervision and criticism was ANS&A's role. It would be vital to ensure that the definition of the centrifuge was compatible with its scientific role; however this was not the responsibility of Acutronic. HV added that Acutronic could only supply a machine to ANS&A/WES's specification. N-F noted that for Acutronic the point of sale was when the machine was demonstrated to be working at its proof load capacity. It was agreed that the general nature of the specification in many areas meant that there would have to be trust between the various parties that there was an intention to produce the best possible product (eg in the area of signal to noise ratio) but as far as possible the basic specification needed to be agreed immediately.

Referring to a memorandum of 16 December 1991 RHL stressed that the expenditure schedule, detailed work schedule and milestones needed to be meshed with ANS&A's quality assurance plans. However Acutronic would produce their schedule first and ANS&A would then discuss with them how best they could interact. Acutronic's Quality Control Plan, being developed under the control of N-F and their QAM using SUPERPROJECT software would need to be coordinated with ANS&A. There would be a need for additional line items to provide for ANS&A's technical audit. Progress on design and manufacture was expected to be rapid this year and early interaction was vital.

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The discussion turned to technical issues relating to the centrifuge and its delivery.

On the swinging platform ANSYS code would be used for stress analysis. This model would be supplied for user friendly analysis: it could be used for a future dynamic analysis. Dynamic testing of other Acutronic machines has shown good correlation in operation and at rest. ANS&A/WES to receive calculations but will be required to sign a non-disclosure agreement. Examination of the platform slab will require existing small diameter holes to be remachined to allow access by probes.

Examination of the booms was possible. The desirability of having the boom divider as open as possible was discussed. This was considered more important than its radial position. Methods for attaching equipment to the booms (using compression rings) or the central axis (using tension cables) were discussed. Loads would need to be defined.

The open boom divider would be important for high speed cameras located in the low g field. Temperature and humidity control within the chamber were discussed. Water flow requirements had been discussed with potential users; flows of around 2 cubic feet per second would be required from the central axis, along the booms and spilt against the wall. A drainage channel at the base of the wall would capture the water and allow recycling.

The Quality Plan was to be prepared but may take two to three months. The detailed work schedule was required early as it was closely related to progress payments. A visit to Paris by ANS, RSS, J-FC would be arranged within two weeks to discuss the implementation of QA.

The delivery of key spare parts which may be difficult to replace in the future (such as bearings) would be defined after the design phase.

The Specification for the centrifuge presented in the September 1991 Acutronic proposal was then reviewed, correcting errors that had been identified and rewording certain sections to reflect particularly the chosen deliverables.

Discussion on the safety of the swinging platform focussed on the nature of failure in the event of overload. It was agreed that degradation of stiffness would be very likely in advance of the 2.7 factor to the elastic limit. New load cases such as blast overload and thermal stressing on the platform slab would have to be considered. The detection of damage by looking for permanent strain or by ultrasonic testing was considered.

The importance of establishing a point of contact within each organisation was agreed.

The suggested containment structure layout as proposed by Acutronic was discussed. There had been considerable revisions to their original suggestions. The containment structure and the laboratory building were to be separated and access would be by underground passage through doors in the wall. Air flow throughout the structure was stressed as critical. Details such as the spacing over the electrical cabinets in the motor chamber and the arrangement of the stairwell were deliberate design features relating to air flow. Access for serviceability was discussed. Motors could be removed one at a time. The platform could be dismantled by fork lift. The roof shear beams would be adequate to support the entire centrifuge if necessary. Changing counterweights would require the roof to be removed and an overhead crane to be brought in. The nature of the services was still to be specified in detail. The design of the containment would have to consider flotation; its absolute elevation was not fixed but could be adjusted to suit. The foundations had not been specified at all. Access for crane and lowloader would need to be incorporated in the layout. Early completion of critical concreting (under careful supervision) would be important in ensuring a smooth installation subsequently.

RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-005
Present:	ANS, RSS, J-FC	Date:	23 Jan 92
	J Perdrat, Nicholas-Font	Time:	9.00
		Prepared:	RSS
		Notes:	
Subject:	Centrifuge contract and QA		

ANS described the background to the WES centrifuge project, from the initial discussions at the Paris '88 Centrifuge Conference and the April 89 response by ANS&A to the WES BAA through to the present award of the centrifuge contract. The emphasis the Corps had placed on a general purpose civil engineering centrifuge required a unique 350g capability, particularly to address blast modelling problems. Given these new fields of operation, and the poor record of safety of operations on US facilities, it would be vital for ANS&A together with Acutronic to work towards understanding the facility and documenting its design and manufacture.

JP described Acutronic's present position contractually. The Acutronic contract with WES refers to the Acutronic product description; the contract is a follow-on from a previous contract for a pre-design for the centrifuge. This pre-design had been accepted by WES. The main centrifuge contract was cost-plus but with a defined budget. Any deviation in the software or hardware would have to be renegotiated (ie. any deviation from the plan of work). For example no buckling calculation has ever been done for any Acutronic centrifuge; for WES this would require a deviation. Both the pre-design and the product description were considered contractual. JP commented that the role of ANS&A still needed to be defined; for example the US Government Representative role had been verbally stated but not seen in writing.

ANS&A's role was then discussed: to define the quality of the centrifuge; to define the quality of the capabilities; and to commission these capabilities. ANS&A's series of contracts addressed (1) Quality Assurance and the technical oversight of the design, manufacture and commissioning processes, and (2) the development of instrumentation and equipment, the achievement of capabilities and the production of research data.

Dr Phillips was now considering moving to Vicksburg in the summer of 1993 to be in place during and beyond commissioning. J-FC and RSS would be primary contacts with Acutronic.

JP stressed the need to define ANS&A's role in relation to Acutronic and to identify a single point of contact. Acutronic would supply the names of the Project Manager and QA Manager. Four AFA documents were considered contractual (excluding Acutronic USA documents such as their QA Manual):

- (a) AFA Quality Plan;
- (b) AFA 684-1 Product Description;
- (c) AFA Price offer (family tree - audited price calculation);
- (d) AFA Pre-design.

There was a need to build a Quality Plan; this would be based on earlier centrifuges, eg. Nantes and City. The updated schedule would be completed within 30 days - the first version to be by Acutronic. JP expressed concern over the future of certain companies that may be associated with the project, such as component suppliers.

The meeting resumed in the afternoon.

Techniques for analysing the box grillage structure of the platform were discussed. The sufficiency of relying on elastic FE calculations for analysis of a grillage box structure was questioned. The necessity of addressing modes of failure as well as elastic deflections was emphasised by ANS&A. It was suggested that outside agencies (such as the French Welding Institute) might have useful comments to make in this area.

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It was agreed that the calculations presented in the Predesign were incomplete and in particular, in the area of the platform slab at least, were of a different structural form.

JP noted that for this machine stressing calculations would largely comprise FE output which would be difficult to interpret without the preparer. RSS stressed that this would not be acceptable: calculations would have to be sufficiently documented so as to allow a qualified engineer to understand them without recourse to the originator.

The date of the next meeting was set for 27 February 1992 to discuss the Quality Plan, milestones and the platform design.

RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-006
Present:	RSS, J-FC	Date:	2 March 92
	Nicholas-Font, Ona, Aliphat,	Time:	11.00
	Gawad, Sabard, Rouille	Prepared:	RSS
		Notes:	AFA offices (Les Clayes sous Bois)
Subject:	QA		

This meeting replaced the meeting scheduled to take place on 27 February.

A new version of the Acutronic QA Manual QM/001 was received and the old one returned.

RSS explained ANS&A's purpose in reviewing technical progress on the project and briefly discussed ANS&A's Quality Plan and the channels for communications and contractual links which had been established since the signing of the contract. The detailed schedule of activities was requested; it was explained that AFA were billing to a simplified version of the schedule and that a detailed schedule had not been prepared. A copy of the simplified schedule was presented.

N-F then introduced the Project Team who were attending the meeting: Mr Ona (Project Manager), Mr Aliphat (QA Manager), Mr Sabard (mechanical design), Mr Gawad (FE analysis) and Mr Rouille (electrical design). He explained that his purpose was to introduce these staff to ANS&A and that he himself would not be a part of the design team (with the exception of the aerodynamic calculations which he had now completed). Mr Ona was the AFA designated point of contact for ANS&A.

Summarising the present position N-F explained that AFA were currently designing the platform; it was expected to be complete by the end of March. Negotiations with contractors and the Welding Institute would be initiated in April. The structural computations had taken into account the possibility of the large platform option.

Frequency computations for the central axis and the booms had led to significant changes in design; early problems had been resolved.

The power requirements and gearbox had been computed. It was intended to order the motor and gearbox that week; N-F had completed the aerodynamic calculations.

The calculation procedures were then explained. Following the completion of elements of the design it was intended to produce a report which would be available to ANS&A. For example the platform design was now considered complete, and it was expected that a report on this aspect would be ready sometime in April. RSS commented that by April it would be too late to make useful comments to AFA and proposed that the meeting could usefully review technical progress even in the absence of a written report by hearing verbal reports on each individual area of work.

Mr Sabard then described the analysis approach for the platform slab. FE graphical output was available which showed maximum stresses in the metal of the slab above each of the four pins which attach the slab to the hanging brackets. It was noted that only a udl over the entire area of the platform had been considered to date. RSS explained the concept of the circular and rectangular model 'footprints' and it was agreed that these cases would be analysed as soon as possible. Alternative approximations to the circular footprint which could be used for computational simplicity were discussed.

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The structure of the platform slab was reviewed in detail; access to the slab for the inspection of welds from the underside will be through 10 mm diameter holes in each of the 64 plates. Fatigue was not considered to be an important issue in the design. Acceptable dynamic loads on the platform had not yet been defined.

The modelling of the support pin was discussed. These conical pins are expanded by bushings into their mounting sockets within the platform slab. The additional stresses that this process will impose on the grillage had not yet been taken into consideration. It is expected that by around mid-April Acutronic, with the Welding Institute and subcontractors will discuss the welding and assembly of the platform.

Other loadings, such as thermal gradients were discussed. An approach using radial stressing on the platform slab over a footprint area equivalent to a 20° C temperature differential between package and platform would be analysed to provide an estimate of the magnitude of temperature stressing effects.

Dynamic analysis of the booms had shown that the structure was initially too flexible and natural frequencies were being predicted of a similar order to the rotational frequency of the centrifuge itself. Base plates had therefore been added under each leg support (100 mm thick), the central axis stiffened and the booms increased in diameter to 640 mm OD (with 300 mm hole) from 500 mm (and 200 mm respectively).

Moderate stress levels were noted at the hinges and at the supports, except in the case of maximum imbalance.

The slip ring stack and use of space at the top of the machine was identified as an important topic for discussion at the next meeting.

The aerodynamic and power calculation had been based on both platforms. Aerodynamic coefficients for the WES centrifuge would be similar to the figures given for Nantes in the Paris 88 paper. The mass inertia of the machine as been calculated as $1 \times 10^6 \text{ m}^2\text{kg}$ with a mass in rotation of 92 tonnes (at 350g), more at lower speeds or with the larger platform. At continuous speed at 350g the predicted power need are around 1.3MW. The peak power is in excess of 2.2 MW. For the large platform at 200g these figures are 0.8 MW and 1.6 MW respectively.

The limitation on power is not provided by the motor but by the amplifier: the motor can withstand around 3 times its continuous power whereas the amplifier cannot. The motor/amplifier is expected to be ordered this week.

RSS agreed to prepare meeting minutes for circulation. The next meeting for both J-FC and RSS to attend was set for 9 April 1992 at Les Clayes. J-FC would be likely to visit Acutronic around 30 March.

RECORD OF MEETING

Project:	WES	Reference:	25-03-FOM-007
Present:	RSS, ANS, RH Ledbetter	Date:	12 March 92
		Time:	9.00
		Prepared:	RSS
		Notes:	Vicksburg

Subject: Centrifuge project

Dr R Phillips position was discussed in view of his possible move to Vicksburg in the summer of 1993. RP would interact with other labs over a period of around 12 months prior to commissioning, ramping up his involvement in equipment development, research tasks and training. RP would need to establish official VISA requirements - ANS to discuss with Comati in London and to follow up before next visit to WES.

RHL would take up the subject of RP's resident role at WES with W Marcuson. The proposal to have an ANS&A Associate in Vicksburg has three elements:

- (1) The principle of a full time position for around 2 years from Aug 93 to Aug 95.
- (2) That this position should be largely or entirely based at WES.
- (3) That none of the contractual arrangements made would prejudice a future application for citizenship.

It was noted that Acutronic were under considerable pressure; three contracts were now underway simultaneously and the timing of each of these would be critical to Acutronic's overall performance.

Equipment would be purchased substantially against Geotech PRIPS money and hence there was considerable pressure to interact closely with the other laboratories in order to achieve capabilities for them at minimum cost to Geotech.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-008
Present:	RSS, ANS, RH Ledbetter, P Gilbert, P Schroeder, R Mosher	Date:	12 March 92
		Time:	10.00
		Prepared:	RSS
		Notes:	Vicksburg

Subject: Committee of users

RSS described ANS&A relationship with Acutronic, nature of Quality Assurance and work in France. Design had progressed rapidly since the signing of the contract and there was an urgent need to define attachments. The Quality Plan emphasised the importance of understanding the facility and of achieving Total Quality Management of the future research product. Needs for training were discussed briefly and PG presented his report of his experience in Cambridge in 1991. There was an expectation that S Ketcham might be able to visit Cambridge during 1992.

In the area of stress analysis concern was expressed over the stresses induced during fabrication of the platform slab: the need for careful alignment of the supporting pins, particularly if replacement (eg. smart) slabs or packages were to be contemplated in the future.

Issues related to environmental modelling were discussed: the control of temperature through the use of systems such as the vortex cooler, for example; the complications of materials handling aspects, glove boxes, transport of models, use of real contaminants, real soils and examination of models.

Meetings were then arranged with individuals.

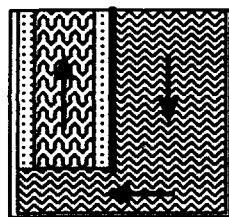
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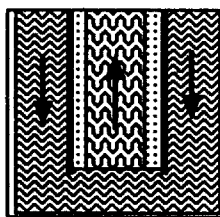
RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-009
Present:	RSS, ANS, RH Ledbetter, M Boyd	Date:	12 March 92
		Time:	1.30
		Prepared:	RSS
		Notes:	Vicksburg
Subject:	Hydraulic modelling		

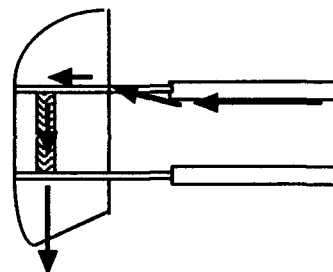
Primary interest of hydraulic lab is in flow along non-cohesive erodable banks. High flow requirement is essential. RSS outlined the programme and discussed the drawings of the centrifuge. Need example or demonstration experiment with good velocity distribution at the input. May later develop a curved section but initially straight section adequate. MB would discuss demonstration experiment with colleagues and respond as soon as possible.



Option A



Option B - probably better



Could use fairing
to help still water

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-010
Present:	RSS, ANS, RH Ledbetter, P Schroeder	Date:	12 March 92
		Time:	2.15
		Prepared:	RSS
		Notes:	Vicksburg

Subject: Environmental modelling

Lab demo projects were sources of basic research funding (under Whalin's discretionary control). Areas of specific interest included:

Subaqueous capping of dredged materials. Long term consolidation and stabilisation. Fluid slurries. Time for consolidation. Armoured capping - does it remain in place (typically rip-rap - 8" cobbles for high energy sites, eg. Great Lakes). Could use U tube for bottom current. Coastal engineering equally concerned with movement of dredged disposal mounds in near shore environment by shear.

Wetlands, concerned about ultimate elevation that can be achieved. Wetlands research project (creation and maintenance). Have used dredge material to build wetlands for many years. But not a big area of research.

Landfills. Long term interest in assessing hydraulic barriers (clays or synthetics) differential settlement and cracking. Confined saturated clays - are they penetrated at all by organics?

Trench disposal. Corps has only become interested in DOE work on trench disposal in past few years.

Contaminant movement, eg. with steam stripping.

Water flushing.

Groundwater codes for contaminant transport available on station but not yet validated.

In general there is very little experimental work done at WES except in area of leaching - in columns or beakers. Contaminants include PCB, dioxin, heavy metals. Special licence is needed for large experiments, eg. volume of a few drums of material. Centrifuge test would only use small amount, however, in large 'drum' of soil.

Adsorption. Could increase the specific surface and temperature and use scaled contaminants. Major areas of study at present include irreversible adsorption and non-equilibrium adsorption. Probable no NMR work on station at all. Experimental techniques include use of isotherms. Water is applied to soil and quantity of contaminant in leachate is measured. Not much work is done on where it is adsorbed. Differential thermal imaging (DTA) has been used to classify clays in the past. Probably now being overtaken. Refer to Dr J Brannon on Station.

Demonstration experiment. Leachate production and contaminant concentration from confined dredge material as function of time. Contaminant flow through sand blanket (used for low energy sites). Fluid mud of clay (2 - 3 feet), then 2 - 3 feet of sand: but exact thicknesses depend on the geometry of the depression in the sea bed. Placed using submerged diffusers.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-011
Present:	RSS, ANS, RH Ledbetter, K Davis, staff	Date:	12 March 92
		Time:	3.00
		Prepared:	RSS
		Notes:	Vickaburg
Subject:	Structures modelling		

Platform slab

The design of the platform slab was considered under blast loading. Grillages of the form proposed are immensely stiff and therefore not good absorbers of energy. Mechanisms based on field experience of eg. lock gates might be expected to include either shearing of pins or dimpling of the outer skin. Concern was expressed over the weld details on the slab and over the purpose of the bolts beside the pins.

Proof tests could be carried out at 1g using eg. concrete instead of sand; this would bracket the upper charge limit. Accelerometers at different levels would record the transmission of shock waves into the platform. However a honeycomb layer and rubber mat would probably be adequate to protect and isolate the platform.

Demonstration test

Shallow buried munitions in rock: air blast and debris effects. Uneconomic to model at full scale. Data might include the influence of charge density on initial velocities. Fractured brick might be used in place of soil.

Schmidt (Boeing) has extensive experience of modelling projectile penetration and explosion. He could be contracted to comment on centrifuge design and the nature of instrumentation and cameras he could supply.

Cratering. Pavement cratering, with varying water table depths and/or layering. Interested in the size of breach in the pavement or in an underground structure.

Piles. To be discussed with Ed Jackson.

Model making requirements.

Usually damp sand or clay soil at 1g. May need more sophisticated technique, eg. downward hydraulic gradient consolidometer or layering capability; these could be part of the geotechnical lab kit.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-012
Present:	RSS, ANS, RH Ledbetter,	Date:	12 March 92
		Time:	4.00
		Prepared:	RSS
		Notes:	Vicksburg
Subject:	Agenda summary		

The following points were noted:

Quality Assurance:

The family tree still needs to be supplied.
Acutronic's final product description needs to be supplied (and one for each member of the Committee).
Formal notice should be given by Acutronic of any variation to critical items (eg. the platform slab).
Note also that the grey book is incomplete.
Specifications for critical items of equipment (such as motors) should be supplied to the client.
A written statement identifying ANS&A as WES Representatives still needs to be prepared.
Invoices are needed on time from Acutronic.
It would be helpful also to see CVs for key members of the Acutronic Project Team.

Staff and development of capabilities

Ryan Phillips; refer to earlier meeting notes.
RHL to check possible salary range.
RHL to investigate equipment sources in the US, particularly for weapons effects.
A small centrifuge could be supplied with a cold capability to WES with Ryan Phillips and used for training in the period prior to the arrival of the large machine.
Training courses could then be mounted at WES using eg. 100mm samples.
The Tyndall Centrifuge was not ruled out. RHL and W Marcuson may visit to inspect the Tyndall facility.

Building (refer also to following meeting with GHale)

Contractual arrangements for the design and construction of the building were discussed.

Equipment

Shaker development. Gopal was expected to be in post in Cambridge by 1 June. A spring loaded shaker was currently under development. ANS would be visiting Japan and would be discussing specifically shaker development in Japan. A servo-hydraulic shaker was understood to be under development for the 665.
ANS&A's May Report should include conclusions and recommendations. WES would need firm estimates in the summer and would then look to place an order in October/November.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-013
Present:	RSS, ANS, G Hale	Date:	13 March 92
		Time:	9.00
		Prepared:	RSS
		Notes:	Vicksburg
Subject:	Building		

Options to complete the building work were discussed. The difficulty of designing a structure economically which could support the range of experiments now proposed was noted. A contractor who was not familiar with the style of work which was to be undertaken would face considerable problems in accepting liability for a structural design to house experiments that were as yet unknown.

WES considered that there was an advantage to having the same contractor responsible for the containment and the centrifuge. However it was noted that Acutronic have no past structural design experience and have not built the containment structures for their other large centrifuges. The importance of Total Quality Management of the facility, encompassing all aspects of the centrifuge center was stressed. WES emphasised their intention to involve ANS&A in the design of the containment in a similar fashion to the current QA activities being carried out for the centrifuge.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-014
Present:	RSS, ANS, G Hale, RHL, W Landes, B Logue	Date:	13 March 92
		Time:	10.00
		Prepared:	RSS
		Notes:	Vicksburg
Subject:	Contract		

The value of QA for the centrifuge facility was stressed; it was expected that the same approach would be adopted for the building containment.

Progress on the supply of the centrifuge

Meetings had been held in Paris with Acutronic France. Key items such as the detailed work schedule and Quality Plan had not been received as yet. WES had received the preliminary monthly expenditure plan. A letter would be prepared for Acutronic USA addressing these issues.

Building

The history of the containment structure concept was discussed. The original Acutronic Proposal had been rejected (although no formal letter had yet been sent); a revised version of the structural concept (seen at the January 10 meeting) showed level separation and was greatly improved. Acutronic had been told that this drawing would be used as the basis for a 35% design by an AE. An alternative option to accepting Acutronic's offer was still open: ANS&A could team with a constructor and submit a proposal to complete the whole works.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-015
Present:	RSS, G Hale, RHL, David Haulman	Date:	13 March 92
		Time:	2.00
		Prepared:	RSS
		Notes:	Vicksburg
Subject:	Building		

The design criteria for the containment structure for the centrifuge were discussed with David Haulman (Construction Services). Out-of-balance forces, air pressures in the chamber and the natural frequencies of the structure were important considerations. The maximum imbalance condition would impose large cyclic forces on the foundations. Air flow in the chamber was important, and it was likely that there would need to be provision for substantial fluid flow along the booms, onto the wall and recycled through a drain around the perimeter of the chamber. Access would be by lift: level separation was necessary for safety. The location of the structure was not yet fixed but the current sketch from the manufacturer showed the position on level ground.

A government estimate was needed for construction. A local AE would be contracted to provide an outline design. Progress would need to be reviewed at close intervals. The water table needed to be located and a SI would look for possible clay pockets (as had been found under the Geotech Building).

RSS could brief AE on the nature of centrifuge testing while on a future visit.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-017
Present:	RSS, J Nicolas-Font, Acutronic staff	Date:	23 April 92
		Time:	11.00
		Prepared:	RSS
		Notes:	Les Clayes
Subject:	Progress		

Non disclosure agreements between Acutronic France and ANS&A representatives were received. RSS signed and returned the original.

The notes of JFC's meeting (25-03-ROM-016) had been received by Acutronic. There were certain issues which Acutronic had responded to directly in a letter to JFC (copy received) and others which would be addressed in Acutronic's 1st Report.

Structural Design Aspects

The necessity of having considered the large platform option as part of the initial sizing of the centrifuge was agreed.

Stressing difficulties with the small platform at 350g were noted. A new steel had been selected (specification received) with a yield stress of around 690 MPa. Six pins were now proposed to attach the slab to the frames. Analysis using ANSYS under self weight and with the circular footprint had given maximum stresses of around 237 MPa (Von Mises) which was considered acceptable. Prestress from the insertion of the pins had not yet been considered. The selfweight of the slab is around 2000 kg. The alignment of the pins was critical and tolerance on the diameter of the pins would be small - around 0.1 mm. Load would be distributed between the six pins as predicted deflections were of the order of 1 mm, considerably in excess of the tolerance. The support frame was also designed with a lower stiffness (in the axial direction) of the central member.

The support frames were now estimated to have a weight of around 1200 kg each. Stressing analysis of the frames had also given problems with high stresses predicted around the "hook" where the frame is pinned to the boom. High strength steel with yield stress of around 1100 MPa would be achieved by treatment (forging etc.). The bolts on either side of the pins are necessary to carry the tensile forces from the tangential spreading of the frames. Clearance prevents the bolts being loaded in shear.

Pins have been analysed satisfactorily: high stresses where load is transferred to support frame.

Access to the platform slab for weld inspection in the areas of high stress should be possible. The stress analyses (copies received) show high stresses on the underside which would be accessible through the welding holes. High stresses on the upper surface of the slab clearly in compression. Weld details would be discussed with the French Welding Institute around the end of May (once the design is completed).

Dynamic calculations for the centrifuge will be revisited once the final design is complete. The importance of achieving a high natural frequency of the chamber was stressed because of the significant energy found around higher harmonics of the fundamental modes of the centrifuge.

The design of the swinging platform was now commencing. Attachments would have to be defined soon by ANS&A/WES. It was expected that this would take one to two months. The design of the rest of the machine would follow.

The spilling of water in the chamber was discussed. The Acutronic sliding door arrangement has seals on the

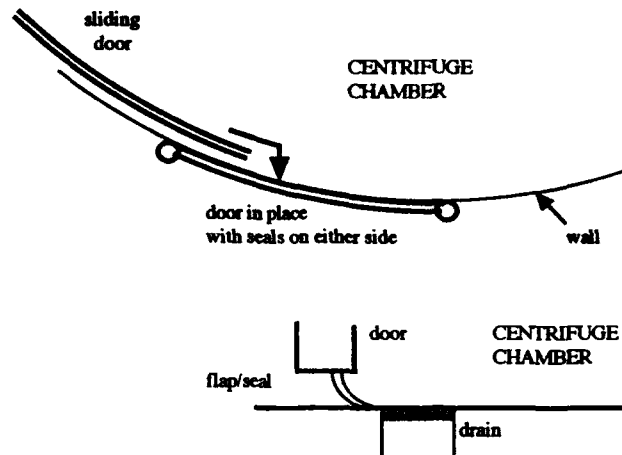
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25-03-ROM-017 (contd)

sides and across the top of the door and an additional flap or seal could be added to the bottom of the door.

This may need to be checked for wind pressure at 350g but in principle it was thought that there was no difficulty with this arrangement.



Detailed Work Schedule

It was noted that the work schedule which had been received was a simplified work schedule and was not sufficient to oversee chart progress. A detailed work schedule will be prepared based on sub-assemblies, linked or cross-referenced to the Family Tree. It was agreed that such a detailed schedule would assist discussions on technical achievement.

Specifications, calculations etc.

A copy of the file which has been sent to JFC will be sent to RSS in Cambridge. This file contains specifications etc and will gradually be built up as the work progresses. Three copies will therefore be made: one for JFC, one for RSS (WES) and one for Acutronic.

Quality Plan

Acutronic's Quality Plan (Revision 0) had been received by RSS on 21 April.

Audit

Meetings were held although not to a fixed schedule. These were primarily the responsibility of Mr Aliphat but any member of the Team could call a QA meeting. For example the Technical Director might call a meeting to discuss the work of a sub-contractor. RSS suggested that Section 7.2.2 be altered to reflect more strongly the necessity of QA audit and that a principal function of such meetings was to confirm adherence to the QA procedures.

Technical responsibility

No mention is made in the QA Plan of technical responsibility. For example Mr Nicolas-Font (Technical Director) is not mentioned in the document. It was explained that the role of the Project Manager, Mr Ona, was largely administrative and all technical decisions and instructions were the responsibility of Mr Nicolas-Font in his capacity as Technical Director. It was suggested that Mr Nicolas-Font should be identified under the

corporate section. RSS recommended that a new section be added to explain in detail the structure of technical 25-03-ROM-017 (contd)

responsibility and the procedures by which instructions were issued, eg. verbally or in writing etc. Mr Perdriat (who joined the meeting in the afternoon) suggested that detailed written comments should be made by ANS&A following receipt of a fair translation in English. However ANS&A agreed to work with the version of Acutronic's Quality Plan which is in the original French language, being the language of the engineers and staff who would have to implement it.

A statement on the achievement of technical quality should also make reference to the interfacing of Acutronic's Quality Assurance activities within the overall Total Quality Management of the centrifuge facility, which was the responsibility of ANS&A. In explaining how technical quality would be achieved reference would be made to Acutronic's "Instructions and Procedures" documents. These were viewed; many are still in draft form but it was hoped that they would be published shortly. For example a new draft approval sheet with space for the signatures of preparer, checker and approver (which would replace the current sheet which required only one signature) was noted.

Under Section 8.0 it was noted that one function of the QA Manager was to question the project team with regard to meeting the product specification.

Acutronic's first Quarterly Report will be commenting on JFC's meeting notes (25-03-ROM-016).

The letter from Mr Voss to WES dated 13 April was discussed. Errors in the letter in the discussion of (a) the detailed work schedule (it was a simplified schedule and not a detailed schedule which had been received by ANS&A) and (b) the Quality Plan (which should have read Manual) were noted.

RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-018
Present:	RSS, RP, Paul Gilbert	Date:	27 April 92
		Time:	9.00
		Prepared:	RSS
		Notes:	at Vicksburg
Subject:	Geotech experiments		

Experiments of interest to Geotech include soil-structure interaction, settlement, rapid drawdown, climatic conditions, eg. freeze thaw.

Could test tall towers, for example. Would like to use clay early on in an experiment (eg. Georgia Kaolin, or Edgar Kaolin from Florida). Concern over investment in clay mixers and consolidometers early on. Clay is however a key part of the work of the Soils Group: a tall tilting tower would have wide application.

An alternative test would be a lock model, investigating earth pressures on the walls and uplift caused by falling water levels in the lock. Probably use plane strain box with sands and (ultimately) clays; perhaps have clay preparation in FY94 equipment proposals. Sketches to be prepared by PG of typical model layout.

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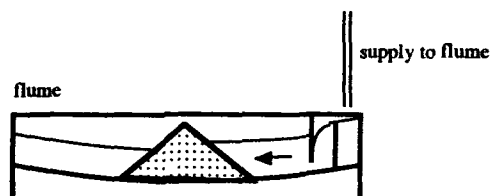
RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-019
Present:	RSS, RP, Steve Maynard	Date:	27 April 92
		Time:	10.00
		Prepared:	RSS
		Notes:	at Vicksburg
Subject:	Hydraulics experiments		

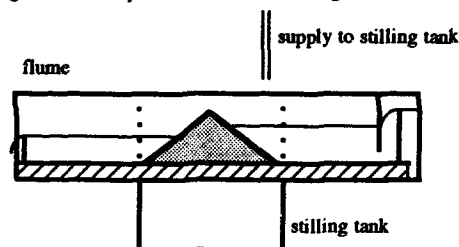
The meeting concentrated on the proposals from Steve Maynard and Burt Boyd to investigate head loss through a rock dyke in a long flume.

The length of approach upstream of the dyke and length of exit downstream were critical to the success of the experiment; the dimensions shown may be insufficient (the flume is around 3 m long). The experiment is based on an actual project that was carried out at WES at scales of 1:9, 1:18 and 1:36. (Head losses of around 6 inches to 1 foot prototype were found across the dyke.) It is intended as the perfect application of centrifuge modelling for hydraulics problems - for models to investigate turbulent flow, which cannot be achieved at 1g. The experiments that had been carried out at 1g showed a strong scale effect at 1:36. The difficulty with increasing the length scale is that the Reynolds number drops drastically (maintaining a Froud model).

Other experiments of interest included measuring forces and vibration on gates (such as below), perhaps 60 feet typical dimension, which are currently modelled at a length scale of around 1:20 using brass.



The original concept had been that the long package would be carried in the tangential direction. Problems of curvature and of the new Acutronic design for the hanger (with three straps) were discussed. The problem of accurately trimming the centroid of the flume to hang exactly in line with the centroid of the platform was discussed (flow over the entrance weir would need to be uniform). The alternative would be to carry the flume in the upright direction (which would avoid both of these problems) but its length would mean that it would have to be blocked up on the swing. This could provide room for a stilling tank.



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25-03-ROM-019

The length of the flume would create severe difficulties in its present form. Alternatives such as using a smaller length scale (eg. 1:50) or accepting a smaller flume (perhaps it could be reduced to around 2.5 m) were debated. It was noted that in hydraulics modelling length scales of smaller than 1:36 were very difficult and would only be of limited use - difficulties had been experienced in using brass at 1g to make miniature gates etc.

The supply of water by scoop or trough was discussed. A steady flow was critical (varying pressure in the water column caused by fluctuations in the supply pressure would be useless) and a scoop may therefore be preferable as steady conditions are maintained. However the speed of a scoop was probably too high - a very large reservoir would be required around the central axis of the centrifuge. The underslung doughnut solution would be greatly improved if many inlets were specified; this would even out the conditions in the doughnut.

The speed of the centrifuge with g is estimated as follows:

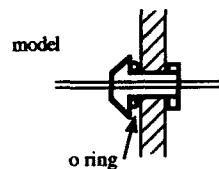
g level at	frequency Hz	velocity m/s	velocity m/s	speed mph	speed mph
7.5 radius in m		1.50	7.50	1.50	7.50
18	0.78	7.35	36.74	16.44	82.21
36	1.10	10.39	51.96	23.25	116.26
72	1.56	14.70	73.48	32.88	164.42
108	1.91	18.00	90.00	40.27	201.37
350	3.44	32.40	162.02	72.50	362.50

Discussions would be held within the Hydraulics Group to consider the issues of flume design and water supply system.

RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-020
Present:	RSS, RP, RHL, Kim Davis	Date:	27 April 92
		Time:	11.00
		Prepared:	RSS
		Notes:	at Vicksburg
Subject:	Structures experiments		

Any equipment ordered in the short term, eg. during FY93, will need to have wide application. It is expected that initially a box with a blast liner will be adopted both for economy and because the timescale of most projects makes the selection of more complex systems premature. A circular chamber will be satisfactory but future work may use rectangular boxes with windows for conducting half space experiments. Possible sealing arrangements for the insertion of transducers might be as follows:



Potential projects

Damage to tunnels in jointed rock from aerial bombardment. Depth typically 5-15m to crown of tunnel. (RSS noted the work of Prof Einstein at MIT in modelling jointed rock on the centrifuge.) Centrifuge perceived as providing new capability primarily because of the volume of the model and secondly because the facility would be in Vicksburg and immediately accessible. The typical volume that might be available within a Vicksburg blast liner could be around 1m diameter x 1m high (approx. $0.75 \times 2.7 = 1.9$ tonnes of 'rock'). However it was stressed that it would be difficult to pursue future sponsors until the centrifuge was actually in place and there was therefore some reticence about defining experiments at this stage.

Two other areas mentioned were (a) penetration experiments (Robert Rohani) perhaps using 22 calibre bullets, cubes of steel or aluminium, and (b) placement and stacking of concrete dolos (Ceritto) to investigate the significance of design shape.

Instrumentation

Block motion in rock - eg. relative displacement or velocity of different blocks dynamically; solutions might include using reflected laser light through a window in a half space model. Pressure measurements. Cameras would be mounted near the axis with mirrors on the model.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-021
Present:	RSS, RP, RHL, W Marcuson	Date:	27 April 92
		Time:	1.00
		Prepared:	RSS
		Notes:	at Vicksburg
Subject:	Centrifuge progress		

The meeting briefly addressed a series of topics related to the centrifuge development.

On the earthquake shaker, the form of excitation which would be adopted at WES for the centrifuge was arousing widespread interest in the geotechnical community in the US. Variation of amplitude and frequency was considered important. An electrohydraulic system was perceived by some experts to be a likely approach.

On the development of future revenues for the center the importance of identifying early on future sponsors for the WES centrifuge was stressed; this would necessitate the marketing of the centrifuge with other labs and agencies.

In considering the management of the centrifuge center it was agreed that a range of skills would be needed amongst the key staff, including the ability to interpret users' needs and for conceptual model definition, data acquisition and marketing.

Possible arrangements whereby RP could spend time at WES for a period of at least two years from August 93 were discussed.

Progress by Acutronic in design was considered. Certain aspects, such as the cyclical air pressures in the chamber and the consequences of catastrophic imbalance have important implications for the design of the containment structure.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-022
Present:	RSS, RP, RHL, R Mosher	Date:	27 April 92
		Time:	1.30
		Prepared:	RSS
		Notes:	at Vicksburg
Subject:	Information Technology Lab		

Problems of interest are primarily in the field of soil-structure interaction, excavation and placement of fill - construction processes in general. For example understanding the nature of shear stresses and earth pressures behind a lock wall arising from the construction of the lock and placement of fill would be a good example. Civil works provides funding for research. IT engineers would expect to work with Geotech Lab to complete a test programme.

Tools for placement of fill, compaction (and ultimately excavation) would be great interest, particularly related to wall soil interaction but also for pile foundations under static or dynamic load.

Action:

Paper by Bolton and Sun on earth pressures on retaining walls to be sent to Reed Mosher.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-023
Present:	RSS, RP, RHL, G Hale	Date:	27 April 92
		Time:	3.30
		Prepared:	RSS
		Notes:	at Vickaburg
Subject:	Centrifuge progress and buildings		

Discussed meetings with Acutronic, progress with design (concerns over the stress analysis of the platform) and the response received from Acutronic USA (dated 13 April) to the letter from the Contracting Officer dated 20 March 1992.

Site Investigation, primarily to locate the water table, and detailed surveys of the gulley next to the laboratory building were being carried out by Geotech Lab to assist in the siting of the containment building. A contract had not yet been placed with an AE for a partial design. Water had been found at around 7 or 8 feet below the slab level of the present building and hence the water table would inevitably be above the foundation (in its present location). Resiting of the structure further out into the gulley was being considered. There would need to be a briefing of the AE on centrifuge testing and containment once the AE contract had been awarded. ANS&A would need to interact closely during the design phase.

The construction of the new centrifuge facility had been announced in a presentation at the Corps Geotechnical Meeting (addressing Divisions, Districts and OCE) in Salt Lake City. It had been explained that ANS&A's proposal had been accepted and that Acutronic were supplying the mechanical equipment. A Press Release was not considered desirable but ANS&A were now free to discuss details of the project with third parties; the project was no longer confidential. An article in ASCE magazine was another possible route.

On equipment development PRIP money for FY93 was now considered to be in the clear; it will need to be spent within the fiscal year. A list of equipment and budget prices would be prepared for discussion during the coming summer. The earthquake shaker would not be in the budget until FY94; all equipment in FY94 and FY95 would require to be individually justified.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-024
Present:	RSS, RHL	Date:	27 April 92
		Time:	7.00pm
		Prepared:	RSS
		Notes:	at Vicksburg
Subject:	Earthquake shakers		

The progress at Cambridge with the design of a spring actuator was discussed. The desirability of developing (in the future) a multiple fire mechanism and the capability to vary the amplitude of excitation in flight was noted.

In deciding the nature of the drive system that would eventually be selected for the initial WES shaker it was agreed that high g performance and minimal cost were top priorities. This would be unlikely to be achieved by servohydraulic systems, but the capabilities of such systems and the risks associated with their development would be discussed with users of present systems and manufacturers. In particular comment on likely performance at high g would be sought. At present it was considered that the risk associated with such a development would be very high. It would be particularly difficult if the system delivered to WES was not capable of exploiting the power of the WES centrifuge.

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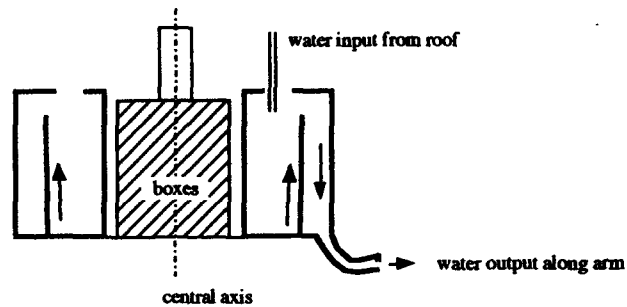
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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-025
Present:	RSS, RP, RHL, S Maynard	Date:	28 April 92
		Time:	9.00
		Prepared:	RSS
		Notes:	at Vicksburg
Subject:	Hydraulics Lab		

Steve Maynard will be visiting Nottingham between 12-18 July 1992 and will attempt to combine this with a brief visit to Cambridge.

Solutions to the delivery and supply of water on the centrifuge were discussed. An on-axis tank was the favoured solution, mounted around the slip ring stack and assembled in segments.



The internal diameter of the hollow cylindrical tank would be around 1.5m; it would have an internal weir and be assembled in segments. The pipe along the arm would need to be rigid - a flexible pipe would be unlikely to carry the flow velocities.

At the flume end the emphasis would be on using the available volume to still the incoming water. Steve Maynard to prepare a sketch of the central hollow tank, to size the pipe along the arm and to provide a conceptual outline of the stilling tank that would be needed on the platform.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-026
Present:	RSS, RP, RHL, V Cerritto	Date:	28 April 92
		Time:	11.00
		Prepared:	RSS
		Notes:	at Vicksburg
Subject:	Platform analysis		

The analysis of the pins and platform carried out by Acutronic to date was discussed. Concern was expressed over the boundary conditions which had been used in the ANSYS analysis and whether the global stiffnesses of the connections between the slab and the hangers had been adequately modelled - particularly relating to rotation of the pins.

Alternative arrangements to mount the slab on the hangers were discussed. The hangers themselves could take a truss form although this would be likely to require a considerable extra weight of steel.

The structural analysis capabilities of the Structures Lab were discussed. RSS noted that it was ANS&A's intention to take up the stressing issue directly with Acutronic immediately on his return to the UK. JFC had been asked specifically to raise the issue during his meeting with Acutronic today.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-027
Present:	J-FC, Nicolas-Font, Sabard, Gawad	Date:	28 April 92
		Time:	11.00
		Prepared:	JFC
		Notes:	at Acutronic, Les Clayes
Subject:	Centrifuge design calculations		

Since the previous meeting on March 30th, Acutronic sent to J-F Corté the following elements which were examined by JFC prior to the meeting:

(parts of general document: WES - Mechanical Design of the model 684-1 Centrifuge, March 1992. J57009)

- family tree updated 15 March 92
- drawings 684-10 0000 to 0004
- model 684-1 key specifications (March 92)
- small platform dimensioning (March 92) §III 0.0 to 6.3
- power consumption - definition of power plant (March 92) §VII 1 and 2

and Acutronic Quality plan for WES project.

Questions discussed with Acutronic during the meeting.

Definition of motor drive unit

Chapter VII mentioned above defines the specifications fixed by Acutronic to the suppliers of the motors and gear-box.

Power and torque requirements have been evaluated according to the same approach and modelling as the one used for LCPC centrifuge, which has proven to be sound. The highest values correspond to the 350g case with the small platform. The mass estimate of the small swinging basket used by Acutronic seems to overestimate by about 1500 kg what is likely to be achieved. This represents a small margin in reserve for the run-up phase (if the other masses and inertias are correctly estimated). The power values required at the end of the run-up phase to 350g and for stationary rotation at 350g are about 2000 kW and 1500 kW. These values exceed by about 25% the estimates made before by Acutronic in the product description.

A margin of safety of 10% (respectively of 20%) has been added by Acutronic for the definition of the motor (resp. the gear-box), which looks adequate.

At the end of the design of the centrifuge rotor design, verification of the power requirements should be made with actual values of masses and inertias.

The motor drive system has been ordered by Acutronic:

- motors to Leroy Sommer (France)
- gear box and lubricating system to Campabadal (Spain).

(Note: control in the factory should include that of the lubricating system.)

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25-03-ROM-027 contd

Interface between centrifuge and building

Acutronic has agreed with JFC for the need for a special chapter dealing with the questions of interface with the building. This section would contain only information pertinent and necessary for the design of the building and the requirements imposed by the centrifuge.

Centrifuge

Displacement of the large counterweight

At the moment Acutronic indicates that the proposed system would only permit displacement of the counterweight at a maximum speed of 17 mm/min and when the centrifuge is at full stop. A more efficient solution should be considered if possible.

Swinging basket for 350g

A new design is considered with:

- a platform supported by 6 pins,
- lateral supports with 3 "legs" each.

This solution was presented to S Steedman already on April 23. One considers here only elements not reported at that time.

* **Platform**

FEM calculations with ANSYS show that stresses in this design are likely to be acceptable with N A XTRA 70 steel which has an elastic limit of 690 N/mm² resistance in tension of around 800 N/mm².

These calculations were made however with the position of the axis of the pins kept fixed. This does not take into account the influence on the load distribution among the 3 pins due to the compliance of the lateral supports. The stiffness of the 3 "legs" can be chosen so as to minimise relative displacement of the 3 pins axes. This should not challenge the present solution but a general verification is to be done.

Some additional calculations are still to be done in order to finalise the design of the platform, considering:

- the stresses generated in the platform by the tightening of the bolts holding the pins,
- the stresses generated in the tubes housing the pins.

JFC invites Acutronic to produce drawings showing the principal stresses in the plane of the most highly stressed areas.

* **Pins**

FEM calculations (22 April) show that the design should be adequate. Calculations are a bit pessimistic since rotations are prevented at the boundaries.

* **Lateral supports**

The design includes now 3 legs; it should lead to an acceptable solution with:

- a maximum stress of 400 N/mm² (tension in the inner surface of the hinge housing),
- a high grade steel 30 NCDV 14 treated for an elastic limit of 1100 N/mm²,
- a mass of 1260 kg for each support.

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25-03-ROM-027 contd

General consideration about the design of bolts and screws

The various bolts should be selected in order to carry loads with a factor of safety of at least 2.7 as the other elements. They should be tightened to a minimum of 50% of the nominal torque in order to ensure a proper assembly.

Next meeting

The next meeting is scheduled on June 1st, at Acutronic offices in order to examine:

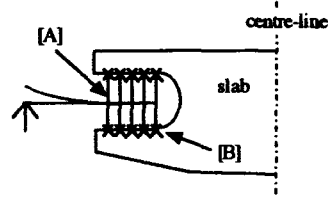
- the progress of the centrifuge calculations,
- the detailed design planning.

RECORD OF MEETING

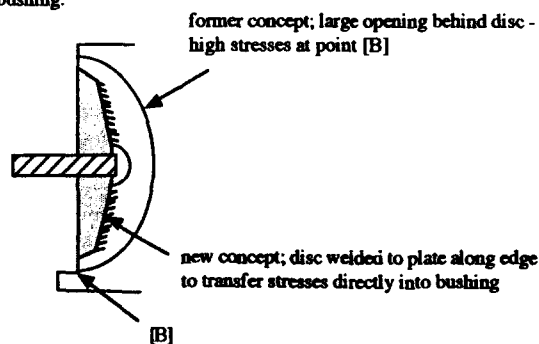
Project:	WES	Reference:	25-03-ROM-028
Present:	RSS, Mr Nicolas-Font, Mr Gawad, A Hoy (BEQE Ltd)	Date:	12 May 92
		Time:	11.00
		Prepared:	RSS
		Notes:	at Acutronic France, Les Clayes
Subject:	Platform analysis		

RSS visited Acutronic with Mr Alan Hoy (BEQE Ltd) to discuss the numerical analysis of the platform carried out by Acutronic to date. New analyses with improved boundary conditions around the pins had not yet been completed; the next stage would be to look at the preload from the pin assembly.

The details of the mesh (for the analysis of the slab) around the pins was discussed. It was explained that rod elements were used with radial spokes [A] connecting to the "bushing". The pin and bushing were considered to be a single unit, incapable of relative movement because the chosen taper of the pin (around 5°) was less than the friction angle of metal on metal (around 5.7°). When loaded it is considered that the pin cannot slide and therefore that modelling as a solid unit is acceptable. However the stiffness of the rod elements (such as [A]) are clearly the key to the rotational stiffness of the pin; this will be adjusted in further analyses to match the stiffness of the pins deduced from the pin analysis itself.



High stresses near [B] (which were a concern from the earlier plots) would be smoothed out by a proposed redesign of the back of the bushing.

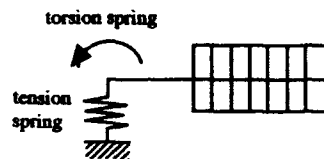


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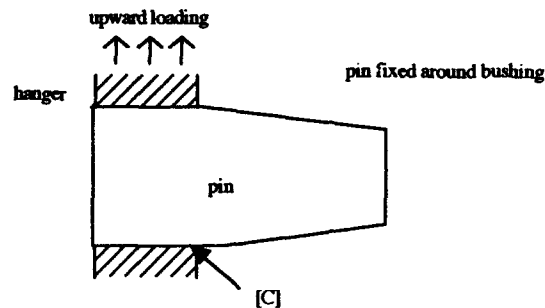
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Global stiffnesses

Pin/hanger stiffness will be applied to model of slab; a tension spring and a torsion spring would provide the appropriate restraint at the end of the rod element.



In the analysis of the pin/hanger joint the assumption of a fixed pin is an assumption of infinite rigidity in the platform. The hot spot identified under the pin at [C] will in practice be smeared out if some translation/rotation is applied to the pin. However, the assumption of infinite rigidity is considered to be a worst case for stresses in the pin itself.



Hanger

The three straps will give a minimum weight solution. Any alternative, such as a truss, would add considerably to the weight because of the need to transfer moment into the outer straps.

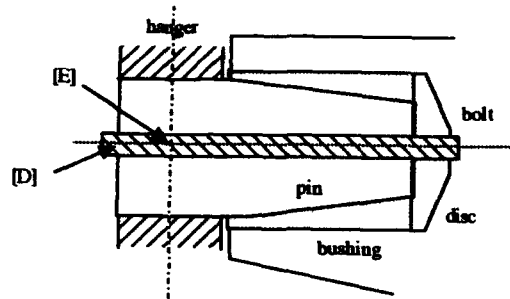
Dynamics

Earthquake loading on booms still needs to be defined. RSS will provide a rough indication of the shaken mass for Acutronic's initial dynamic calculations. Blast loading was also discussed; this is considered to be primarily an issue for container design.

Finite Element modelling

Block elements used to model the bushing will also be used to model the disc at the end of the pin. As far as possible triangular elements are to be avoided in areas of high stress. Approaches to modelling the hanger/pin/bushing assembly were discussed. A simple model using rods and shell elements (for the slab) could be carried out as a separate check but it was noted that rods and shell elements are not very compatible in the analysis.

However blocks will be used to model the pin and bush assembly and to reduce elements elsewhere (eg. towards the centre of the slab).



Fix at either [D] or [E], use stiff rod elements to the inside of the bolt-hole.

Von Mises stress representation being used by Acutronic is the SIGE (equivalent stress) command. This is based on:

$$\sigma^* = 1/\sqrt{2} \{(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2\}^{1/2}$$

This representation can be directly compared to the yield stress in tension. Future users of the centrifuge will be able to use the final FE model of the quarter slab to investigate other footprints.

Failure of the slab needs to be defined. One indication of overload would be elongation of the hangers - this could be simply measured. However Acutronic are not in a position to do such calculations.

RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-029
Present:	J-FC, Acutronic France	Date:	1 June 92
		Time:	10.00
		Prepared:	RSS
		Notes:	at Acutronic, Les Clayes
Subject:	Centrifuge progress		

A meeting was held at Les Clayes attended by Jean-François Corté to discuss centrifuge progress with design.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-030
Present:	RSS, ANS, RHL	Date:	2 June 92
		Time:	9.00
		Prepared:	RSS
		Notes:	at Vicksburg
Subject:	Centrifuge progress		

Copies of the Version C centrifuge specification had not yet been received by WES.

WES had not yet responded to Acutronic USA letter of April 13.

The forthcoming meetings at Bochum (opening of 661 Centrifuge) and at RPI (inauguration of 665 Centrifuge) were discussed. Presentations at these meetings by ANS would discuss the wide range of applications foreseen for the WES centrifuge. The value of the centrifuge contract was \$3m.

The Cold Regions report prepared by C Smith at Cambridge was discussed. It was noted that Smith was due to leave Cambridge in September.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-031
Present:	RSS, ANS, RHL, WM	Date:	2 June 92
		Time:	9.45
		Prepared:	RSS
		Notes:	at Vicksburg
Subject:	Centrifuge progress		

Options for Ryan Phillips extended visit to WES were discussed. RP would be seeking a visa through the lottery system.

Project Reliance (chaired by WM) will help to encourage integration of facilities, for example between the Navy and WES. The contrast between the largely civil works of the Coastal Lab and the Navy research was noted; however WM expected to encourage Navy research to use the centrifuge.

Equipment funding was likely to be centrally funded by the Station, with a tax on each of the Laboratories.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-032
Present:	RSS, ANS, RHL, K Davis, S Maynard, P Gilbert, L Hales,	Date:	2 June 92
		Time:	10.00
		Prepared:	RSS
		Notes:	at Vicksburg
Subject:	Equipment needs		

ANS described the current work being conducted under the Phase 2 ANS&A contract. A starting point for equipment would be cylindrical tubs for operation at upto 350g; as equipment was developed an increasing number of Labs would be brought on board.

- 1) Sand pouring, vacuum saturation in a circular tub would provide the capability for the first experiments in inflight site investigation and bearing capacity. The first data report would be on the punch bearing problem with tests being run by Ryan Phillips.
- 2) The second series of tests, in a blast liner, would need interaction with structures staff and would involve 1g tests on the tub and liner system. The need for staff experienced in the science of modelling on the centrifuge was discussed: engineers, in addition to technicians, would be needed to provide advice and guidance on issues such as grain size effects, saturation etc. It was noted that the collaboration with ANS&A was expected to continue for some years; ANS, RSS and particularly RP, who would be resident in Vicksburg for some time and may eventually become a staff member, would be available.
- 3) Temperature control would be achieved in thermal liner perhaps using the vortex tube (to provide either a hot or cold environment). Thermal control would require insulators on the walls and temperature control on the base and top. Collaboration by ANS with C.CORE was noted; C.CORE were expecting to take delivery of an Acutronic 680 for commissioning in June 1993. RHL/ANS/RSS were planning to visit CRREL later this summer.
- 4) The environmental liner would require to be electrically passive. Resistivity probes would be expected to be the first transducers to be used in an experiment such as monitoring the arrival of salt water from a capped dredge disposal. In future devices to detect PCBs would be needed, or optical probes might be developed to detect organics. X ray images were another potential source of information after an experiment from a dissected model. Geotech Lab used to have a capability in this field.
- 5) The earthquake capability required a careful consideration of structural boundary conditions; a shear stack for example could be used to provide deformable boundaries with appropriate shear stiffness to match the contained soil. An embankment model with liquefaction was envisaged as an early experiment.
- 6) The soils group required the capability of modelling clay. A consolidometer would be required, and a plane strain box for problems such as lock walls. Plane strain boxes were perhaps 5-10 times the cost of a circular tub but could provide the opportunity for long problems such as embankment construction, perhaps a levee with reinforced earth. Construction processes could be modelled with overburden pressure or using a heavy fluid in bags (this would be appropriate to the Information Lab).
- 7) Coastal capabilities and demonstration experiments still needed to be assessed; could involve explosions on a beach or earthquake effects on coastal facilities.
- 8) A flume design and stilling tank to provide a capability for Hydraulics Lab was still of concern; it would probably need a 1g model (at WES) to test the concept. Funding for such a model, perhaps a 1/4 scale plexiglass replica would need to be considered but would probably be of the order of \$5000.

Initial items would be budgeted for, but further items would not be priced because of the difficulty of pricing development items. Staff for the centrifuge center would be initially provided by the Geotech Lab. Other Labs with experiments to conduct would use their projects to pay for their work, after the first initial demonstration of capabilities. The center itself would not be a tax on any of the Labs as it would be provided "paid up".

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-033
Present:	RSS, ANS, RHL, GH, D Haulman, Ed Johnson*, Tom Tollison*, Bob Hawkins*	Date:	2 June 92
		Time:	1.10
		Prepared:	RSS
		Notes:	at Construction Services, WES
Subject:	Containment design		* with Johnson-McAdam

The meeting was arranged with Johnson-McAdam, the WES AE, to brief their engineers on the particular needs of the containment structure, for which a 35% design was being sought.

ANS described the background and basis of centrifuge modelling. The scope of work to develop a 35 % design was discussed. The purpose of the 35% design was to provide a good estimate of the cost of construction.

Detailed discussion of the containment structure and its services ensued. Uncertainties exist over:

- 1) critical dimensions;
- 2) the pressure wave on the interior of the chamber;
- 3) the necessity of access to the chamber from the roof and from the side;
- 4) the power supply and the adequacy of the present switch gear;
- 5) the detailed layout of power, services and lighting required in the chamber.

The meeting concluded with a visit to the site.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-034
Present:	RSS, ANS, RHL, GH	Date:	2 June 92
		Time:	4.30
		Prepared:	RSS
		Notes:	at WES
Subject:	Centrifuge progress		

The invoices received from Acutronic had been paid. The difficulty of monitoring cash-flow without a revised breakdown of activities was noted. Acutronic's first quarterly report had not yet arrived. However the end of the detailed design phase was considered to be a very significant milestone to ascertain whether or not the project was on target; this was still some way off.

A letter to Acutronic USA, copied to Acutronic France, would be needed to address the following:

- 1) The absence of the quarterly report;
- 2) The absence of the detailed work schedule linked to the family tree;
- 3) The absence of the Version C Product Description copies requested previously;
- 4) The information needed to address the AE's questions on the containment structure (at least part of which was expected to be in the Version C document).

Other issues raised in earlier meetings, such as the supply of specifications etc, should be addressed to Acutronic France by RSS directly.

Access to the centrifuge chamber was discussed. It was agreed that a single shaft would be used, with a staircase and a large landing at the floor level of the centrifuge chamber, where a fork lift could be parked during operations. A crane would be able to lower equipment to the landing where a mobile unit such as a fork lift or "engine hoist" could transport it into the centrifuge chamber itself.

The role of Ciel was discussed. WES had been expecting to issue purchase orders for equipment to Ciel for items such as, for example, a general purpose tub. Concern was expressed over the contractual obligations and liabilities this might impose on Ciel. The specific role of Ciel, mentioned in ANS&A's response to the BAA, was noted.

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RECORD OF MEETING

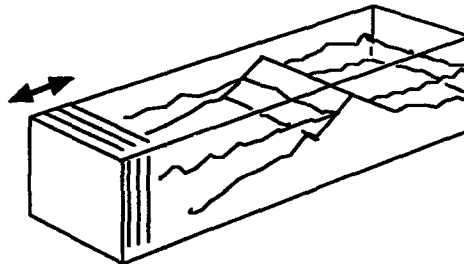
Project:	WES	Reference:	25-03-ROM-035
Present:	RSS, ANS, RHL, L Hales, G, Bradley	Date:	3 June 92
		Time:	8.30
		Prepared:	RSS
		Notes:	at WES

Subject: Coastal Lab capabilities

The wide range of projects related to the coastal and the offshore fields which had been undertaken on the centrifuge were discussed. The complexity of the field problems in the coastal area was noted. Jetty failure, for example, often required modelling of wave attack from different directions with current flow and large and complicated geometries of site. However the Coastal Lab had a long history of using physical models for a wide range of problems; scale models of dolos, for example, at 1:30 or even 1:50 had been made for experimental programs.

The emphasis at this stage on demonstrating capabilities with the centrifuge was highlighted. Clients would need to be educated as to the benefits of physical modelling; the directional wave generator, for example, operated by the Coastal Lab had proved difficult to sell. One route forward might be for a new hire to act as the centrifuge link between Coastal and the Centrifuge Center.

A demonstration experiment could address the impact of waves on a coastal dyke:



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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-036
Present:	RSS, ANS, RHL, GH	Date:	3 June 92
		Time:	10.50
		Prepared:	RSS
		Notes:	at WES
Subject:	Centrifuge progress		

Possible contractual arrangements for the ordering of equipment were discussed. ANS&A's response to the BAA had specifically nominated Acutronic France and Ciel to provide the centrifuge hardware and instrumentation and equipment. Equipment could therefore be ordered under the BAA without going to bid.

Two invoices from Acutronic USA had been received and paid. These were broken down by materials and labour but were not linked to the tasks identified on the family tree. The quarterly report now due from Acutronic should address progress by subassembly.

The AE concerned with the outline design of the containment structure had been in contact with D Haulman, submitting resumes for engineers with expertise in dynamics. Confirmation was sought that the maximum flow envisaged through the chamber was 2 cubic feet per second (25-03-ROM-001 refers).

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-037
Present:	RSS, ANS, RHL	Date:	13 July 92
		Time:	pm
		Prepared:	RSS
		Notes:	Albany, NY
Subject:	Centrifuge progress		

- 1) Acutronic's first quarterly report and D Version specification had been received by ANS&A. RSS and JFC were expecting to visit Acutronic on 16 July. RHL (but not GH) may visit Europe in early October. The commissioning tests were discussed. Further calculations by ANS&A may be necessary in fiscal 1993 to confirm performance in certain areas.
- 2) The progress of the 35% design study being carried out by WES's AE was discussed. The site had been surveyed and two soil borings completed. The present position of the centrifuge, out in the gulch, has a berm all around the structure.
- 3) ANS&A's draft final technical report for Phase 2 had been completed; ANS&A's recommendations for equipment purchase were briefly discussed.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-038
Present:	RSS, RHL, ANS, JP (Acutronic)	Date:	14 July 92
		Time:	1.30 pm
		Prepared:	RSS
		Notes:	RPI, NY
Subject:	Centrifuge progress		

- 1) The detailed work schedule (linked to the family tree) was being prepared and would be supplied to ANS&A.
- 2) The file of specifications for sub-assemblies can readily be supplied. RSS to pursue with JN-F.
- 3) The stresses on the foundation were not changed at present but the total weight of the machine may be slightly different as a result of the redesign of the swinging platform and hangers. The stresses under the motor set were now reduced as the motors will now be mounted on a steel skid plate (which will distribute the stresses into the foundations better).
- 4) The pressure wave in the chamber was discussed. Measurements made on a 665 model at Les Clayes had proved very useful in validating their calculation approach. At full speed the centrifuge will rotate at around 230 rpm (≈ 4 Hz). AFA were strongly of the view that the minimum structural natural frequency should be 3 times this value. The wall would probably be straightforward because of its high inertia and the exterior damping. The roof, however, would be likely to prove the weak point for the dynamic design.
- 5) The slip rings and rotary joints would be straightforward to modify if WES required. (Unless parts had already been ordered.) 3 Phase power rings would be fitted as standard. Equipment issues will interact with Acutronic's detailed design and ANS&A pointed out that the absence of a detailed work schedule could pose problems.
- 6) The water flow system will need to be above the boom. Mounting points on the drive box will need to be discussed; at present the design has 8 mounting points but it may be necessary to allow for 12.
- 7) The overall design should be complete by RHL's proposed visit in October although not all of the detailed drawings will be finished at that time.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-039
Present:	RSS, JFC, Mr Nicholas Font,	Date:	16 July 92
	Mr Gawad, Mr Sabard (Acutronic)	Time:	10.30 am
		Prepared:	RSS
		Notes:	Acutronic offices, Les Clayes
Subject:	Centrifuge progress		

1) Family tree and activities chart

The current version of the family tree J57009 Revision F was received and compared with the cost tracking plot (by activity) dated 15 June. Subassemblies on the family tree, eg. basket assembly 001 can be cross referenced with the cost tracking. A more detailed breakdown, eg. to platform, platform support and shrouds would be possible and would involve adding more lines.

A plot indicating the logical connections between activities and their durations and dates was requested and will be sent to ANS&A by Acutronic.

2) The 'Grey file' of calculations and specifications (a copy of that held by JFC) was received and inspected by RSS to be held in Cambridge. The file was later withdrawn for final amendments and would be sent on to Cambridge by mail.

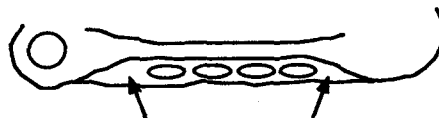
3) Review of progress

Platform

Detailed drawings of the platform and the platform bushing and pins were available for discussion. FE computations now show the inclusion of the pin in the slab and show greatly improved stress distributions below the pin and in the transfer of load into the pin itself. A model of the pin and the hanger alone (with fixed constraint around the pin) is considered conservative for the stressing of the pin itself and hence for the selection of material.

Platform support

Arrangements for the supporting shroud were discussed. The attachment detail as presently configured is likely to lead to high stresses in the mounting due to compatibility of strain between the main strap and the attachment detail. This will need to be redesigned.



modify and remove metal here to reduce extensional strain

The size and position of the fixing points needs to be defined. Similarly the electric and hydraulic channels have not yet been addressed. The need for termination panels on the supports was discussed. These need to be defined by ANS&A and communicated to Acutronic by October.

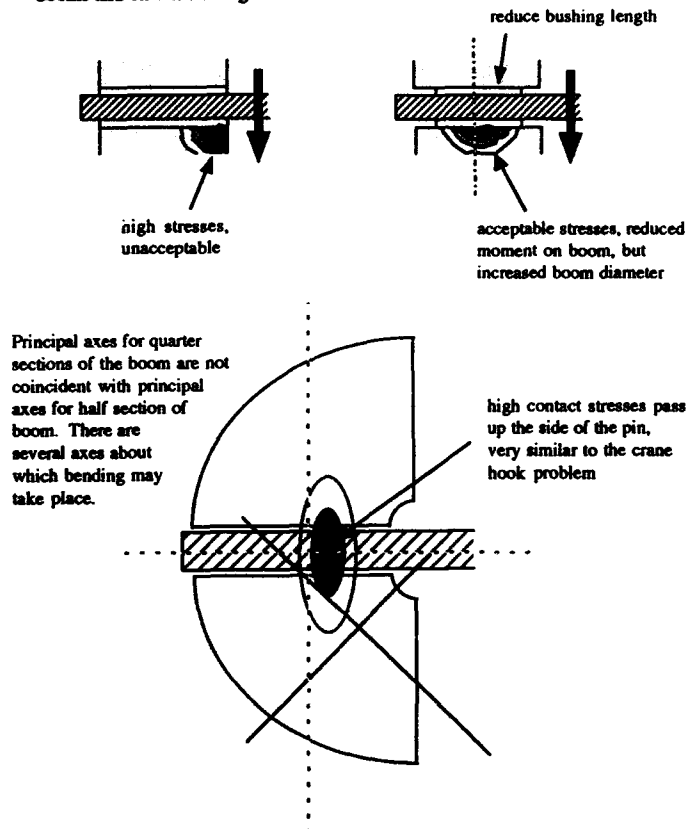
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Ref: 25-03-ROM-039 contd.

Hinge assembly

Analysis of the pin connection to the boom has shown very high stress concentrations in the boom itself. Some rearrangement of the bushing detail has moved (and reduced) these stress concentrations. However this has necessitated a significant increase in the diameter of the boom at the ends over the original design concept. This was discussed in detail. Altering the computation of the bushing contact area is awkward because it requires rebuilding the mesh. Several lengths of contact area were tried, the extreme being over the full area - this being the original solution which gave very high stresses at the lip. It was agreed that the primary problem is the contact stress. ANS&A stressed the importance of considering alternative solutions, FE computations or alternative designs, which could minimise any increase in boom diameter. The increased boom diameter will reduce visual access between the booms and make the running of lines along the booms and onto the swing more difficult.



Progress against the family tree was summarised as follows:

- 001 complete except shrouds (0012, 0013, 0018)
- 0020 complete except for pin problem discussed above
- 0024 complete end July
- 0021 drive box not designed
- 0030 base largely complete
- 0031 transmission to be done in September

Ref: 25-03-ROM-039 contd.

0032 bearings complete
0033 lubricating still to be done
0034 foundation complete
0035 imbalance complete
0036 slip rings to be completed end of July
0037,38 rotary joints to be done in September (needs recommendation from ANS&A)
004 power partly complete; motor, gear reducer ordered, position encoder to be ordered in September.

Next meeting agreed for 15 September 1992 at Les Clayes.

RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-040
Present:	RSS, RHL	Date:	3 August 92
		Time:	9.30 pm
		Prepared:	RSS
		Notes:	Telephone meeting

Subject: Equipment proposals

1) Questions on the Phase 2 Draft Final Report

The recommendations of ANS&A's Phase 2 Draft Final Report were considered in detail. It was agreed that a detailed specification of many items was difficult because of the unique nature of much of the equipment. This had led to the use of the phrase "performance to be confirmed".

2) Contract to supply equipment

Discussed Ciel/ANS&A/WES relationship. It was noted that Appendix A represents a first pass at equipment costs with a broad range of items and costs. The following was agreed:

Ciel to be asked to quote for the supply of Items 1, 2, 3 and 5. Some breakdown of costs would be necessary to identify where savings could be made to meet the available monies this coming year (eg one torospherical end instead of two etc). Shipping costs to be included. RSS would request this bid from Ciel on behalf of WES and would then write to WES enclosing Ciel's bid with ANS&A's recommendation.

RHL to discuss contractual arrangements with Betty Logue. ANS&A's initial plan had been that Ciel would be contracted directly by WES but it may be preferable for ANS&A to submit separate proposals for the supply of equipment under the BAA using subcontractors as necessary.

3) Ryan Phillips

WES expecting RP to work with them for a minimum of two years as an ANS&A employee, posted to Vicksburg. As an ANS&A employee it would be ANS who should write to RP to offer the posting. Funds for RP would be provided from WES through ANS&A under contract.

4) Building

The containment structure had been priced by the AE. WES considered the figure high and some rethinking had been taking place. A significant element of the cost, around \$200K, was in the heavy crane and pavement from the existing building to the centrifuge. Similarly the elevator would cost around \$100K. Current approach to provide a 'prep' room 40' x 40' next to the centrifuge chamber with heavy craneage and access to the large storage area behind the gulch, with a light crane running up to the existing building. This room would clearly be evacuated during operations but would be used for final model preparation and for fork lifts and heavy equipment etc. RHL to meet with AE on 4 August.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-041
Present:	RSS, GLewis	Date:	14 September 92
		Time:	1.30 pm
		Prepared:	RSS
		Notes:	RAF Burtonwood

Subject: Equipment proposals

1) Structure of proposals

The financial information that would be required in ANS&A's equipment proposals was discussed. The following breakdown was agreed:

Design manhours and cost
Overheads
Quotes from subcontractors, eg CIEL
Profit (scaled down according to proportion of subcontract)

The subcontractor quotation should include catalogue references where possible, but must include a statement of manhours and cost, overheads, hardware and profit margin.

2) Timing

Contracts could be completed within 30 days. Ideally the London office should pass the paperwork on to Burtonwood by the first week in October for a November start.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-042
Present:	RSS, RP, RHL	Date:	16 September 92
		Time:	8.45 am
		Prepared:	RSS
		Notes:	WES

Subject: Centrifuge progress

1) Equipment proposals

ANS&A's proposals for equipment were discussed. The total cost of the equipment to be supplied in FY93 was estimated at \$300K. Delivery would be in mid-September 1993 to a USAFB in England to permit shipping to Vicksburg to be completed by the end of that month. The estimated costs were similar to those quoted in ANS&A's draft Phase 2 Final Report but had increased slightly due to the involvement of ANS&A in design and specification (not originally envisaged).

2) Agenda

The Agenda for the present visit to WES was agreed.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-043
Present:	RSS, RP, RHL, Committee:	Date:	16 September 92
	Wayne Jones, Paul Gilbert	Time:	9.30 am
		Prepared:	RSS
		Notes:	WES

Subject: Centrifuge progress

1) Programme

RHL discussed the programme difficulties caused by the unexpectedly high cost of the containment structure. The full implications of this were not yet clear but it was still hoped that sufficient funds could be found in FY94 to complete on schedule.

2) Acutronic progress

RSS discussed Acutronic's progress during the detailed design phase. Difficulties had been experienced with the very high loads being transferred to the boom and this had still to be resolved but it was now expected that some 'flaring' of the end of the booms would be necessary to accommodate the transfer of forces within the specified limits on factor of safety. RSS was planning to visit Acutronic on 23 September to agree a strategy with them.

3) Containment structure

The 35% design was now complete and a copy of the report would be sent to Acutronic USA shortly. ANS&A received two copies of the report. The arrangement of the centrifuge and its associated prep room were discussed in detail. Practical aspects concerned with the transport of models from model preparation areas onto the arm and the implication of the location of the control room and the distance to the centrifuge were considered carefully. A general preference for an overhead crane on parallel rails instead of the single crane rail shown in the scheme was noted.

RHL noted that the position of the centrifuge in relation to the control room had been discussed informally with Acutronic France who did not envisage any significant difficulties.

It was agreed that a single entry door to the centrifuge chamber would be preferable to two doors as shown in the drawings. There would be three air conditioning systems: the chamber itself (although not in flight), the prep room and the control building. There was extensive discussion of the layout of the prep room; it was noted that a rectangular room may prove more practical than the configuration shown.

WES expected to take these comments to the AE; a final design for the containment structure would probably be released by the end of September.

4) Equipment development

RSS discussed the nature of the proposals for the initial items of equipment and instrumentation that were to be purchased during FY93. RP described in detail ANS&A's proposals for the data acquisition system. The aim of the conceptual system was to achieve on board signal conditioning and to use microprocessors at the centre of the arm for control and data acquisition. These would be controlled remotely through the optical slip rings with the video routed separately. It was suggested that Mike Ellis (IT Lab) might have a contribution to make in this area.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-044
Present:	RSS, RP, RHL, GH	Date:	16 September 92
		Time:	2 pm
		Prepared:	
		Notes:	WES
Subject:	Centrifuge progress		

1) Programme

Estimates of the cost of the containment structure based on the 35% design had proved higher than expected. Following a meeting on July 23 at WES it had become clear that there were insufficient funds to complete construction of the containment structure and to pay for Acutronic's effort during FY94. This would have the consequence that the project would be delayed by 12 months as construction of the containment structure would have to be completed in FY95.

It was still hoped that additional funds would be found to complete the programme on schedule in FY94, and this should not be ruled out for certain until January 93.

There was extensive discussion of the options available should this prove unavoidable. The sequence of construction of the containment structure could be phased to run over FY94 and FY95. (Construction Services had estimated that construction of the containment structure would take around 1 year.)

The implications of delay for Acutronic were considered carefully. It was noted that a sudden withdrawal of funding to allow the containment structure to be completed could be very difficult for Acutronic. A preferable alternative may be to store the completed centrifuge (in Europe or at WES) for up to one year whilst the containment was completed and then to request Acutronic to instal and commission the facility in FY95. This would inevitably incur additional costs.

The phasing of the construction costs was discussed. Economies could be achieved by postponing completion of the berms, prep room, pavements and covered walkway, overhead crane etc. This may achieve sufficient savings in FY94 to allow the initial construction to proceed. However a partial capability would be unlikely to be satisfactory.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-045
Present:	RSS, RP, RHL	Date:	16 September 92
		Time:	3.15 pm
		Prepared:	RSS
		Notes:	WES
Subject:	Centrifuge progress		

1) Use of minidrum centrifuge for training

The visit of RP to WES could be delayed by one year if the overall programme was also delayed. Part of the equipment RP had been planning to bring to WES to assist in training and equipment development was the minidrum (a prototype of which was under construction at Cambridge).

This could be shipped with the other equipment and be used with the trolley mounted data acquisition system. Other labs could use the drum to develop their capabilities and to generate data, interest and ultimately proposals in centrifuge modelling prior to the commissioning of the 684-1 centrifuge.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-046
Present:	RSS, RP, RHL, PH	Date:	16 September 92
		Time:	3.30 pm
		Prepared:	RSS
		Notes:	WES

Subject: Centrifuge progress

1) Programme delay

The importance of containing cost escalation was stressed in discussion of the consequences of a programme delay. It may be acceptable to build, install but not run the centrifuge if this solved the cash-flow problems. However it would be undesirable to have a reduced capability whilst further funding was awaited as this would have a negative impact on the reputation of WES.

2) Minidrum

The minidrum could be an attractive proposition for training and equipment development, but the same arguments applied as for the 684-1 about the use of the drum to actually claim a low level of capability.

3) Training and involvement of other Laboratories

In the event of a delay in the programme the extended period available for training could prove advantageous as it could be more individually based. However the costs that this would incur for the Laboratories would be unlikely to be met. In practice it should be expected that because of costs training will be limited to a period such as the six months originally envisaged prior to and during commissioning of the centrifuge when it becomes clear that the facility is actually taking shape.

4) External relations

It was noted that the US geotechnical community was taking an increasing interest in the activities of the WES centrifuge programme and that it was important to keep interested parties informed of progress. There are many centrifuge developments on US which may prove very useful to the WES centrifuge center.

5) Items for procurement in FY93

ANS&A's proposals for equipment purchases in FY93 were discussed.

6) Blast load simulators

Blast load simulators similar to that proposed by ANS&A for use on the centrifuge were constructed for WES in the 1960's and were still in use today. A number of references were available which could assist in the design of a chamber for use on the centrifuge. It was agreed that fabrication to a BS for pressure vessel design would be satisfactory.

The use of blow-off or pop-off valves to limit internal pressures was discussed. The importance of considering friction from the soil acting on the sides of the chamber and causing a line load around the perimeter at the base was noted. A lower torospherical end would not be necessary; normal practice was to bolt the chamber to a concrete floor.

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Ref: 25-03-ROM-046 contd.

The availability of a blast chamber would provide new opportunities for research in the field of stress wave propagation. There were many problems in the field which could exploit such work, particularly in the area of munitions store design. The purchase of such equipment at an early stage would encourage other laboratories to participate in the programme.

7) Development of other novel equipment

Model studies may be necessary as a part of the development of complex and novel items of equipment. Examples such as the hydraulics flume were considered.

RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-047
Present:	RSS, RP, RHL, JBalsara	Date:	17 September 92
		Time:	8.45 am
		Prepared:	RSS
		Notes:	Structures Lab, WES
Subject:	Blast modelling		

1) Blast chamber

The structures lab was visited to view the blast chambers used for 1g model testing. Instrumentation and data acquisition for blast models was discussed.

The nature of blast loading within a confined chamber was discussed; Structures Lab could provide assistance in the computation of peak dynamic and static pressures in the proposed centrifuge blast tub.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-048
Present:	RSS, RP, RHL, BLogue	Date:	17 September 92
		Time:	9.45 am
		Prepared:	RSS
		Notes:	Contracts Office, WES

Subject: Contractual issues

1) ADP

Discussions were held over the requirements for the procurement of FIP resources and whether these covered the development of instrumentation and equipment systems for the centrifuge.

Guidelines on the application of the Regulations governing the purchase of ADP equipment indicate that in the case of the centrifuge data acquisition systems the ADP equipment is incidental to the primary function of the proposal (that is to gather information on pressures, displacements, accelerations etc. within a soil model).

Secondly, the ADP equipment is embedded within the system that is to be supplied.

Thirdly, the ADP equipment is incidental to the BAA in terms as a proportion of the value of the project.

Reference was made to the Memorandum "FIRMR Applicability to Research and Development" authored by R Ellis.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-049
Present:	RSS, RP, RHL	Date:	17 September 92
		Time:	11.15 am
		Prepared:	RSS
		Notes:	WES
Subject:	Summary		

1) Equipment proposals

Interest in the blast tub was strong and ANS&A should continue to prepare a proposal on the lines recommended in the Phase 2 Final Report, incorporating the additional information received from the Structures Lab. A proposal for the fabrication of the blast tub could be made before the end of October. RHL would locate the references discussed during the earlier meeting with PH.

The drafts of ANS&A's equipment proposals were discussed and estimated costs presented.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-050
Present:	RSS, RHL	Date:	19 September 92
		Time:	6 pm
		Prepared:	RSS
		Notes:	Telephone meeting
Subject:	Centrifuge progress		

1) Programme

The necessary funds for the completion of the centrifuge containment structure have been identified and the commissioning of the centrifuge is on schedule for 1994.

2) Equipment proposals for FY93

Shipping costs will be borne separately by WES and will not need to be included as a part of ANS&A's budget.

3) Currency fluctuations

RSS to discuss the difficulties posed by fluctuating exchange rates with Burtonwood and with J Cornati.

4) Electrical Engineer

Approval has been given to identify an electrical engineer from Instrumentation Services Division who can assist with the specification and layout of data acquisition systems, particularly high speed dynamic data capture. The engineer will be available for telephone consultation and to research problems in the US, or to locate suppliers. It is anticipated that the engineer will have a long term involvement in the development of the centrifuge center.

5) Instrumentation and equipment

Approval has been given for the purchase of easily identifiable items of instrumentation and equipment to be purchased in the US using T&E funds rather than the PRIP funds earmarked for the equipment development. This will free up more of the limited PRIP monies to be used for the supply of unique equipment rather than standard off-the-shelf items. Obvious items might include pore pressure transducers, displacement transducers, cabling etc. All such items would need to be less than \$5000 each. If necessary items could then be shipped to the UK for integration with the rest of the kit.

6) Blast tub

The release of these funds may enable the purchase of the blast tub to proceed as originally envisaged, in addition to the penetrometer, circular tub and data acquisition system.

7) The proposed visit to CRREL on 5/6 October by ANS and RSS had not yet been confirmed.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-051
Present:	RSS, J-FC, AFA	Date:	23 September 92
		Time:	11 am
		Prepared:	RSS
		Notes:	Meeting at Les Clayes
Subject:	Centrifuge progress		

1) File of calculations

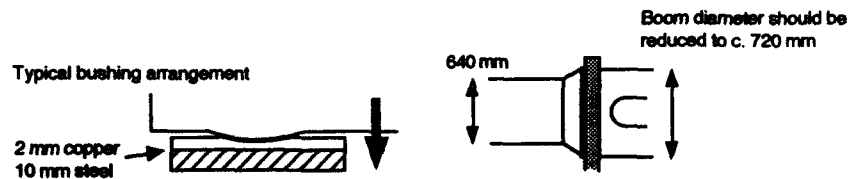
AFA sent a copy of the grey file of calculations as requested to ANS&A on 21 July. RSS to locate.

2) Containment structure

The 35% design carried out by the WES AE was discussed. Acutronic USA could expect to receive the part design shortly from WES with a request to bid.

3) Centrifuge arm

The use of a bushing with a spherical bearing to support the swinging platform was discussed in detail. It was agreed that this should be adopted for the design and that this would enable the increase in diameter of the boom near the ends to be minimised. AFA would complete calculations to the best of their ability on the spherical bearing and enquire of suppliers, eg. SKB, whether a more sophisticated calculation was available. ANS&A would request that independent analysis be carried out for this problem as the rigorous analysis is beyond the capability of AFA. (AFA's calculation would be based on mean stress.)



Booms have now been forged in the UK.

4) Swing

Swing arms will be stepped by machining from laminated steel. Attachment points have now changed as the shroud will be made from composite materials cast in a shell and glued to a lightweight frame, itself bolted to attachment points on the hangers.

5) Shroud

Shroud design will include attachment points for camera and lights. These should be as versatile as possible to be able to see on either side of the central strap for example. Options, such as an internal lightweight frame to support the cameras within the shroud were discussed.

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Reference: 25-03-ROM-051 contd.

6) Services to swing

There are six hydraulic lines to the basket. These could be fixed and should be located inside (between the booms) rather than on the trailing edge outside. A wooden model could be used to investigate options. The location of termination panels was still to be determined. ANS&A's proposals for the conceptual data acquisition system were discussed.

It was agreed that RP and J-FC would agree the arrangement of:

- a) the arrangement of fixing points on the swing;
- b) the camera positions and lighting;
- c) the number of optical rings and racking arrangement at the centre;
- d) the nature of the termination panels for electronics and hydraulics;
- e) the need for a second termination panel near the boom divider.

J-FC and RSS would present this information to AFA at their next meeting in late October.

7) Slip ring stack

The provision for racking and connector panels on the central stack was discussed.

8) Programme

Progress on the programme was discussed. A number of items are delayed somewhat over their estimated completion date (as at 30 July 92) but overall progress was satisfactory.

9) Safety Management Systems

The implications of the new building layout were discussed. External doors will need security shutdown with the exception of access to the stairwell (and hence the slip ring stack and motor chamber) which will be simply monitored open/shut from the control room.

10) Stressing and analysis of the base

A number of load cases had been considered, the most critical of which was clearly the maximum imbalance under loss of payload. This condition produced stresses just under yield in the spring steel mountings. Concern was raised over the fatigue life of these mountings in this condition. From maximum speed the mountings could be subject to several thousand cycles before the machine came to rest and tests would be needed to confirm that the mountings had adequate fatigue strength to accept this.

11) Forces on structure

Forces on the building structure will need to be recomputed using the final weights and loadings from the centrifuge.

12) Location of the building

The location of the control room with respect to the centrifuge will need to be checked carefully with regard to low level signals. AFA will consider this.

13) Future meetings

J-FC and RSS will visit Les Clayes on 26 October. A Final Design Review meeting will be held at Les Clayes on 18/19 November. Mr R H Ledbetter, Dr A N Schofield and Dr R Phillips will attend this meeting with RSS and J-FC.

RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-052
Present:	RSS, ANS, RHL, S Ketcham, E Link, D Goodings, CRREL staff	Date:	5 October 92
		Time:	9 am
		Prepared:	RSS
		Notes:	Meeting at CRREL, New Hampshire
Subject:	The Army centrifuge: cold regions applications		

Meeting at CRREL to discuss progress on the centrifuge and cold regions capability. Attended by ANS, RSS, RHL; organised by S Ketcham for CRREL staff. Presentations were made by ANS on mechanics of materials, RSS on ANS&A's response to the BAA and RHL on the centrifuge specification. After lunch further presentations by RSS and ANS addressed project experience in dynamics and in cold regions modelling.

Discussion focussed on:

Experiments on sea ice.

1) Buckling of an ice sheet was considered to be an ideal demonstration experiment. Modelling the correct thermal gradient can be calibrated out by conducting a second experiment and measuring the sag of an ice sheet under vertical load as a function of the characteristic length.

2) Crushing of ice. Model of Molipaq at 1g produces a buckling and not a crushing mode of failure. At high g such an experiment should produce the crushing mode observed in the field. Needs a uniform ice sheet, and, if anything at the boundary, adthickness. The Molipaq problem is significant because it involved a broad area of contact. Problems which have a narrow area of contact, such as lighthouses, can be modelled at 1g because the area of contact is much smaller and crushing at 1g can then be achieved.

3) Axisymmetric bearing capacity. The problem of a slowly moving load or point load on the ice surface not considered interesting as can be readily studied in the field. The question of fracture was discussed. No satisfactory analysis exists to model fracture.

4) Breakup of glaciers, impact from floating burgie bits etc need further consideration.

5) Rip rap and its interaction with ice also of interest.

Frost heave

The project proposed to the Army by Goodings leave was considered likely to be funded. The applicability of the centrifuge to model a wide range of different frost heave problems, such as floating boulders, pipelines etc was discussed. The importance of the thaw cycle was noted. Soil-structure interaction with frozen ground was also considered to be a problem of significant interest.

Navy and Coastguard research

Possible areas of common interest were discussed. The Navy have conducted experiments on the penetration of ice sheets but this data only extends to 2 feet thick sheet. Data from thicker ice sheets would be valuable.

Harbour construction is the responsibility of the Corps of Engineers, not the Navy. The Coastguard also have an interest in this area and have tested model ships at CRREL.

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Reference: 25-03-ROM-052 contd.

Proposed research on frost heave

The project proposed by Goodings to model frost heave on the centrifuge was discussed. The first phase would address the nature of frost heave in the free field, using two different soils, two different water tables and experiments at a variety of g levels. The experiments would be conducted in a circular tub with a constant temperature condition at the base and insulated walls.

During phase 2 a footing or pile foundation would be included in the soil and subject to several freeze thaw cycles.

The meeting concluded in the early evening.

RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-053
Present:	RSS, ANS, RHL, S Ketcham, T Tucker, Devinder Sodhi and CRREL staff	Date:	6 October 92
		Time:	8.45 am
		Prepared:	RSS
		Notes:	Ice Engineering Center, CRREL
Subject:	The Army centrifuge: cold regions applications		

The background to the application of cold regions modelling using centrifuges was discussed. Experience had already been gained in frozen ground experiments. The sea ice or iceberg area was considered more challenging because of concerns about the nature of fracture mechanisms.

However, monies would be available during FY94 to develop a sea ice container for use on the Army centrifuge. Collaboration would be sought with P Wadhams and the Scott Polar Research Institute in Cambridge to study the plane ice sheet problem and the crushing of ice against a Molipaq (or similar).

Buckling of ice sheets was regarded as a simple experiment. Ice structure interaction models could be used to analyse the results of the centrifuge model. There could be considerable interest in this area in a Joint Industry Project with oil companies (but not with Navy – although it was noted that there is an Ice Mechanics Advanced Research Program funded by the Office Naval Research in place which has funds to continue for some years).

The planned delivery of an Acutronic centrifuge to CCORE was discussed. Although informal visits take place there is no collaboration between CCORE and CRREL.

Research interests in the sea ice area might also include:

- 1) Ice growth (fundamental research);
- 2) Forces involved in pressure ridge formation; research needed for ice forecasting models used by Navy;
- 3) Ice-structure interaction; submarine fin breakthrough is of interest, although this has waned recently. Now oil industry interest is recovering again because of developments in offshore Siberia;
- 4) Remote sensing of sea ice by satellite; passive and active microwave images (ice concentration, type of ice, thickness of ice);
- 5) Weapons effects research (eg torpedoes) has been of great interest in the past but since the loss of Malcolm Mellor there has been little further work except for some studies of mine performance in snow;
- 6) Penetration of projectiles into ice;
- 7) Navy interest seems limited at present to acoustics and the interpretation of characteristic signals of different failure modes. A possible link with Professor Ffowcs-Williams at Cambridge was mentioned;
- 8) Properties of rubble ice and pulverised ice.

In the analysis of ice behaviour it was agreed that fracture mechanics (used to explain the low failure loads observed in the field) had probably been "pushed too hard" and in practice the extent of its application may be rather limited.

It was agreed that D Sodhi should sit on the coordinating committee to represent the ice work.

ANS&A's role was discussed. This included:

- a) Definition of set of initial experiments;
- b) Quality Assurance of Acutronic;
- c) Quality Assurance of building;
- d) Support from resident Associate in Vicksburg for some years;
- e) Delivery and commissioning of appurtenances.

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Reference: 25-03-ROM-053 contd.

As a part of the capabilities to be delivered the control of the test environment would have to include a capability for cooling and freezing in flight. It was agreed that a specification for a cold package would need to be agreed by Spring of 1993. S Ketcham would prepare an initial response in this area.

RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-054
Present:	RSS, ANS, RHL, S Ketcham, E Link,	Date:	6 October 92
		Time:	10.00 am
		Prepared:	RSS
		Notes:	CRREL
Subject:	Summary of CRREL involvement		

The involvement of the Ice Mechanics Group had now been achieved. It was clear that the opportunities to establish links with other groups at Cambridge (eg SPRI or in acoustics) were strong and ANS&A would look to set up a joint research project over the coming year.

There was a clear need to clarify the equipment during FY94 for cold regions work; the importance of achieving skilled technicians and mechanics was noted. It was expected that equipment would be duplicated at CRREL for model preparation purposes.

In the area of weapons effects there had been no successor to Mellor. Work on mines in snow had been undertaken by Johnston in Alaska field office. Weapons effects on structures not considered important: no missile silos in arctic and radar sites very soft anyway.

Contamination issues may become very high profile in Arctic. CRREL presently seeking to collaborate on providing consulting advice to oil companies to support work in Siberia.

It was confirmed that basic research initiatives funded by the Office of Naval Research were limited to the areas of optics, electromagnetics and mechanics.

CRREL would be shadowing work of Goodings on frost heave if her proposal was accepted. The priority would be to use the centrifuge initially as a research tool for basic issues.

Interaction with CCORE is important to CRREL. The opening of the CCORE centrifuge, scheduled for June 1993, was noted. However there are many areas where collaboration with WES is advanced: these include pavements, environmental, hydraulics (ice) and mobility, and weapons effects in snow.

The tight schedule within which ANS&A has to specify and supply test equipment was discussed. CRREL involvement would be needed in the definition of initial experiments and in the development of a programme for the commissioning of capabilities. Two items of equipment would need to be fully specified by May 1993 to model ice and frozen ground. There was also a need to identify necessary support facilities such as cold rooms and freezers. S Ketcham would coordinate this activity with D Sodhi.

The development of equipment may require prototype testing to prove the concept. CRREL will not support development of equipment using own FRIP funds but will gladly participate in WES programme.

The importance of involving the Districts (eg Alaska and Transatlantic) in finding new projects for the centrifuge was noted.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-055
Present:	RSS, J-FC, AFA	Date:	26 October 92
		Time:	11 am
		Prepared:	RSS
		Notes:	Meeting at Les Clayes
Subject:	Centrifuge progress		

Mechanical design

Acutronic have, as of now, used up almost all design hours. Predict overrun of around 2000 hours on project as a whole. Completion of redesign of pins and hinge to save weight will require authority from WES.

The weight of the centrifuge has increased by around 20% over the original design: now around 60 tonnes. This was principally due to the change in weight of the swinging platform - it was noted that this should probably have been realised earlier.

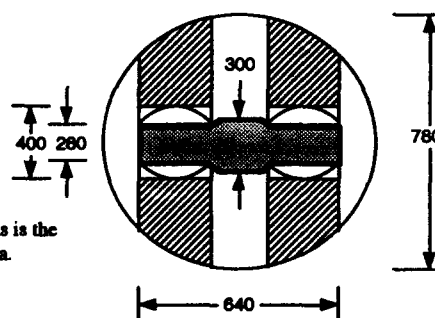
However, G&A expenses and overhead costs have reduced from the proposal. This will compensate to some extent. A report on the cost implications will be submitted to WES shortly.

The following design items are unfinished :

- a) pins and hinge arrangement;
- b) services and service channels on platform;
- c) attachment points on straps.

Pins/hinge design

Now revised further to use standard SKF bearings and to achieve 640 mm width of each boom along full length. Stress analysis shows acceptable stress levels in boom. Pin will need to be of increased diameter in centre to carry high bending stresses.



It was noted that this was not a design variation; this is the first acceptable solution that meets the design criteria.

Services

R Phillips letter to J-FC of 19 October was circulated as a basis for discussion. Variations between the service requirements as detailed in the letter and those in the proposal 'C' version were discussed.

	Requested configuration	Proposed Acutronic configuration
Signal	64	46
Video	8	2
Power	12	12

plus access to 80 Amp sliprings (80 Amp protection)

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Reference: 25-03-ROM-055 contd.

Optical	4	1
High pressure hydraulic	4	2
Low pressure hydraulic	6	4
Cold rings	2	0

Such a configuration on the electrical slip rings is possible. Further optical joints could be ordered. However there is insufficient space for a significant increase (eg to 12) in the number of rotary hydraulic joints. Space is only available in plan area for around 6 lines of 10 mm diameter (C.CORE cold lines are this size). At present 8 channels are planned but although the length of the unit could be slightly increased the building design would need to be modified if the joint became much larger. Alternative arrangements, such as having 4 high pressure and 2 low pressure (total 6 lines), were discussed. This would require some modification of the existing design. It was noted that the joint had already been ordered, however, around 1 month previously. J-FC would check with R Phillips and contact Acutronic (JN-F).

The C.CORE rotary joint is the same unit as proposed for WES with the exception that for C.CORE two of the lines are cold. These have special seals and there is provision to maintain circulation in the other lines when in use, but otherwise there is no significant difference in the design. JN-F will enquire as to whether there would be any difficulties in changing the specification to include cold seals on two of the low pressure lines (against a future change in policy at WES in cold models). In all previous discussions with WES, however, it was noted that ANS&A had not advocated the inclusion of cold rings.

Further options for providing high pressure oil to a package could include repressurisation on arm eg. from the in-flight balancing circuit. This is delivered at around 60-70 bar and could be used to provide pressures as high as 200 bar through repressurisation.

Agenda for visit by RHL to Les Clayes

The Final Design Review meeting will be held at Les Clayes on Wednesday and Thursday 18, 19 November. Mr R H Ledbetter will travel from WES for the meeting. Acutronic will provide a complete set of drawings and a copy of the grey book of documentation. The design process will be presented element by element and decisions on the choice of materials and the impact on cost, weight etc will be discussed.

The principle areas for discussion relating to mechanical design will be on resonant frequencies and the swinging platform and pin/hinge arrangement.

Agenda

Arrive c. 10.30

Visit building

See C.CORE SMS, Power Amp, Logic and Relay

See LNEC 661 centrifuge with automatic balancing

See design office

Presentation of Mechanical Design

Centrifuge Building

The distance from the centrifuge to the control room was discussed. This has been estimated to be 27m from drawings. The maximum physical length of the cables is approximately 50m and it is anticipated that the cable runs will be close to this limit. If the actual cable runs are more than 50m, then amplifiers will be needed, together with a redesign of the interface.

RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-056
Present:	RSS, ANS, RHL, RP	Date:	17 November 92
		Time:	am
		Prepared:	RSS
		Notes:	Cambridge
Subject:	Agenda for Final Design Review meeting		

The Agenda for the forthcoming Final Design Review meeting was considered in detail. It was agreed that the mechanical and electrical design should be considered in the following order.

Platform slab and pin connection;
Pins/hinge detail;
Boom and boom dividers;
Counterweights;
Drive box;
Suspension system and inflight balancing;
Drive system;
Slip rings, rotary joints, services;
Attachment points, cable runs, termination panels;
Issues concerned with the design of the containment structure;
Safety management systems and Acutronic control systems;
Control building and control room.

Training needs and test development prior to arrival of centrifuge was discussed. The minidrum could provide a useful vehicle for teaching activities in cold regions, pollution and earthquakes.

The nature of ANS&A's support during FY94 and beyond should be defined as soon as possible, as RP's position at WES depends on availability of funding.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-057
Present:	RSS, ANS, RHL, RP, Gopal Madabhushi, Keith Wilkinson	Date:	17 November 92
		Time:	pm
		Prepared:	RSS
		Notes:	Cambridge
Subject:	Appurtenances		

Blast Tub

Need to define specification; a blast tub with lid could easily exceed top weight capacity at 350g. The dynamic impulse would need to be calculated but it may be that the blast tub was restricted in its g operations to a lower level to prevent overstressing of the platform and 350g.

Agreed that an initial specification/performance curve would be prepared by ANS&A for CIEL to consider. CIEL would respond with concept and outline cost, milestones etc. ANS&A would then iterate with K Davis and J Balsara of WES before seeking detailed design drawings from CIEL. ANS&A would then agree milestones with CIEL to provide appropriate mechanisms for cost tracking and performance monitoring.

Data Acquisition System

ANS&A will prepare scheme (RP) for consultation with H Greer of WES.

Circular Tub and In-flight penetrometer

ANS&A to prepare specification.

Future appurtenances

Further equipment is likely to be required during next year (FY94). Some aspects of earthquake excitation could be explored relatively inexpensively on the minidrum. The usefulness of the minidrum for training was discussed.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-058
Present:	RSS, J-FC, RHL, ANS, RP, H Voss, J Perdriat, JN-F, AFA	Date:	18, 19 November 92
		Time:	11 am
		Prepared:	RSS
		Notes:	Meeting at Les Clayes-sous-Bois
Subject:	Final Design Review Meeting		

Attendance

R H Ledbetter (WES),	J Perdriat (AFA),
R S Steedman (ANS&A),	H Voss (AUS),
A N Schofield (ANS&A),	J Nicholas-Font (AFA),
R Phillips (ANS&A),	Staff of AFA.
J-F Corté (ANS&A),	

The meeting was chaired by RSS. ANS&A's Agenda as previously circulated (copy attached) was adopted.

Introduction by AFA/AUS

HV and JP introduced the staff of AFA. HV proposed three goals for the meeting :

1. To agree that the design does meet the performance criteria and that there have been no changes to the performance criteria that AFA are trying to meet;
2. That the design has been reviewed by ANS&A and meets QA and safety standards;
3. To discuss recommendations for changes and additions.

AUS and AFA were preparing an updated schedule, cost to date and cost to completion, which would be ready in two weeks time [1].

ACTION 1: HV

A set of up-to-date drawings had been prepared, together with the family tree. JP would supply a document explaining the use of the family tree [2].

ACTION 2: JP

The basic design was complete; JP commented that certain requests had been made during the design which would need to be considered at this meeting and approved before they could be implemented.

Design Review

Large Platform

The designers had needed to consider deflections and stresses to size and evaluate weight. The tubular construction had proved too heavy and a honeycomb structure was chosen based on an udl over the entire platform. The weight had ended up very similar to the small platform (around 2 tonnes for the slab itself).

Small Platform

Block elements had been adopted for the pins, which were embedded into the platform slab model. Three load cases had been carried out: udl over full area, circular footprint and internal pressure. A rectangular footprint had not been considered.

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Reference: 25-03-ROM-058 contd.

The ANSYS calculation could be used to create solutions by superposition, although this would obviously need many runs of the calculation and would perhaps require the WES computers if the quarter slab model was to be extended to a full slab. The ANSYS model could form the basis of the deliverable in this area; this would be a reduction in scope from the contract (which requests a method by which safe loads on the platform can be defined by the user).

The diskettes with the ANSYS model will be supplied [3] as soon as possible (1 week).

ACTION 3: JN-F

Definition of dynamic loads on the platform was discussed. This may need to wait until the machine has been completed and dynamic tests have been carried out in flight. It was agreed that ANS&A will proceed on the basis of the design drawings of the platform, to be supplied by AFA [4], and will provide their expectations of dynamic loading to Acutronic for consideration and comment [5]. The definition of dynamic loading would then be advanced by interaction with Acutronic.

ACTION 4: JN-F

ACTION 5: RSS

High strength steels have been used for the WES platform (as for Takenaka). The ANSYS calculations indicate that at the fatigue stress levels considered, such material would withstand around 1 million cycles to failure. The Tison steel was quoted as having a 13% extension to failure. It was noted that this seemed high; the specification will be sent to ANS&A [6].

ACTION 6: JP

Welding details on the bottom plates will be visible but concern was expressed by ANS&A over changes in cross-sectional thickness of plates on underside. The change in thickness from 20 to 15 mm could be critical in creating local stress concentrations. Options for instrumentation were considered: the SMS includes 3 or 4 strain gauges on the platform - these have not yet been defined. It was noted that full penetration welds will also be deeper than the plates they are joining and this will help to smooth stress flows. The Institute de Soudure (welding institute) will produce an analysis by the start of fabrication. The preanalysis report (in French) will be sent to ANS&A as soon as possible [7].

ACTION 7: JP

Inspection of welds was discussed. Holes in the panels on the underside are sealed at present to avoid chrome plating getting inside. Holes could be machined out later if necessary. Institute de Soudure will be asked to comment on ease of future inspection of internal welds [8].

ACTION 8: JP

Fixing points on the top of the slab were discussed. Threaded holes would be significantly more difficult to drill once chrome plating is complete. Surface of slab could be marked to show position of ribs. Could use a template which was laid over the top of the platform. An aluminium plate could be used in place of a rubber mat to reduce local contact stresses.

The plastic collapse mechanism and nature of ultimate failure of the slab have not been defined by Acutronic.

Pins, hangers

Pins have been designed using both the slab model (for stresses in the interior) and a hanger support model for the concentration of stresses in the pin and the selection of material. Pins are attached using a central bolt with six others on the periphery; this provides a redundant system.

The load on a single strap will increase if loads are concentrated near one or other pin. It was considered that an eccentric load at the top or bottom would probably be the worst case - a central load would be less severe. The hangers will be forged and laminated, then milled into shape. Each weighs around 1400 kg.

Attachment points shown on drawings are for the attachment of the composite shroud and frame. The shroud will be made by Courtauld and is within budget and lightweight.

Reference: 25-03-ROM-058 contd.

Pin/hinge detail

The nature of the calculation method was discussed. An increase in diameter to 780 mm apparently gave stress concentrations within given limits but in fact calculation method was inadequate;

Solutions were therefore considered which could accept permanent strain, eg. a bushing. Redesign would incur additional costs and cause an overrun; ANS&A recommended that any overrun in cost should be explained to WES.

Further implications of adopting a bearing solution, for example on the boom divider, were discussed.

Booms and Boom Dividers

The booms have been forged in the UK and appropriate testing, including chemical analysis, ultrasonics have been or are being carried out. The machine could carry additional load in two ways, either by adding fixed counterweights or by an extension of the boom. Acutronic will provide a description of these options with their cost implications [9].

ACTION 9: HV

The present design of the boom divider does not include holes for services. Acutronic are contracted to provide service channels as far as the end of the boom but services (wiring, hydraulic passages etc.) stop at the slip ring stack (except for the TV and instrumentation services on the platform, strain gauges etc.). The outer boom divider has not been designed at all (although some analysis has been done). Further input is needed to agree the nature of the channels to be provided [10].

ACTION 10: RP

Access between the booms will be provided by a grid/grillage mounted at the underside of the booms. Channels for services will be provided on either side of the walkway. Drawings of the Takenaka system were discussed as a basis for the WES model. The grid will be mounted on stilts where it passes over and around the drive box (these stilts form a matrix of strong points).

The nature of the high fluid flow system needs to be considered carefully as an integral part of the centrifuge design. Preferences were expressed to have such a system underslung if at all possible. ANS&A will explore ideas for the system [11].

ACTION 11: RP

Counterweights

The mass of the counterweights can only be finalised once final decisions have been taken at the platform end. Detailed drawings will be produced once agreement has been reached on the pin/hinge detail.

In-flight balancing uses three phase power - currently the only use on-arm of three phase. No guarantee can be given on the g level upto which the motor will operate.

Drive Box

Larger bearings have been selected than necessary for stressing reasons because of the high resonant frequency of the system. SKF have reanalysed the bearings, which now have a hollow shaft leading down to the hydraulic rotary joint. The drive box design is now completely finished; it will be fabricated from nodular cast iron.

Support for structures at the centre can be provided using the stilts mounted on the drive box. The structure must be symmetrical. It is possible that some tappings could be made into the lower cylindrical casing surrounding the slip ring stack.

Reference: 25-03-ROM-058 contd.

Anchoring system

The lowest natural frequency of the machine is predicted to be 6.5 Hz. The mounting springs have been sized to achieve a safety coefficient of 1 following a total loss of the payload (catastrophic imbalance). Strain gauges used to measure imbalance were then sized to achieve sufficient sensitivity. The maximum imbalance is quoted as 200000 N (at any g level). At 350 g this corresponds to 57 kg. Sensitivity of strain gauges is sufficient to measure 10 kg at 10g (ie. 1000 N).

The springs would need a very high quality surface finish and precautions to minimise internal defects. In the event of catastrophic imbalance it was noted that they will be subject to many hundreds of cycles to their limiting stress state. However systems have been designed to prevent lift-off (two bolts on each leg are specifically for this purpose) and this was agreed to be satisfactory.

The importance of locating pads accurately on the concrete foundation was stressed by AFA. A proper tool would be required for this.

Services and attachment points

ANS&A's letter, sent by RP to J-FC and copied to Acutronic at the last meeting, provided a good indication of ANS&A's intentions. Difficulties with passing the services from the boom divider around the hinges and onto the platform were discussed at length.

It was agreed that ANS&A would finalise a letter [12] recommending the nature of services and service channels to be provided at the slip rings, along the booms and onto the platform, which would be submitted to Acutronic for their consideration following approval by WES. (See also discussion under Slip rings, below.)

ACTION 12: RP

Acutronic will review ANS&A's letter to WES on recommendations for the provision of services onto the platform and will prepare a cost proposal for WES to provide both the support systems and the necessary piping and wiring [13].

ACTION 13: HV

The meeting was adjourned at this point and reconvened the following day.

Presentation of Design Methodology

Before resuming the design review, the presentation of design calculations was discussed. It was noted that it was not Acutronic's practice to update manual computations documented in the Design Book even where significant design changes had taken place on the basis of FE computations. ANS&A stressed the importance of explaining the full logic of the design process in the documentation. It was agreed that Acutronic would provide a commentary, even if only brief, on the FE analysis and design presented in the documentation [14], such that a future user could follow the logic of the design process.

ACTION 14: JN-F

Design Review (contd.)

Drive system

Calculations for the power requirements for large centrifuges developed by Acutronic are generally accurate to 5-7% from experience. Below 10 g no guarantee can be provided on the rate of swing up. However it was stressed that tangential accelerations at start up must be small and estimates of the accelerations at low g were then discussed.

It was noted that tangential accelerations should be limited to around 1/10th of the acceleration normal to the platform. This was not considered to be a difficulty but would be checked [15]. ACTION 15: JN-F

Reference: 25-03-ROM-058 contd.

On slowing down power will be returned to the mains for a brief period. The implications for WES were discussed; solutions can be adopted (eg. using resistors to dissipate energy) if this is not possible. It was noted that WES have their own substation. RHL would investigate this further with WES [16].

ACTION 16: RHL

The instruction manual for installation includes a questionnaire on power supply; this needs to be rechecked [17]. A sample installation manual for the 685 centrifuge was discussed.

ACTION 17: RHL

Interference with signals from the arm was discussed; it was noted that band limiting is necessary to achieve good signals and that the physical separation of the slip rings from the motor set is advantageous.

Installation is considered to be straightforward; the skid will be delivered in two pieces.

Vibration from the drive system is regarded as "absolutely nothing"; the design of the foundation is based on the maximum imbalance and not on imbalance in flight.

Control Systems and SMS

There is extensive commonality between WES and Nikenseki (85-90%); differences in the SMS arise where accelerometers are used at WES for vibration measurement in a more extended manner. There are other differences in instrumentation of the motorised counterweights.

Future development could allow user-defined shutdown scenarios. A small industrial pc and data acquisition card are used on board for storing and monitoring different parameters.

It was agreed that it would be valuable for power electrical experts at WES to review Acutronic's system design. Concern was expressed over the possibility that power outages could cause damage (as these occur quite frequently in the area). It was noted that the only possible damage that could be caused would be if the outage happened during braking of the centrifuge and was also coincident with a thyristor firing; in this event fuses could be blown. Overvoltage and undervoltage protection is provided against in the supply.

At present the computers used in the SMS do not have uninterruptible power supplies (UPS) - although a flash memory with a battery is used in the on-board computer. Acutronic will review with their software designers what information may be lost [18].

ACTION 18: J-NF

Concern was expressed over the frequency and severity of thunderstorms in Mississippi. It was agreed that thunderstorm protection should be discussed with the suppliers (Reliance) [19].

ACTION 19: J-NF

Slip rings

On the slip ring stack a single passage optical unit has been ordered. The electrical slip ring stack has not been ordered but AFA have one in stock (identical to Kajima) which they were expecting to use.

Further consideration is needed in this area. WES and ANS&A will be specifying their requirements in the area of the slip ring stack in the letter currently being prepared by RSS and RP for WES [20]; Acutronic will then respond on practicality and cost implications of ANS&A's proposals for the slip ring stack [21].

ACTION 20: RP

ACTION 21: JN-F

The hydraulic rotary joint has been ordered. An option of exchanging two of the low pressure seals for cold seals was discussed. It was noted that the current design would not accept salt water or

Reference: 25-03-ROM-058 contd.

acidic fluids. ANS&A will define requirements for the hydraulic passages and summarise in a letter to WES [22]. A further option would be to consider purchasing a second rotary joint which could provide alternative seal arrangements.

ACTION 22: RP

This completed the review of the mechanical and electrical design. The meeting then considered the implications for other aspects of the project.

Containment Structure and Control Building

The centrifuge location had now been fixed after many iterations. The control room location was noted to be quite distant from the containment structure - the cable runs will need careful consideration. The high stiffness and mass of the structure was needed to control the natural frequency - although this conflicts with the ideal criteria of breakthrough in the event of loss of a package. It was noted that heat dissipation through the wall will be highly affected by the level of insulation. Heat dissipation has not been considered in the design of the centrifuge.

The space above the centrifuge chamber could be used to store equipment for buffering analogue signals from the machine. It was also noted that a repeat station would be needed in the model preparation room adjacent to the centrifuge chamber. Views were expressed that in the long term the control room would be likely to be moved to a more convenient location.

It was recommended that the roof structure should be capable of supporting the lifting of the centrifuge.

Ventilation ducts in the floor should be kept separate along their full pathway to ensure that the total outlet area was similar to the total input area.

It was also noted that the door design was shown incorrectly on present drawings; the Acutronic door (an offer from AFA to AUS) would be flush with the chamber wall.

Concern was expressed over the predominant wind direction and the orientation of the air inlets and outlets; this would need to be checked [23].

ACTION 23: RHL

The provision of doorways, particularly linking areas of the building subject to a large air pressure difference, was questioned. It was agreed that this should be reviewed together with consideration of access to, and use of, the space above the centrifuge chamber [24].

ACTION 24: RHL

Acutronic Programme

Acutronic noted that the design was ready for the next phases, provided changes were not introduced. Agreement would be needed from WES to introduce any changes. Issues which have been raised which would have an impact on cost and programme include:

- 1) The bearing and hinge detail (cost and programme);
- 2) The slip ring stack (cost, probably not programme);
- 3) Procurement regulations - availability of funding;
- 4) The building design - consequences of a delay;

It was noted that if the present design was accepted, then the centrifuge could be completed earlier than scheduled (if the funding was available). Indeed the programme had already been accelerated (in terms of money expended). The WES centrifuge is presently the last on line - and therefore could be accelerated if required.

Reference: 25-03-ROM-058 contd.

Commissioning

The subject of commissioning was discussed in case any new issues had arisen from the design phase, although Acutronic are not contracted to provide a commissioning plan until later in the programme. It was noted that AFA have an ATP (Acceptance Test Programme) which could be provided if required.

Other issues which might have a bearing on the commissioning include the commissioning of appurtenances such as the blast chamber (which would be tested at 1g first).

The platform slab could be tested statically, but this was done for LCPC and calculations were validated at that time.

Concluding Discussion

RHL reported on the WES perspective.

It was noted that WES were pleased and impressed with the work thus far. Their decision, taken in consultation with ANS&A, was that the present design should be accepted. A cost estimate would not be required for the development of the hinge to use bearings.

However, estimates were expected from Acutronic for:

- | | | |
|----|--|---------------|
| 1) | The extension of the boom or use of additional counterweights to maximise the available potential of the centrifuge; this estimate should include comment on the possibilities that such a modification would provide; | SEE ACTION 9 |
| 2) | The provision of supporting structures and services onto the platform; | SEE ACTION 13 |
| 3) | An alternate (upgraded) slip ring stack based on ANS&A's requirements. | SEE ACTION 21 |

RSS then summarised other issues of concern to ANS&A.

ANS&A's copy of the Acutronic Design Book will be brought up to date and mailed back to Cambridge as soon as possible [24].

ACTION 24: JN-F

Drawing packages will be mailed to the appropriate individuals [25].

ACTION 25: JN-F

Section C-1 of the deliverables to the contract was then reviewed.

Under item a) concerning the definition of loads on the slab, it was agreed that the deliverable from Acutronic will be their ANSYS model package and a friendly interface for use by users on a pc system.

Under item b) in the first instance ANS&A will provide their dynamic loading concept to Acutronic for consideration and comment. As noted during the meeting a final definition of a dynamic loading envelope will not be completed until dynamic testing of the machine insitu is complete.

SEE ACTION 5

Meetings notes will be prepared and circulated by RSS [26].

ACTION 26: RSS

RSS expressed his appreciation for the arrangements made by Acutronic for the meeting; considerable business had been accomplished and an important milestone had now been passed. The meeting was closed at 3.30 pm.

WES CENTRIFUGE (CONTRACT NO. DACA39-92-C-0016)**FINAL DESIGN REVIEW MEETING**

18/19 November 1992

Acutronic France SA, Les Clayes sous Bois

AGENDA

Attendees:	Mr Richard Ledbetter	WES	Mr Jacques Perdriat	AFA
	Dr Andrew N Schofield	ANS&A	Mr Juan Nicholas-Font	AFA
	Dr R Scott Steedman*	ANS&A	Mr Jean-Pierre Aliphart	AFA
	Dr Ryan Phillips	ANS&A	Mr Jean-François Ona	AFA
	Mr Jean-François Corté	ANS&A	Mr Mamdouh A Gawad	AFA
	Mr Henry M Voss	AUS	Mr Patrice Sabard	AFA

* = Chairman

18/11/92

- | | | |
|------|---|--------------|
| 1.0 | Welcome, introductions | 10.30 |
| | Tour of facilities, including C-CORE and LNEC equipment | |
| 2.0 | Status of Documentation | 11.00 |
| 2.1 | Mechanical and electrical drawings | |
| 2.2 | Design documentation (grey book) | |
| 3.0 | Design Review | 11.15 |
| 3.1 | Small swinging platform, pins and hangers | 11.15 |
| | | 12.30 lunch |
| 3.2 | Pin/hinge detail | 14.00 |
| 3.3 | Boom and boom dividers | 15.00 |
| | | 15.30 coffee |
| 3.4 | Counterweights | 15.45 |
| 3.5 | Drive box | 16.00 |
| 3.6 | Pivot (bearings) | 16.30 |
| 3.6 | Anchoring system (inflight balancing) | 17.00 |
| | | 19/11/92 |
| 3.7 | Drive system | 08.30 |
| 3.8 | Acutronic control systems and SMS, control room | 09.00 |
| 3.9 | Slip rings, rotary joints, power and DAC services | 10.00 |
| | | 10.45 coffee |
| 3.10 | Attachment points, cable runs, termination panels | 12.00 |
| 4.0 | Containment structure and control building | 12.30 |
| | | 12.30 lunch |
| 5.0 | Programme | 13.00 |
| 6.0 | Commissioning | 13.30 |
| 7.0 | Any Other Business and closing discussion | 14.00 |
| 8.0 | Depart (for 17.30 flight) | 15.00 |

RSS/RHL

17 November 1992