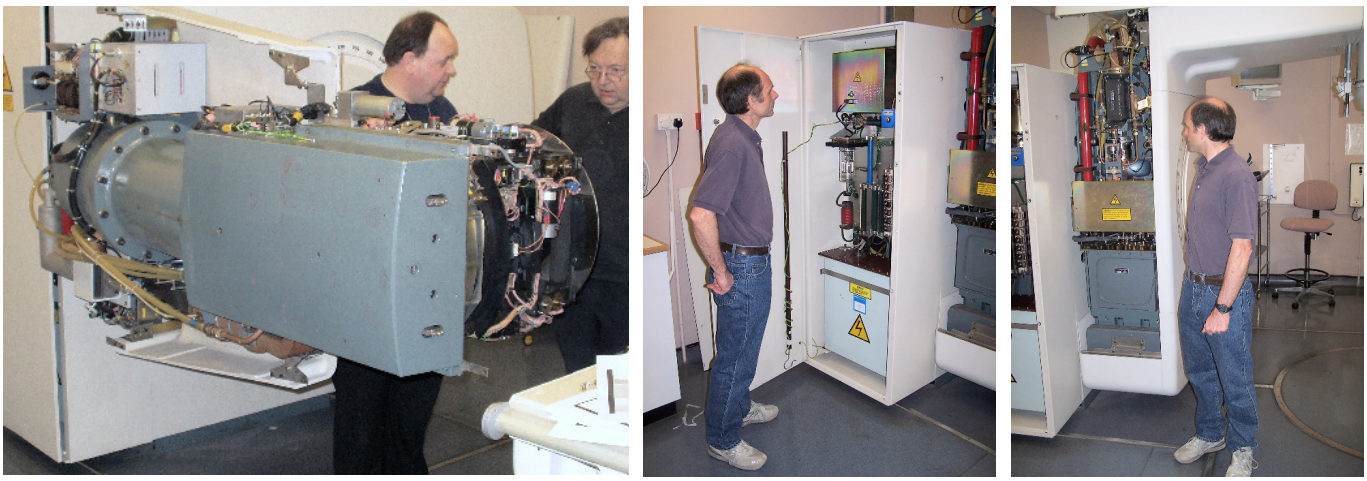
Development of the Gray Institute single pulse electron linear accelerator Part 1

The Radiation Oncology and Biology Initiative in Oxford benefits greatly from this versatile radiation source. Versatility of course comes at a price and since budgets are always tight, a decision was made (nobody can quite remember how or why) to re-utilise, modify and improve an existing radiotherapy machine, a 6 MeV linear accelerator (Philips/Elekta SL75-5), which had become available in Mount Vernon Hospital. When discussions started, the 'plan' had been that the machine would be out of service in April 2007, at which point it could be dismantled…slowly, carefully. Well, nothing quite goes to plan and it turned out that the accelerator was still treating patients up to the end of October 2007. So the project was behind schedule.

This diary was started to show the various stages of the process of removal and modification. The project involved numerous people: from GCI's mechanical workshop John Prentice and initially John Draper, along with Darren Groombridge from the Physics group, Robert Newman and Iain Tullis from the GCI technology Group, Charles Parkins (Buildings Manager) and many others, who were 'roped in to do something' when they made the mistake to wander into the area where the linac was being re-assembled. None of this would have been possible without professional help from accelerator movers (IRS Ltd[1]) and, in particular, an excellent metal cutter and welder, Robert Deveraux[2].

The way it was, in Mount Vernon Hospital Radiotherapy Department, during August 2007.



John Rodgers, one of the physicists responsible for the accelerator, and I, putting together a 'plan': how to do it and how to make it look as neat as it was. Rob Newman (right) pondering on the magnitude of the task ahead of us…..well, him really….

[1] IRS Ltd, Rookery House, Wexcombe, Marlborough, Wilts SN8 3SQ, Tel: 01264731309, Fax:01264731222 Mob: 07831 601403, Irs.ukltd@btconnect.com

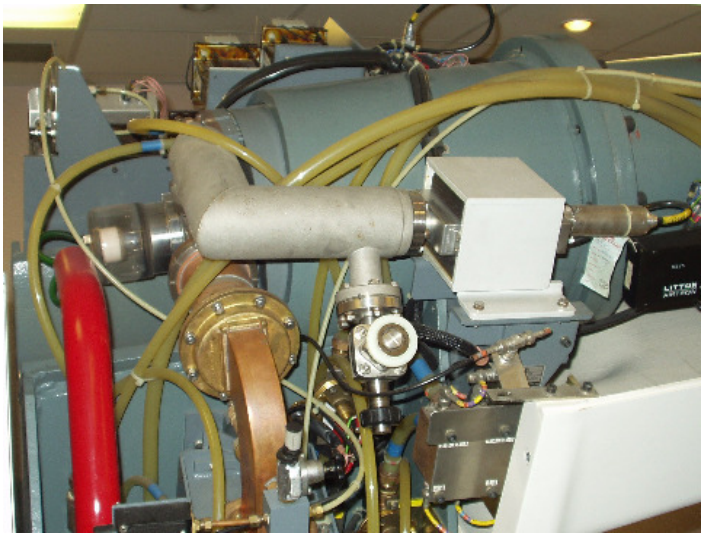
[2] Robert Deveraux



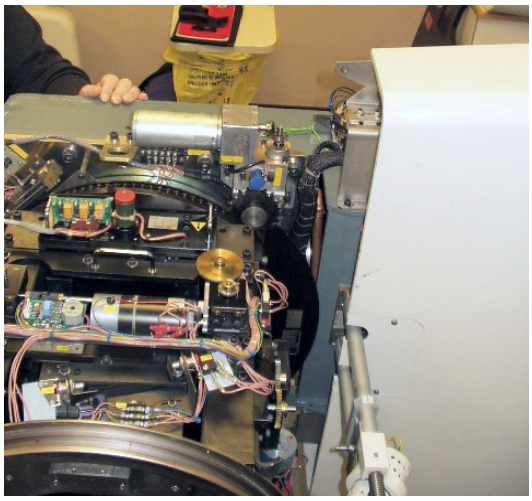
The accelerator power circuits (left), the pulsing circuits (middle) and the modulator and focus supplies (right). John Draper is in the background of the middle image, wandering, along with everyone else, how not to get roped in to this project.

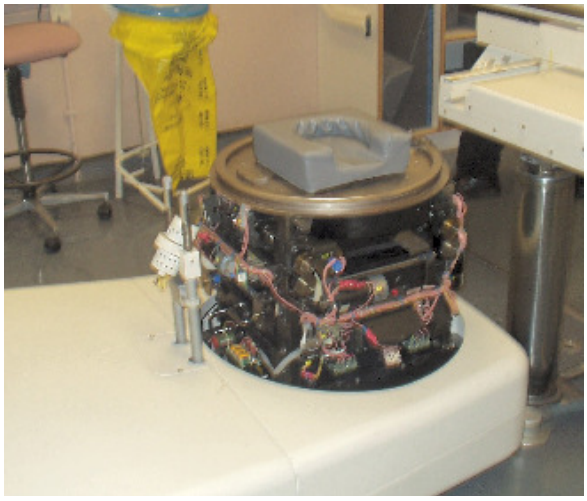


Details of the accelerator: The focus supplies on the left, the gun, mode transformer and vacuum pump in the middle and the radiofrequency generator on the right.

Details of the accelerator: The gun and magnetron drive circuits on the left and details of the gun assembly on the right.

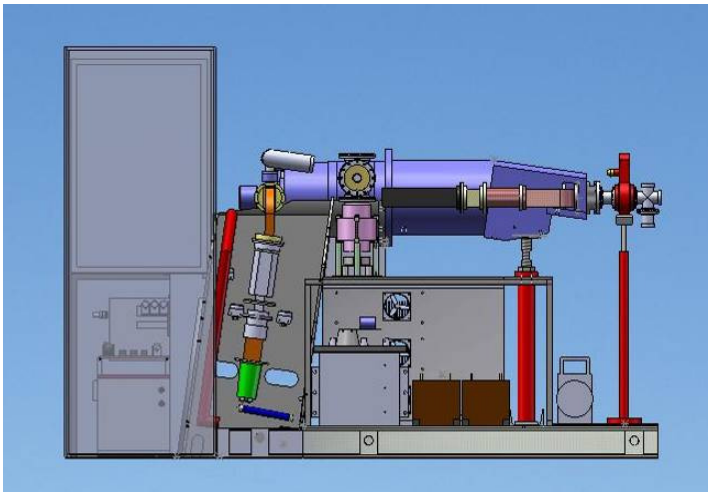


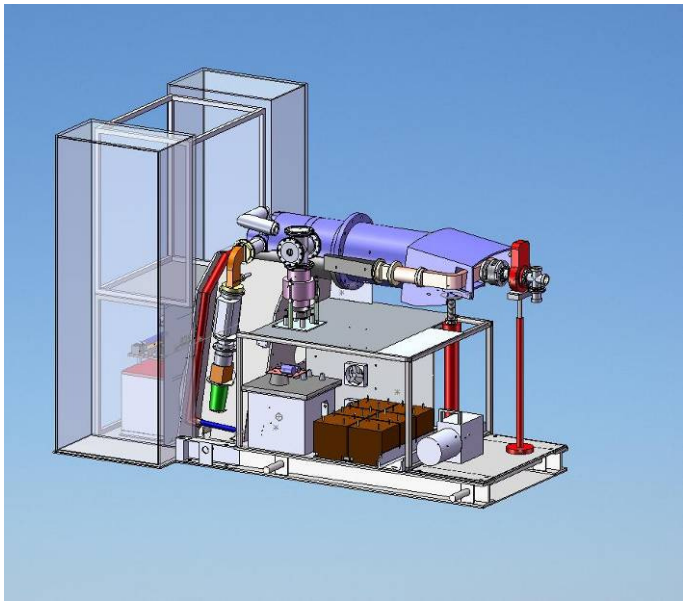


The head assembly, inside which is the x-ray target. This, at least, is one complex item which we will not need.

The linac was dismantled and moved to GCI in the second week of December 2007. That's just another way of saying one week before Christmas 2007. Here we were assisted by Norman Brogden and colleagues from IRS Ltd.

As soon as it was transported to GCI, Iain Tullis and John Prentice measured up the individual items and 'designed' the final assembly in software. Without a good software package such as SolidWorks, this project really could not have been completed easily, nor quickly. The images below show what it should eventually look like:





SolidWorks designs: the elevation and isometric views of the machine. At this stage 'bits' can be readily re-positioned, and it is easy to forget that we are dealing with structures weighing several tons in total.

Now, all was ready to start in earnest……

Taking it all to pieces

During the first week in January 2008, John Prentice led the first wave of the attack to modify the structure. In essence, the activity is best described by the sign on the door in the image below. Instead of seeing the words 'Push bar to open', just imagine the words 'until finished' at the end.

John Prentice preparing himself and the 'job'. Has he done this before??? Let's hope so….

After careful preparation, he clearly had a great deal of fun doing the cutting.

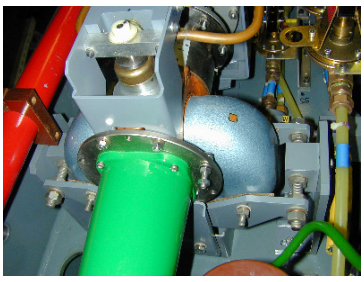




John Prentice cutting off the end-section of the accelerator. It is obvious that it was a good idea to be prepared….Keep legs far apart. Has he really done this before? It seems to have worked….

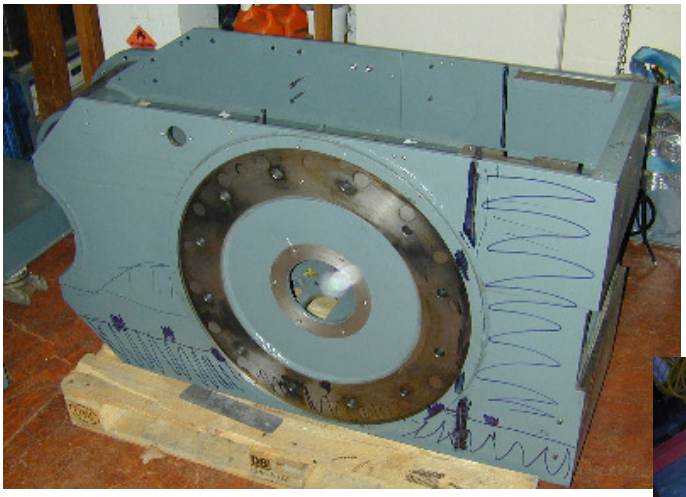
Meanwhile the rest of the machine framework had to be taken apart, and in late January, the radiofrequency components were removed. It is perfectly reasonable to blame Iain and Boris when we find that it is not possible to put it together again. Or, if we can put it together, that it does not work.





Even though the interconnections between the basic components in the linac's radiofrequency system are straightforward, we all know that it is easier to take apart than to put together again. Reverse-engineering a complex bit of kit can be full of unexpected surprises. So detailed, very detailed and very, very detailed pictures are always a good idea. Here is a selection showing the magnetron, the isolator and the output waveguide.

So now, all was ready for marking the sections which had to be removed. Note in the images overleaf how carefully this was done…

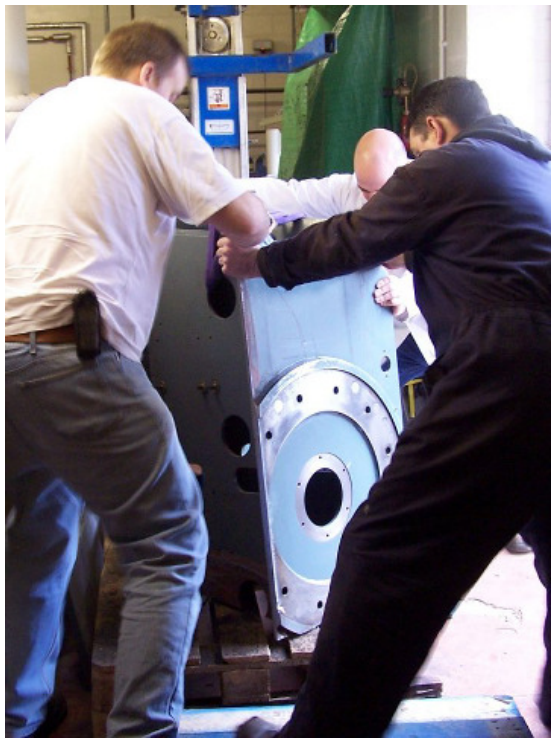


Of course it is imperative to mark out precisely what needs to come off!

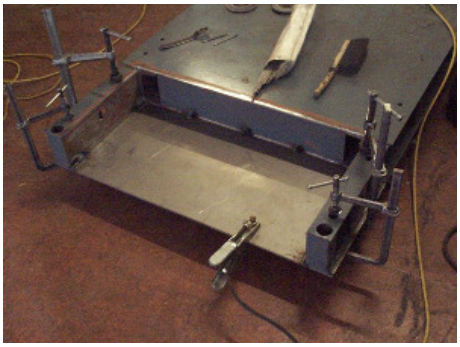
In last week of January, Robert Deveraux (a.k.a. “Rod the Welder”) arrived, making sure that the day was fine and that there was no rain forecast, and got to work flame-cutting the main structure. In fact this activity had to be postponed once or twice because of the weather….any excuse to increase delays even further! In the event, we were lucky with a ‘gap’ in the bad weather, and three beautifully sunny days were chosen. All went smoothly, as the next series of images show.

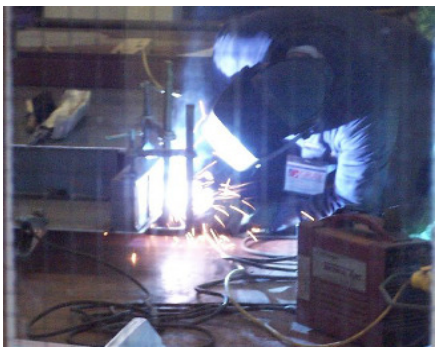
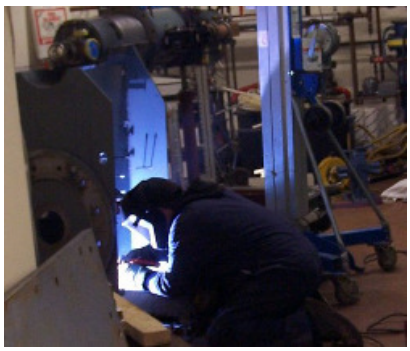
Cutting started in early hours of the morning; part of the circular support frame has been cut off by the time John Prentice and Iain Tullis have arrived….

Flame-cutting the frame of the linac….all that's needed is to do it along a straight line and then to smooth the edges with a grinder. An excellent professional such as Rod makes it look, well very easy!



On the second day, everything is cut and ready for assembly. Now the next thing to do is to bring the components inside.
Trouble is, they are heavy, very, very heavy…
Sometimes it takes three, sometimes two people to just manhandle the items. Of course we all know that Bob James could really have done it all by himself!



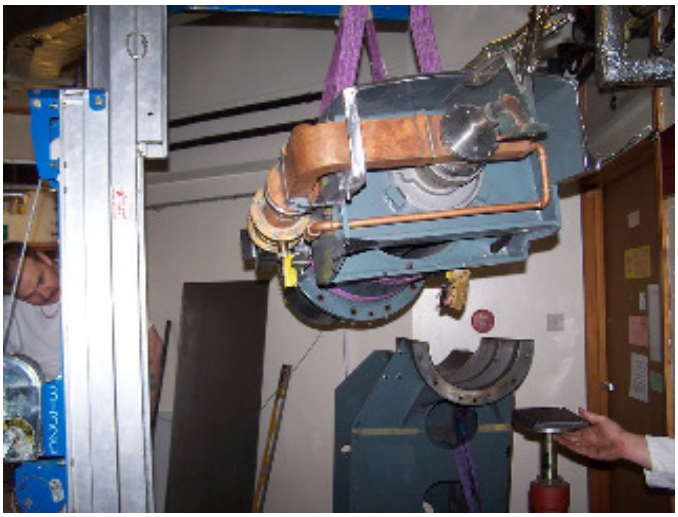




Welding together the baseplate and the main linac frame. Once properly prepared, and with the right expertise, it all fits together oh so easily. Some ten years of experience only required, along with an ability to crouch into awkward places and a serious dose of patience.

On the third day, the pieces are all together!….it is all finished isn't it? Let's go home….

Well, not quite… Something is not quite straight and seems to be at the wrong height.

Oh, yes, we've remembered…The heavy round bit has to be lifted up and attached to the leaning bit…

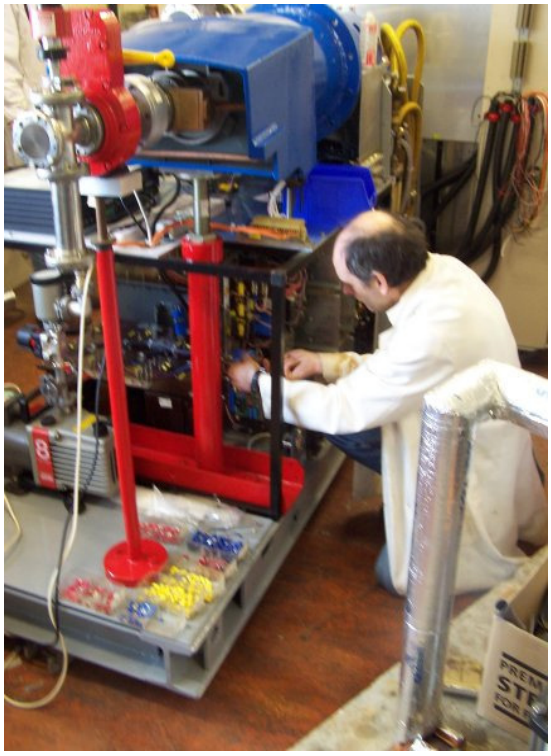



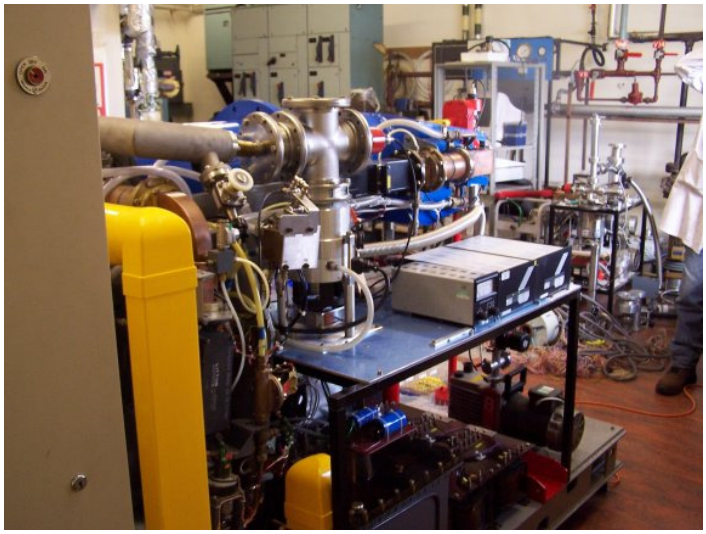
And then the assembly is moved into position…now all that's needed is to prime it and the heavy part of the work is complete…, not bad for 3 days' work.

Nevertheless, the look on John Prentice's face says it all!

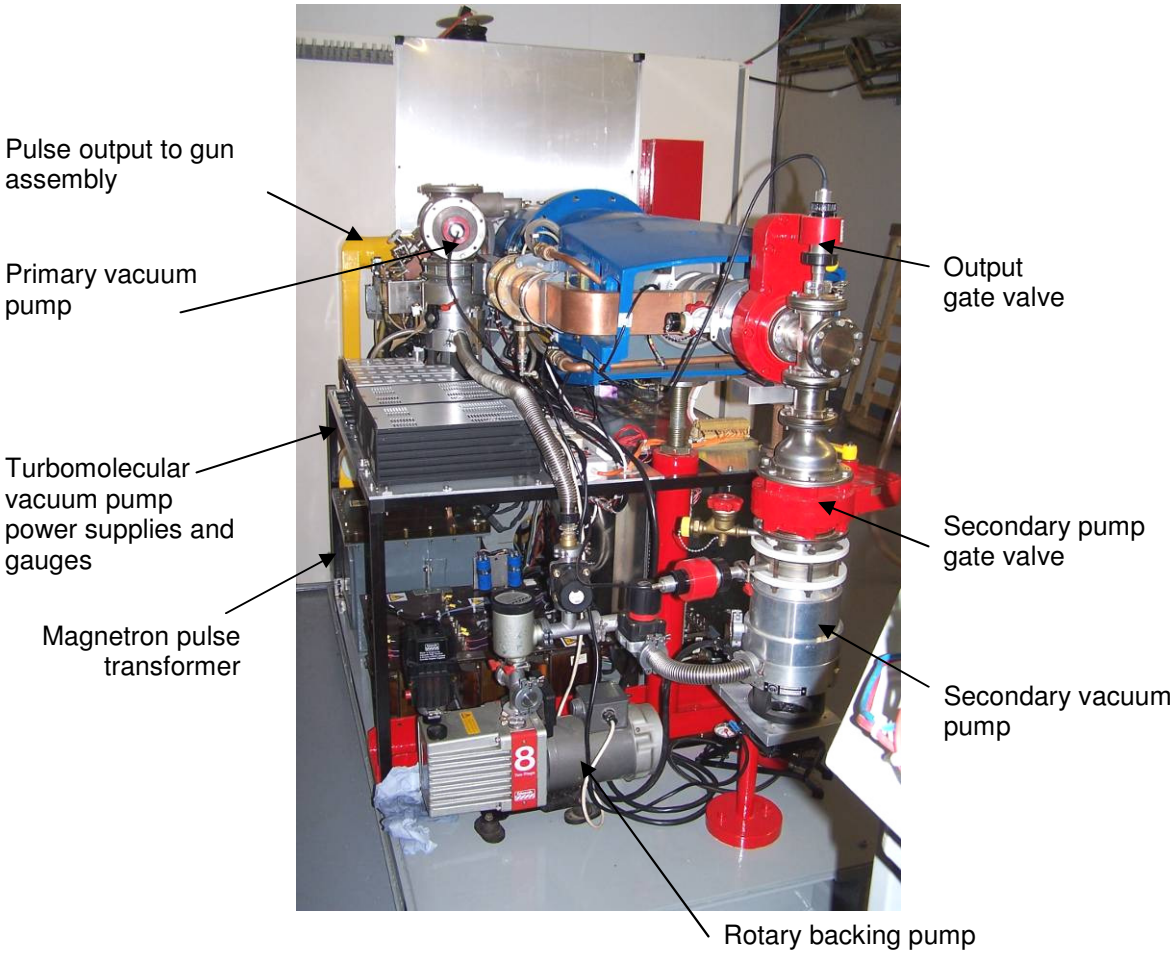
By now, it should be obvious that a reasonable amount of effort had already been put in and effort that we could justly be proud of. What better way to show the pride in the work than to give the machine a good lick of paint.

Then the pieces slowly started to be attached. We were all so busy during February that we forgot to keep a record of day-to-day progress. However, by the first week in March, the installation was taking shape. Most mechanical work had been completed and the painfully tedious, but nevertheless satisfying job of rewiring the system started. Since this is the sort of thing that Robert Newman enjoys (!), he was key in this part of the project. Iain Tullis made sure that everything was where it should be and painted in the agreed colours and the project leader's principle activities were to correct all of the numerous mistakes in his own design.





So in a very short time the machine was ready to be shipped to Oxford. This is what it looked like:



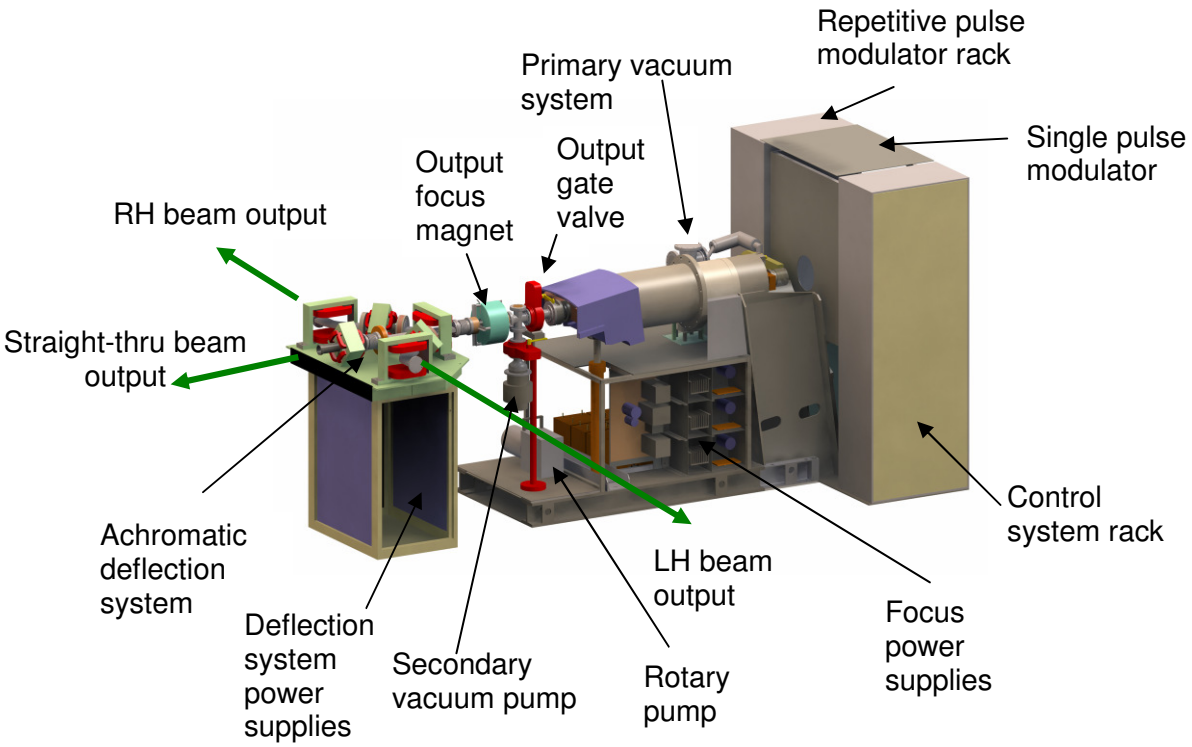
It is interesting to note that, excluding the cutting and welding charges (<£1000) and dismantling and transportation charges (<£15,000), no more than £1000 had been spent on components. This was mainly because of effective re-utilisation of the vast majority of mechanical items.

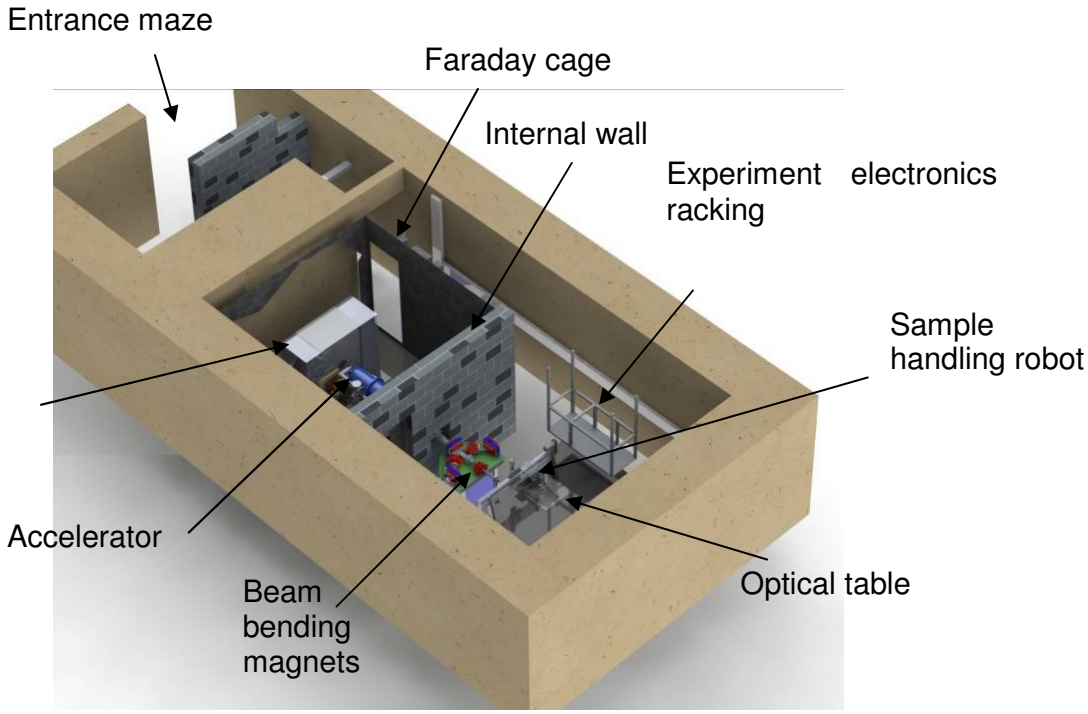
Of course the accelerator is but one of the components of a radiation facility. So Iain Tullis became proficient at drawing up the complete facility in SolidWorks (www.solidworks.com/), virtually attaching the various beam transport components and a complete design was finalized at around the time the machine was transported to Oxford.

The accelerator was to be installed in a vault in the building basement and inevitably not everything went quite to plan. Partition walls, ventilation ducts, cooling system and pipe work all had to be modified to a greater or lesser extent, but ultimately things started to take shape. We were pretty sure what we wanted to achieve and by the end of the year most of the 'hard' work was completed.

The diagrams on the following page show what was to be developed. How this was done is described in Part 2 of this series of documents.

The control software is not described here in detail, but Stuart Gilchrist and Robert Newman were heavily involved in this part of the project, in addition to contributing to the mechanical installation.





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