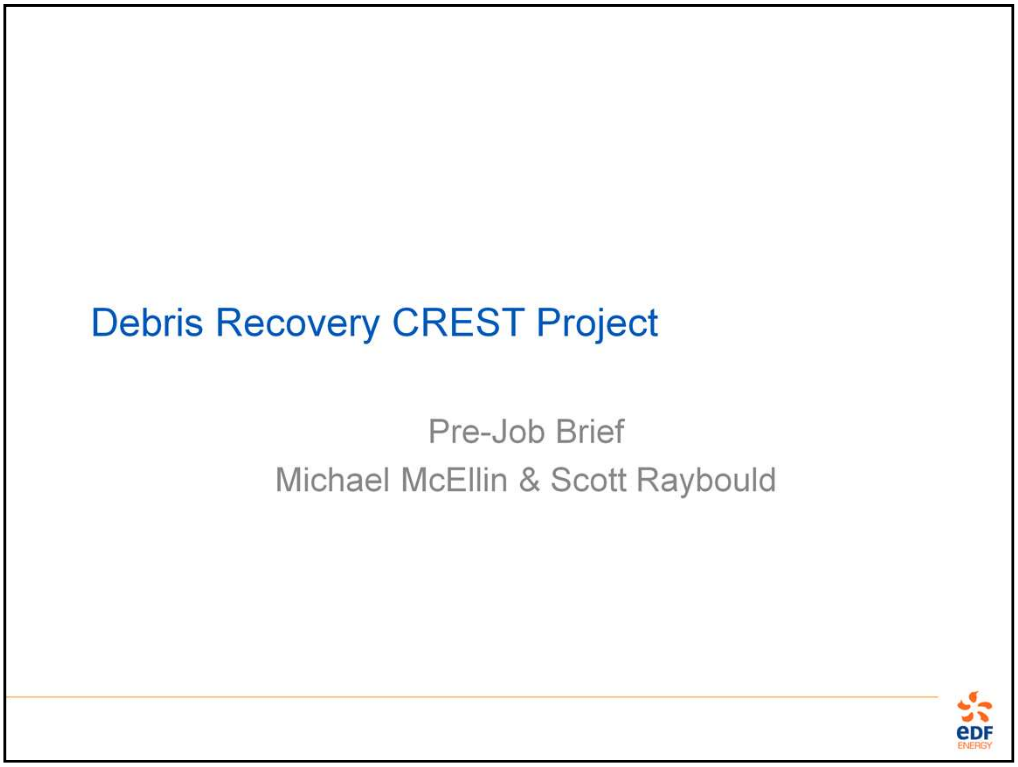


Debris Recovery CREST Project

Pre-Job Brief

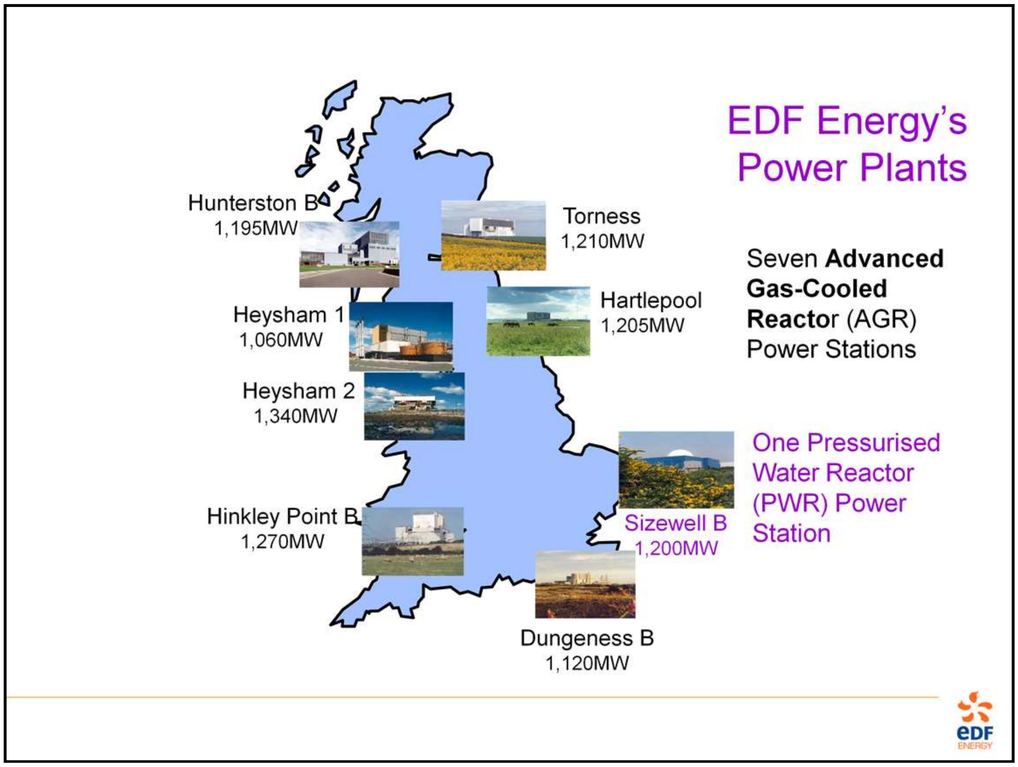
Michael McEllin & Scott Raybould

How do you manage a successful engineering project?

Most engineers know that most projects go wrong the for the same reasons, again and again. In the nuclear industry we have therefore developed a standard way of starting off projects, to remind everyone what can go wrong, why, and what to do to avoid the common problems.

We called it the standard Pre Job Brief. We do it for almost everything – I might participate in one of these every couple of weeks. We all keep cards around our necks to remind us of the most important questions and what to do and what to avoid.

This really works! We make many fewer mistakes as a result of following these guidelines. However, I am going to simplify and paraphrase a bit.



EDF Energy's Power Plants

Seven **Advanced Gas-Cooled Reactor** (AGR) Power Stations

One Pressurised Water Reactor (PWR) Power Station

Hunterston B
1,195MW

Torness
1,210MW

Hartlepool
1,205MW

Heysham 1
1,060MW

Heysham 2
1,340MW

Hinkley Point B
1,270MW

Sizewell B
1,200MW

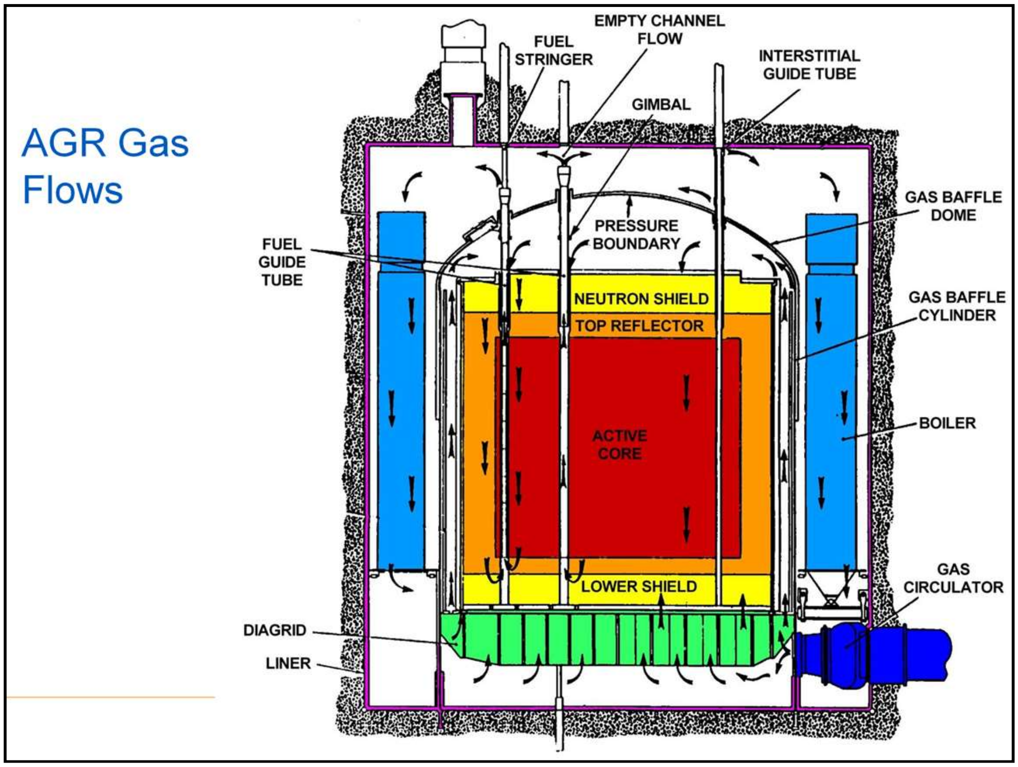
Dungeness B
1,120MW

But first a bit about EDF Energy Nuclear Generation and what I do.
British Energy was formed in 1996, from remnants of the Central Electricity Generating Board, and is currently the largest generator of electricity in the UK. It was acquired by EdF Energy in 200?

We operate seven Advanced Gas Cooled twin reactor power stations – we call those AGRs - , and one Pressurised Water Reactor, or PWR - Sizewell B - in East Anglia.

All the Nuclear power stations are located on the coast to take advantage of the readily available supply of sea water for cooling purposes.

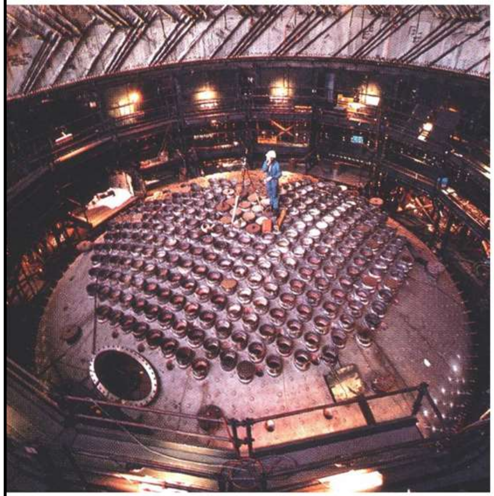
Our nuclear power stations generate about 20% of the UK's electricity (on a good day). A bad day is when a problem of the kind we will discuss has shut down a reactor.

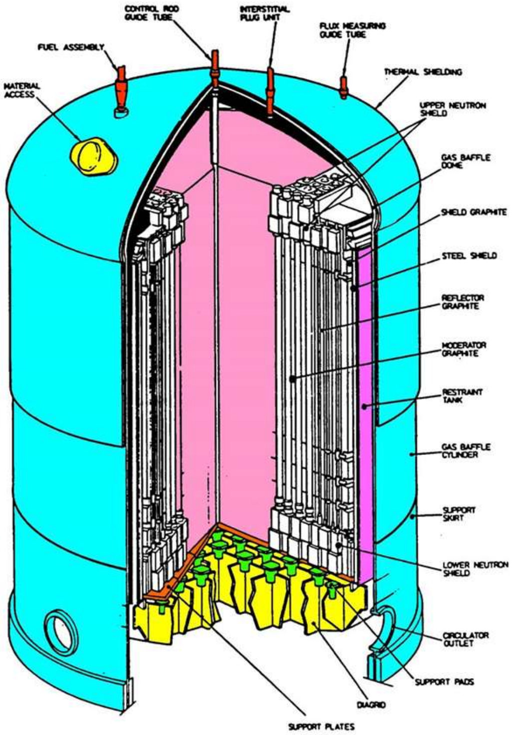


AGR Gas Flows

The primary function of the coolant gas is to transfer heat from the fuel pins to the boilers. CO_2 was chosen because of its low neutron absorption, chemical compatibility with most materials.

In the AGR design it has another function that of cooling the graphite. This is achieved by splitting the gas flow so that some flows up the fuel channels and the rest is diverted to flow down through the graphite. This is the re-entrant flow. Graphite must be kept at about 300°C.

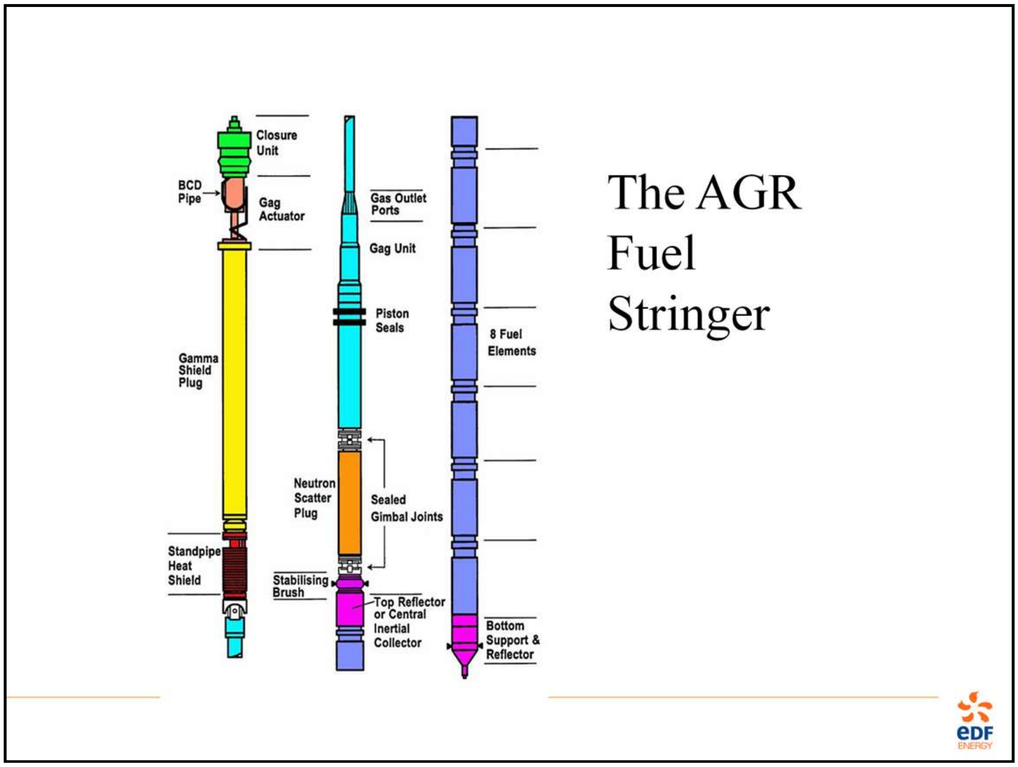




A gas baffle is provided to direct coolant flow through the core in order to minimise graphite corrosion by reducing its temperature.
The gas baffle is a large carbon steel steel structure consisting of a dome over the reactor and a cylindrical portion around the side down to the diagrid.
At Hartlepool and Heysham 1 due to the different location of the boilers only a dome portion is required.

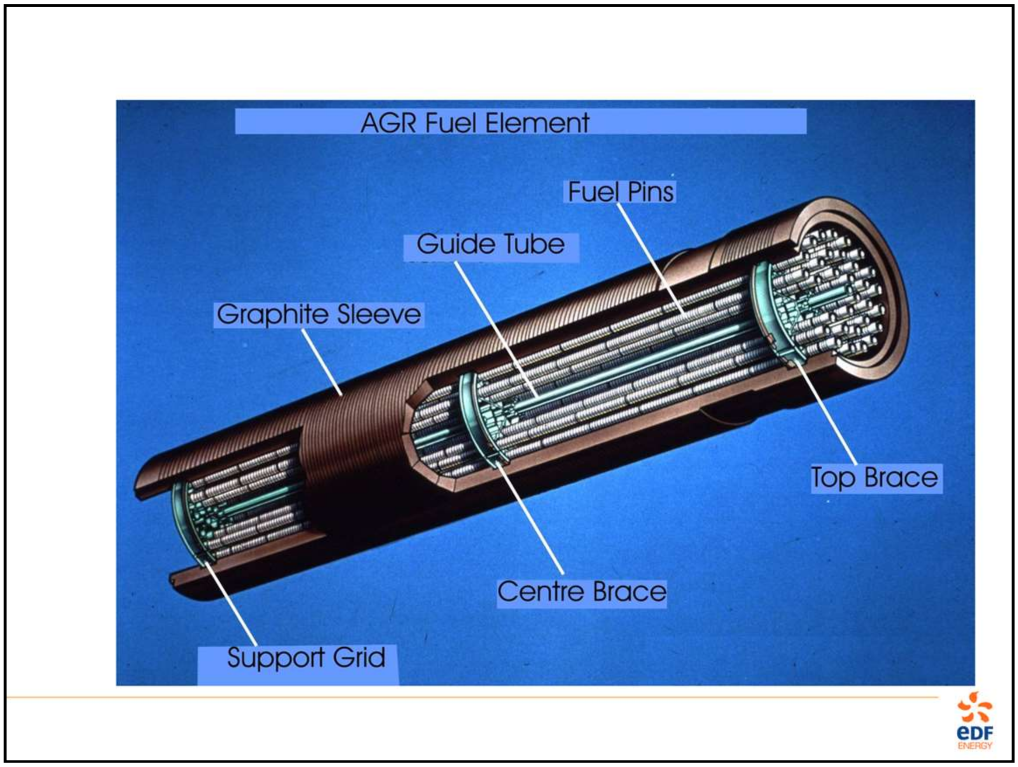
Since the dome portion is swept by hot gas over its upper surface it consequently requires insulating to avoid high temperatures.
The dome is also thick to compensate for the numerous penetrations through it to give access to fuel and control rod channels etc.

These penetrations are fitted with charge or guide tubes, which provide guidance for assemblies through the dome and into the channels in the graphite.



The AGR
Fuel
Stringer

The fuel assemblies are complicated objects almost 30m long – the sections shown must be imagined one on top of the other – but the part that interests us at the moment is the bottom section, consisting of eight fuel elements.



AGR Fuel Element

This is a fuel element, consisting of 36 closely spaced pins, with a powerful cooling flow of high pressure carbon dioxide flowing through the spaces.
(Why carbon dioxide?)

We stack these eight high.
The fuel elements in the centre of the reactor can be generating about 20kW per pin (average of 15Kw)– so this object, about a meter tall – can be generating up to about 700 kW of heat – 150 electric kettles.

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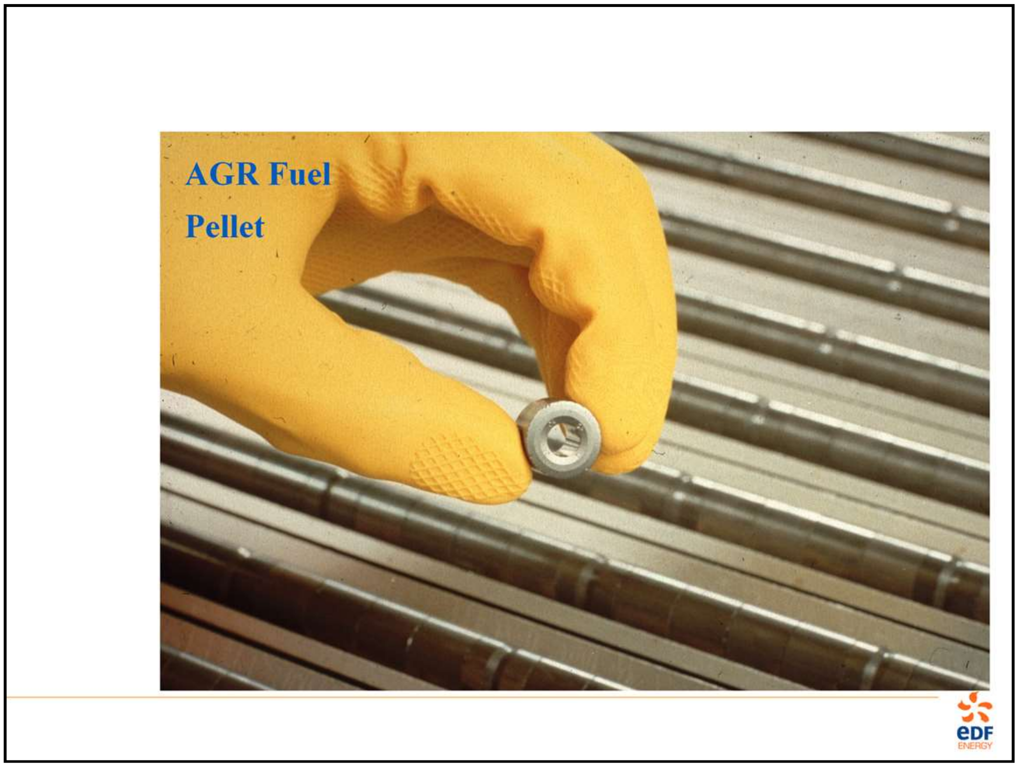
This is what it looks like in real life – big!

In fact, this set up misses out seven of the eight fuel element.

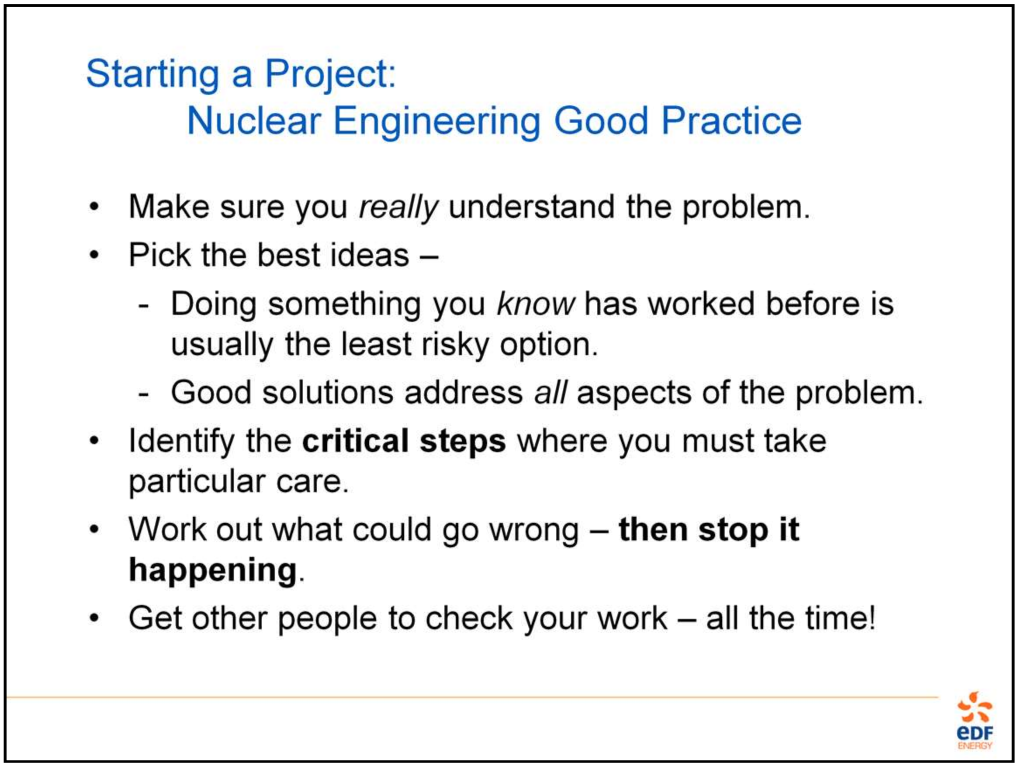
Look at the bottom nozzle on the right. See how it could become partly blocked by debris.



AGR Fuel Pellet

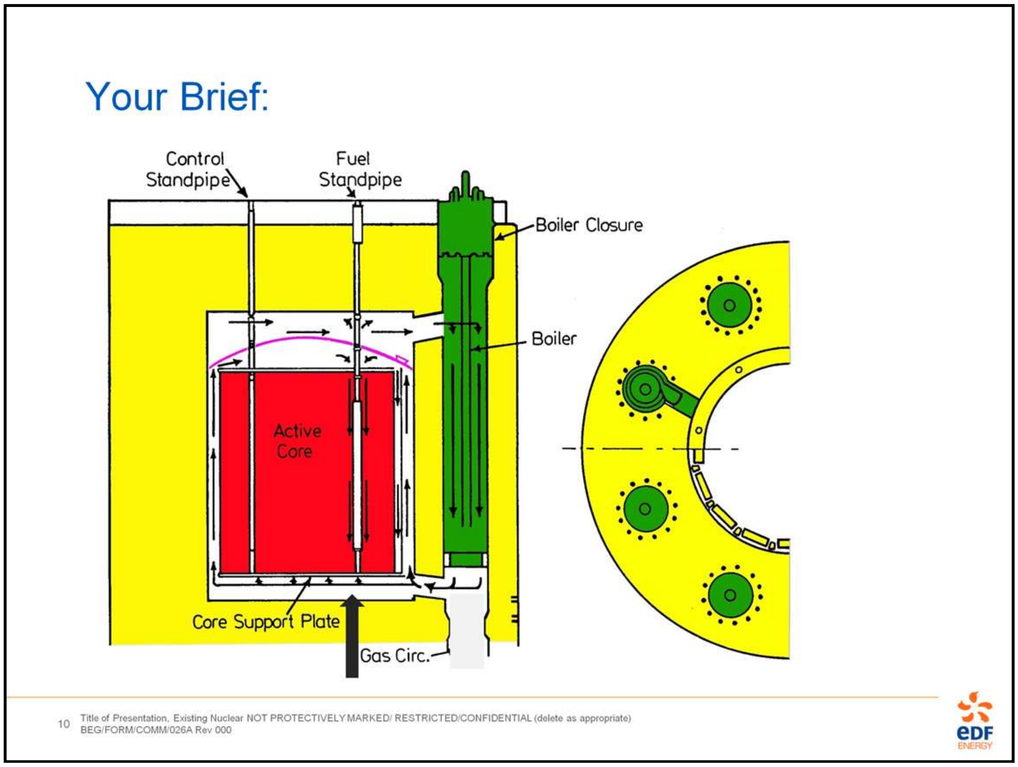
This is the inside of a pin - a fuel pellet. It is a ceramic – Uranium dioxide – which means that it can withstand very high temperatures before melting.
Note the hole down the centre. This is important for two reasons:

- It prevents very high temperatures developing – as they would in the centre of a solid pellet.
- It provides a space within the fuel pin for gasses released during fission to accumulate. If we had no free volume, then those gasses would produce high pressures within the pin, and perhaps cause a pin failure.



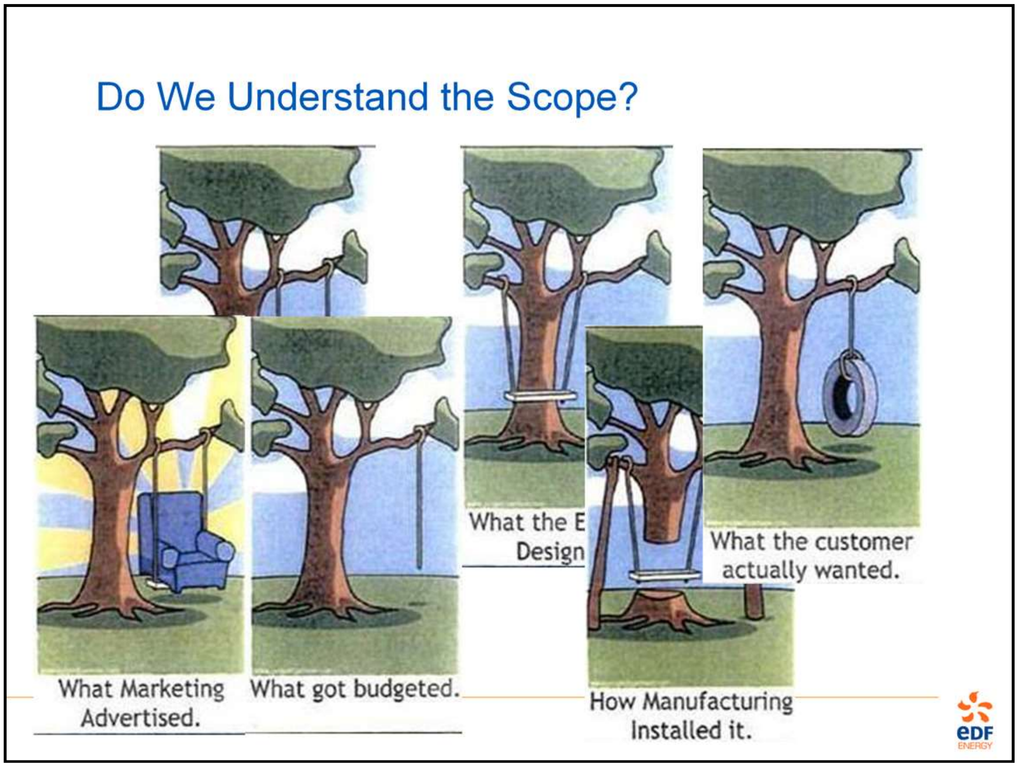
Starting a Project: Nuclear Engineering Good Practice

- Make sure you *really* understand the problem.
- Pick the best ideas –
  - Doing something you *know* has worked before is usually the least risky option.
  - Good solutions address *all* aspects of the problem.
- Identify the **critical steps** where you must take particular care.
- Work out what could go wrong – **then stop it happening**.
- Get other people to check your work – all the time!



Your Brief:

We will supply you with written details.



Do We Understand the Scope?

Many projects go wrong at the first stage: which is understanding the problem.

The first problem is that the customer may know what he wants but may find it difficult to describe. He makes lots of assumptions about what you know, and you make lots of assumptions about what he may want.

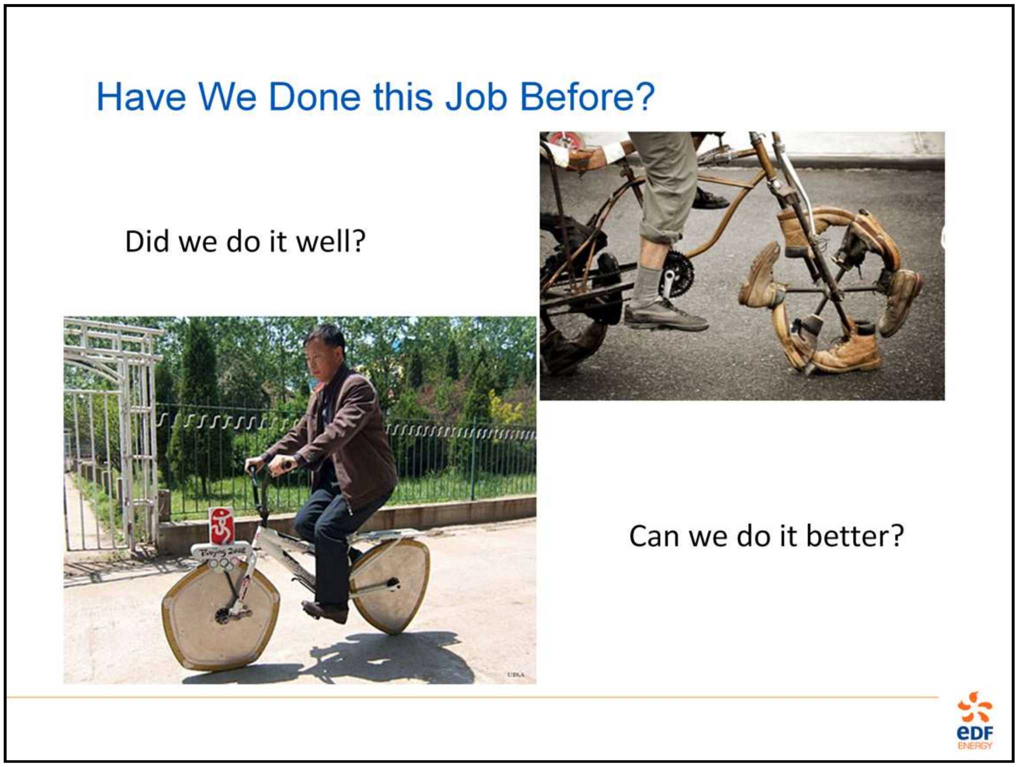
The you have to reconcile what gets promised with what they are prepared to pay for.

By the time you get the designer involved a few misunderstandings have occurred.

And it gets worse when you want to build it.

But all along, this is what the customer actually wanted. This is not quite a true story – but I know of examples that came pretty close.

So, the first rule of good project management is **talk to your client**,
- Ask lots of questions.
- Tell him or her what you think you have understood.
- Get them to confirm that your understanding is correct.



Have We Done this Job Before?

Did we do it well?

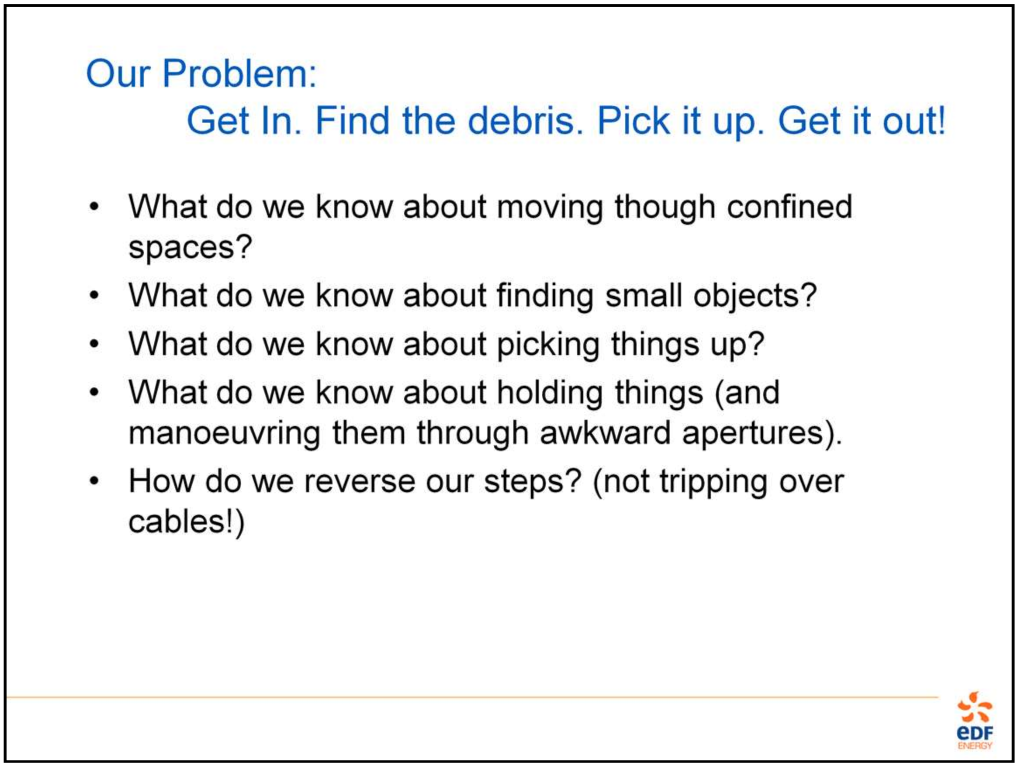
Can we do it better?

Engineering is mainly about learning from other peoples’ mistakes. We do not try to do something differently just because it is different.

If someone else has successfully solved the problem – STEAL THEIR IDEAS! In engineering this is regarded as a GOOD THING as long as there are no patent protections.

If they tried it and it went a bit wrong – can you fix it? The last bike has the advantage that as the wheels are used the sharp points wear down and its gets better – that might well suggest a useful design improvement. Doh!

Can you adapt what they did to your problem?



Our Problem:
Get In. Find the debris. Pick it up. Get it out!

- What do we know about moving though confined spaces?
- What do we know about finding small objects?
- What do we know about picking things up?
- What do we know about holding things (and manoeuvring them through awkward apertures).
- How do we reverse our steps? (not tripping over cables!)

Design: Two main type of question

What must it do?

- Get the device in.
- Find the object.
- Get hold of it.
- Get it out.
- Don’t drop it again!
- Don’t leave anything behind.
- Don’t damage anything.

How well must it do it?

- How easy to use?
- How fast will it work?
- How far must it go?
- How much will it cost?
- How long will it last?
- How likely is it to break?

What are the Critical Steps?

A critical step is something that you can’t afford to get wrong.
It might be a real safety issue – as here – or you may use up too much of your available time to be able to correct the mistake.

When you identify a critical step, make sure you take extra care! Get someone else to check your work!

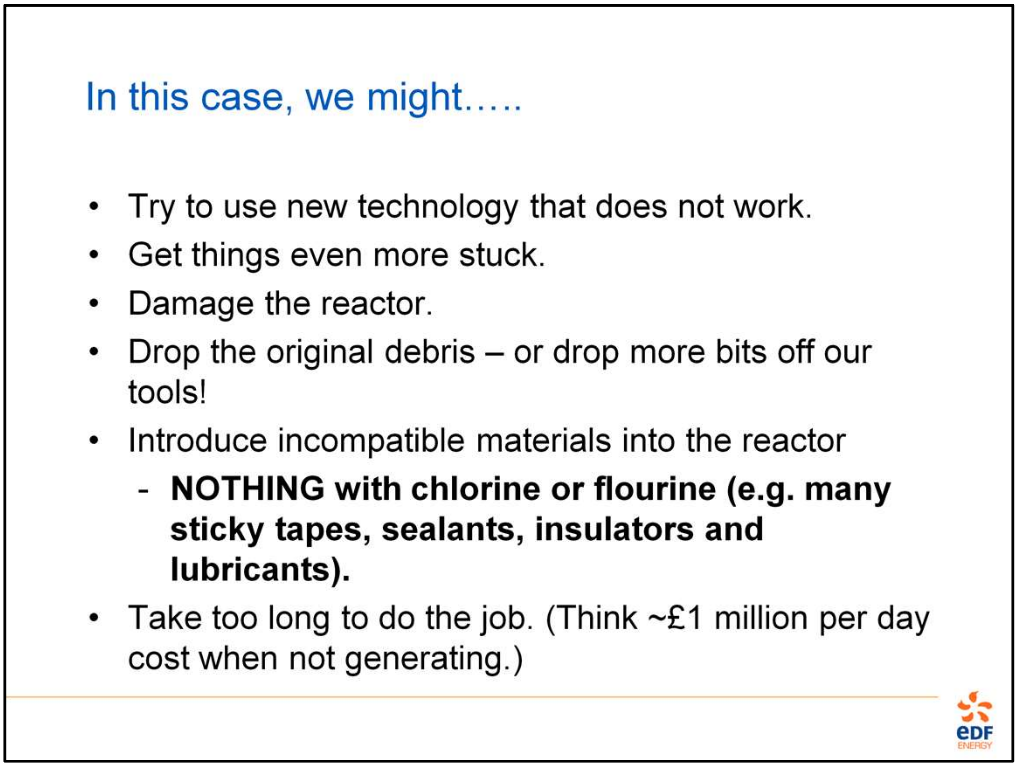
What Mistakes Might We Make?

Everyone makes mistakes.

However, if we think about the type of mistakes that might occur we can avoid some of them.

Yes, they did drop a bomb.

The last picture shows what happens when someone forgets to fasten a latch. It happened recently at Heathrow and caused a serious engine fire – but this picture shows one the many earlier examples of this type of incident – so why does it keep on happening?



In this case, we might…..

- Try to use new technology that does not work.
- Get things even more stuck.
- Damage the reactor.
- Drop the original debris – or drop more bits off our tools!
- Introduce incompatible materials into the reactor
  - **NOTHING with chlorine or flourine (e.g. many sticky tapes, sealants, insulators and lubricants).**
- Take too long to do the job. (Think ~£1 million per day cost when not generating.)

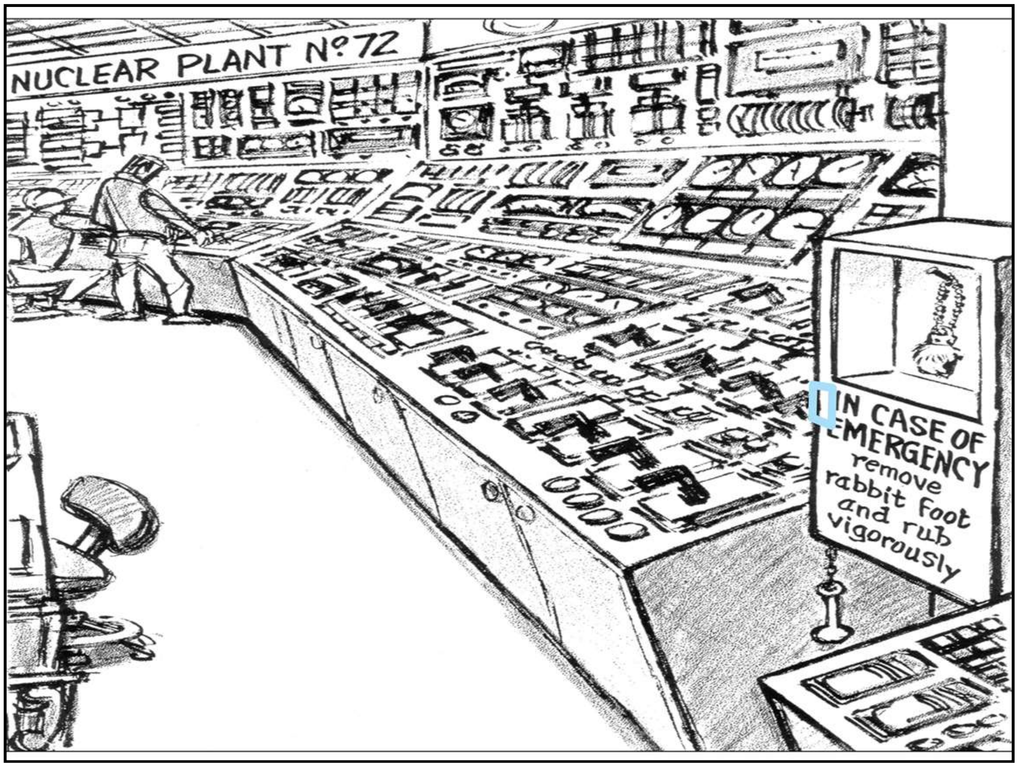
What is the Worst that Could Happen?

One of the dominant characteristics of engineers is their eternal optimism.

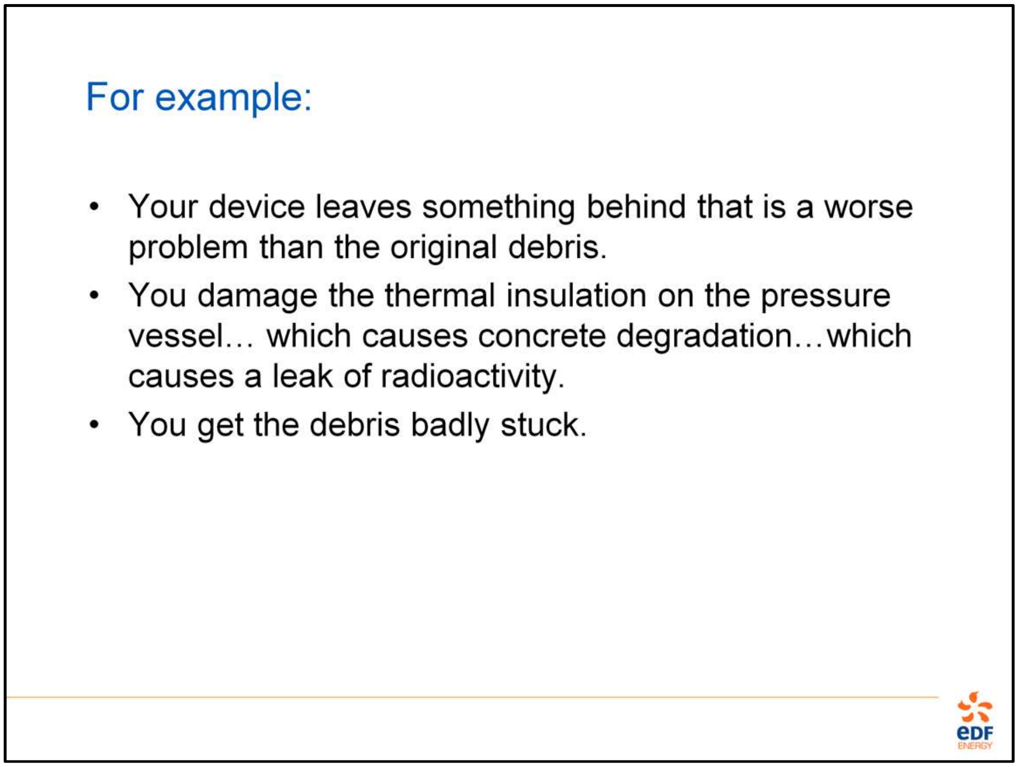
You might like to wonder why these four people think they need breathing apparatus and he doesn’t.

And the electrician is obviously feeling very luck on this this day.

You need at least one pessimist on your team!

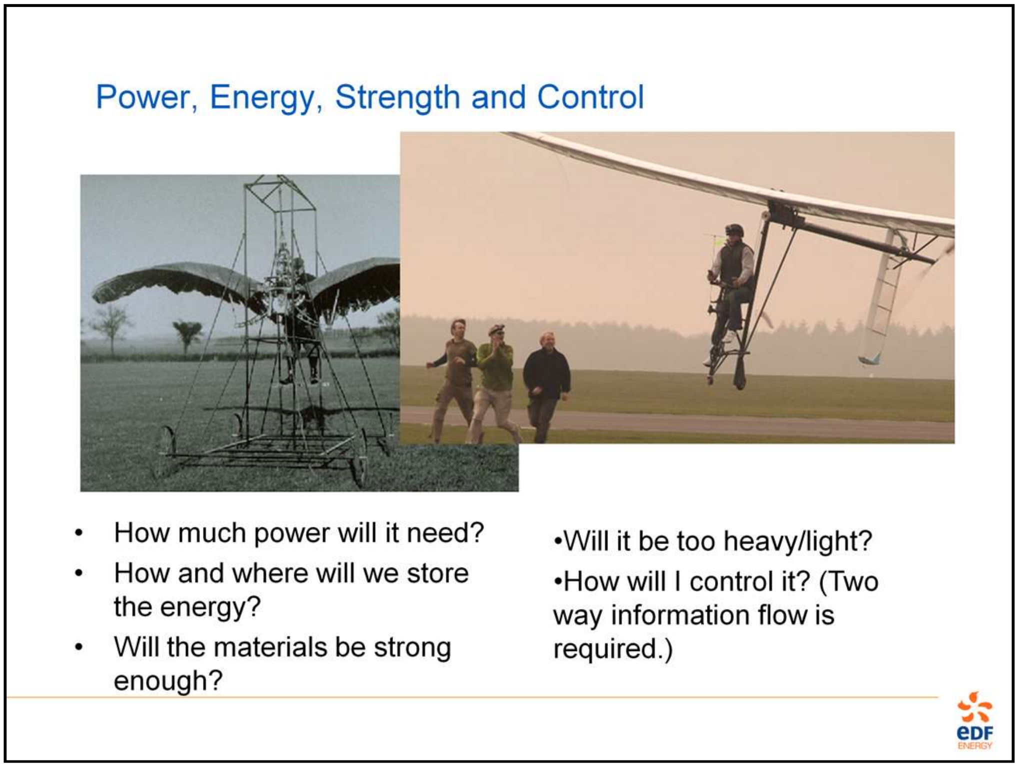


If all else fails! (NOT!)



For example:

- Your device leaves something behind that is a worse problem than the original debris.
- You damage the thermal insulation on the pressure vessel… which causes concrete degradation…which causes a leak of radioactivity.
- You get the debris badly stuck.



Power, Energy, Strength and Control

- How much power will it need?
- How and where will we store the energy?
- Will the materials be strong enough?

•Will it be too heavy/light?

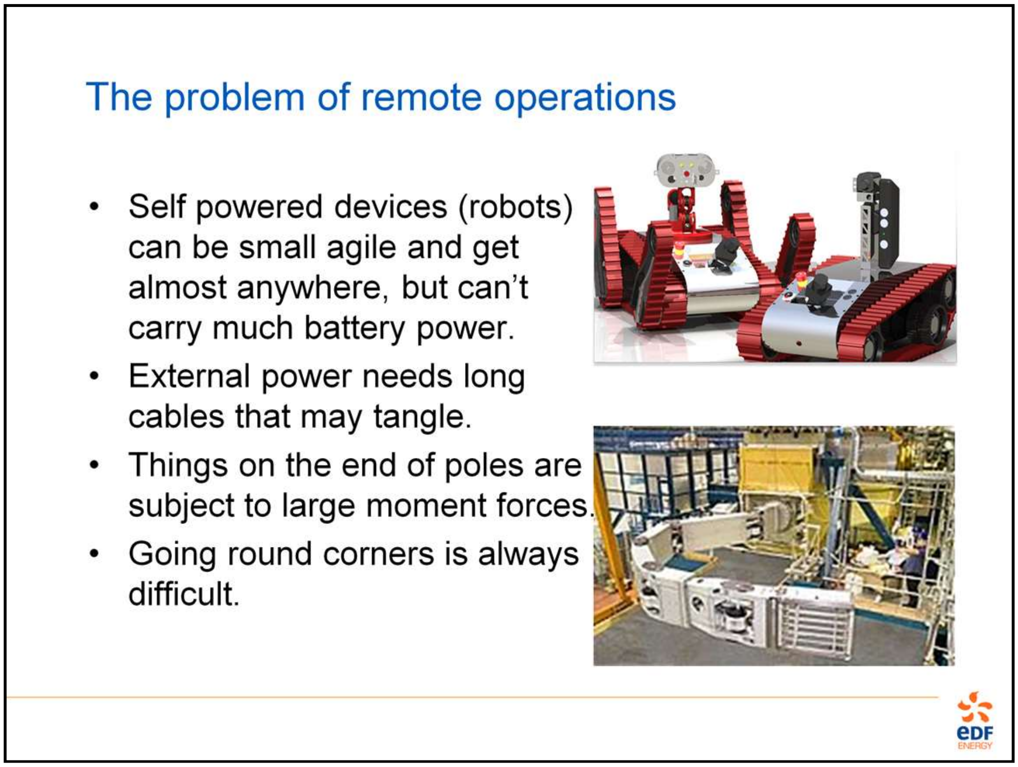
•How will I control it? (Two way information flow is required.)

There are lots of wonderful inventions, that never take off because they do not take account of simple physics and common sense.

This is not going to fly because it is too heavy, the man cannot produce enough muscle power to generate enough lift. If he everything thinner and lighter, the aircraft would probably break, because the materials available would not be strong enough to hold together.

Jem Standsfield from BBC’s Big Bang Theory did better. With modern metal alloys, a really good design and peddling as hard as possible, he could just about get off the ground. But he could not store enough energy in his body to keep going for more very long. Even so, what stopped him achieving the intended flight was finding he could not control the plane.

A lot of cutting edge engineering is at the limits of what is possible with material strength, energy storage, power production and control.

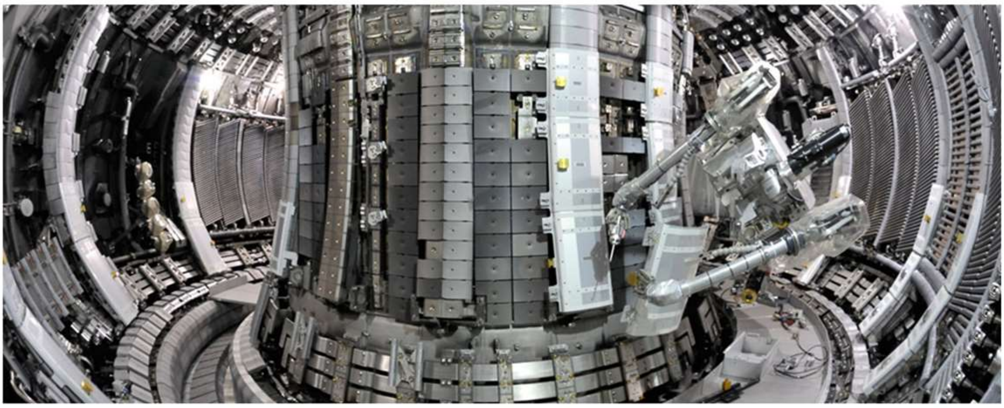


The problem of remote operations

- Self powered devices (robots) can be small agile and get almost anywhere, but can't carry much battery power.
- External power needs long cables that may tangle.
- Things on the end of poles are subject to large moment forces.
- Going round corners is always difficult.

The bottom picture is the remote operations arm used in the Joint European Torus nuclear fusion project at Culham.

The Joint European Torus Manipulator in Action



Sometimes what we have done in the past just doesn’t work well enough. Then we have to consider a different way of doing it.

There is a lot of current interest in “soft robots” – things that can squeeze or wriggle into places that conventional tools just cannot get to.

Snake-bots, for example, are being developed to get into pipes, or wriggle through to gaps in earthquake damaged buildings to see if there are any buried survivors. They can do amazing things – like climbing trees. But can they pick up a bolt or a spring? Think about it.

Really soft robots can squeeze under narrow gaps, or like this octopus arm wrap around objects of practically any shape.

I am not saying that these are potential solutions – but sometimes you can do things very differently and make a big leap in capability.

Engineering is a serious business when you hold peoples’ lives in your hand – but you can also have a lot of fun sometimes.