

Walking and Climbing Service Robots for Safety Inspection of Nuclear Reactor Pressure Vessels

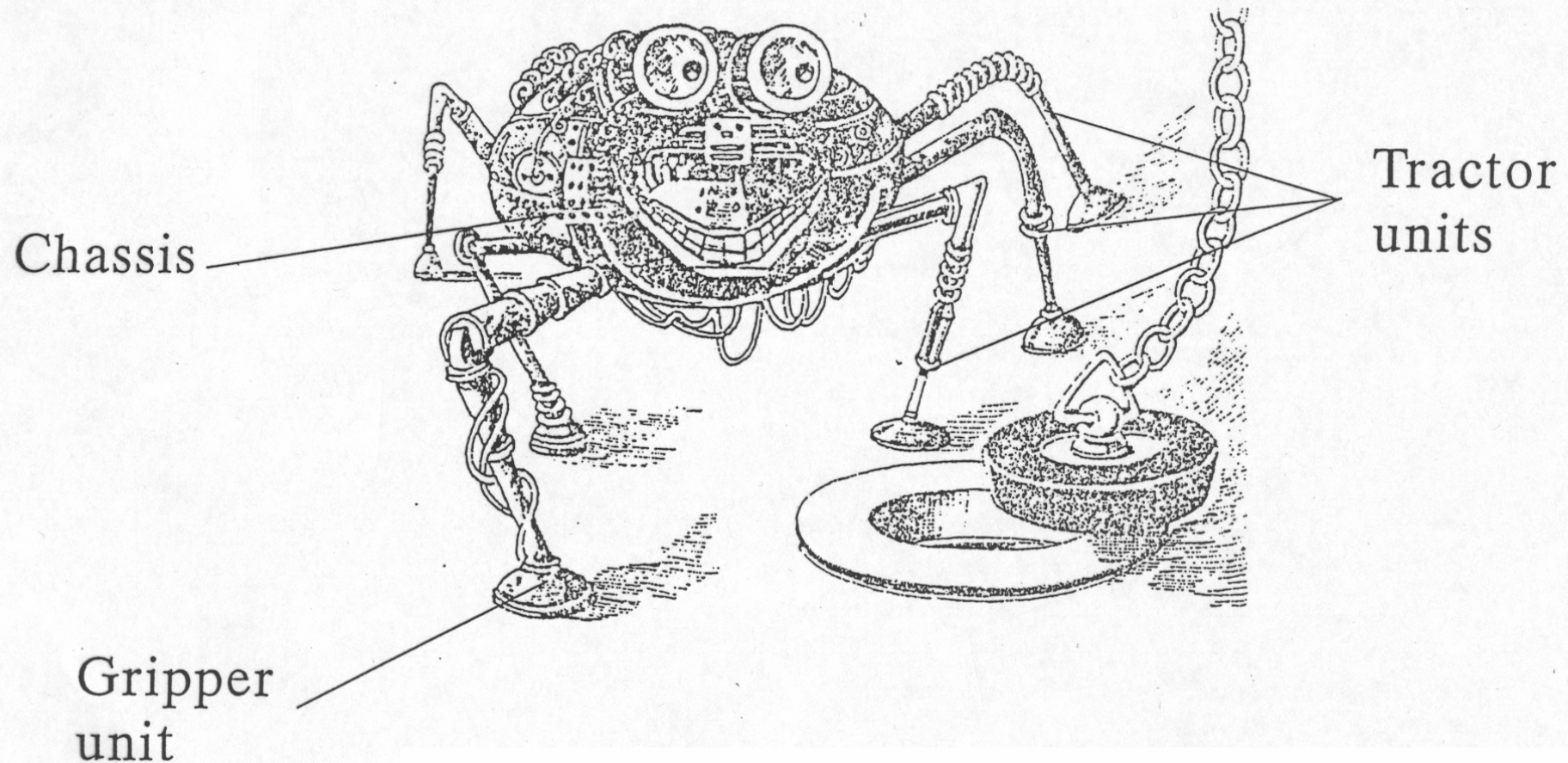
Authors: B.L. Luk , A.A. Collie, D. S.
Cooke and S. Chen

Presented by: Dr. B.L. Luk

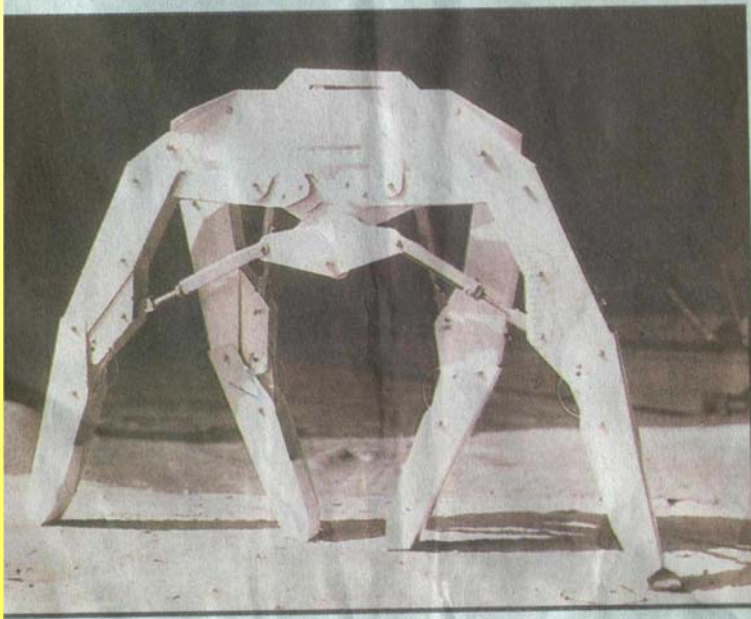
Outline of the Presentation

- Background
- Two major remote operation projects
- Video
- Conclusion

How does a walking & climbing robot look like?



First Legged Wooden Cow Robot in History



推着用三十載成功研製出的木牛流馬。下圖為木牛流馬內部機械結構。

今出現羊城廣州。將之賦予新生命的研製者是新疆古機械研究院專業人士王渝。

王渝今年五十七歲，他表示，這是人類文明發展史不可多得的寶貝，古機械因製造技術高超而失傳，「斷種」的危機很大。他說：「很擔心找不到接班人，找到也不成，也要錢。我無法再養活一個學生。」

月入九百多元的王渝，甘願過着粗茶淡飯的生活，為了籌備十多二十萬元經費供研製古機械之用，已強迫自己改變沉默，只專注研究的性格；今天從新疆走到廣州，也是為了替令他目眩的古機械寶庫尋找再生之道。他說：「每一步都需要錢、材料、加工費、資料費、聯絡費等等，少錢便少幹。」

15歲用紙板研製

王渝憶述如何走進古機械研製的不歸路時說：「農村的夏天，人們都跑到空地乘涼，小孩圍着大人聽《三國演義》故事，說到諸葛亮發明了『木牛流馬』運輸糧草作戰時，我聽得眼瞪瞪的。」到了十五歲，習慣把爺爺從上海買回的玩具

零件拆拆裝裝的他，終用紙板研製「木牛流馬」，一直到八四年四十三歲的他，才把木牛流馬成功研製出來，他說，這可引證中國是最早及最多利用機械人的國家。

諸葛亮夢中傳技

埋首研究的他，不諱言自己不是一個好父親、好丈夫；他對此雖感內疚，但卻未能抽身。對有人指他神經不太正常，他自嘲說：「我幹的是捕風捉影的事，也算不是正常人幹的事。」他不諱言在他生活中，已沒有星期天、也沒有白天或黑夜。

他說：「走路、躺着也可做研究，一天十五、十六小時也離不開古機械研製，甚至做夢亦然。」他續說：「在夢中曾見到諸葛亮，他在《做木牛流馬法》中提到宜可大用，不可小使。」此夢使他想到了當年諸葛亮做木牛流馬，不純是用以運糧草，他是以此作心理戰，是用兵之術。這可從糧盡退兵中窺見一斑！」

■特派記者廣州報道

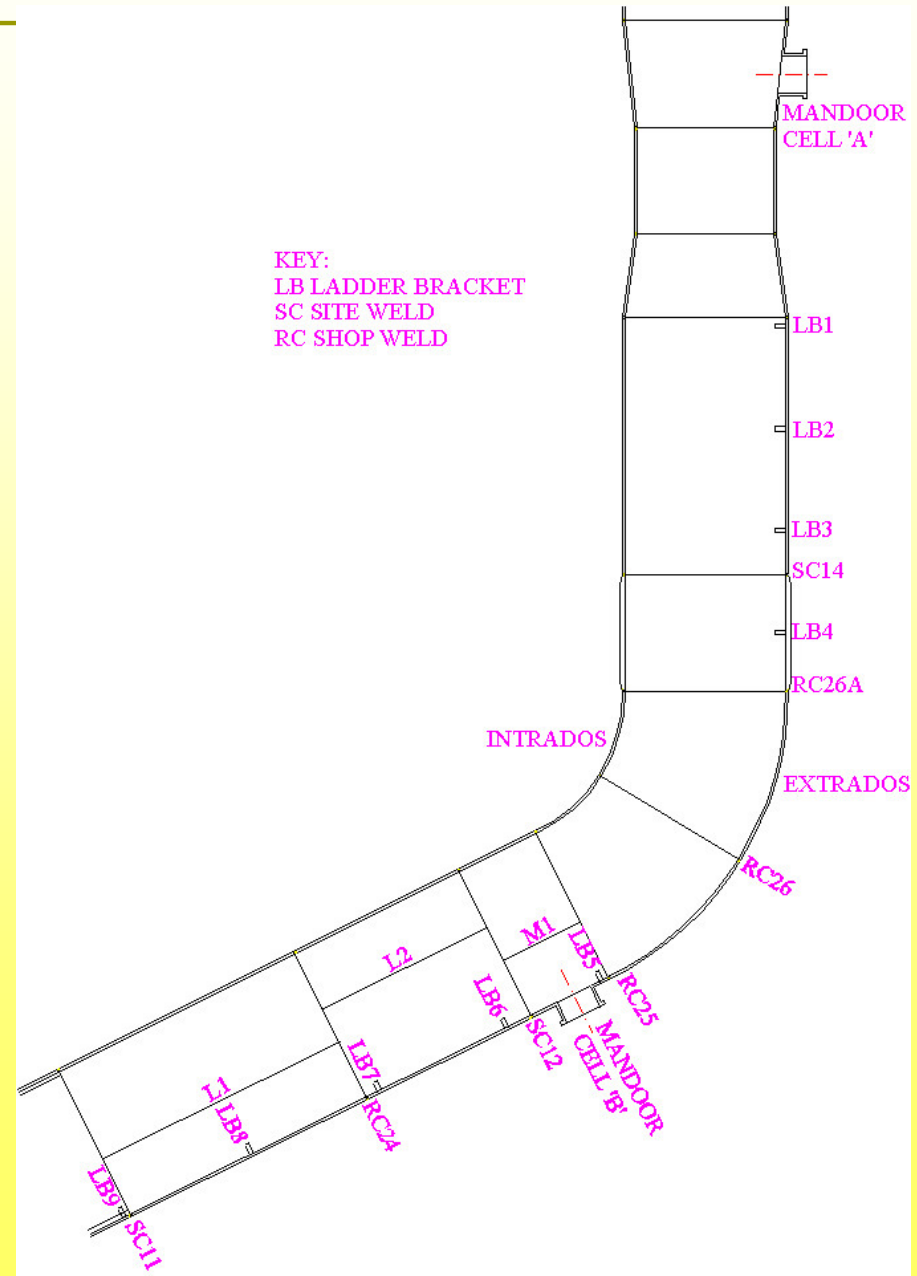


Background

- ❑ Magnox type Nuclear Reactors form the early generation of commercial nuclear reactors in the U.K.
- ❑ Non-Destructive Test (NDT) programmes were set up to inspect some early-built reactors to extend their life span.
- ❑ Two reactors were inspected by the walking and climbing robots:
 - Sizewell 'A' Power Station in Suffolk
 - Trawsfynydd nuclear power station in North Wales

Sizewell 'A' Power Station

- To perform NDT on various welds on the main reactor cooling gas ducts



Tasks

- ❑ The original task was to inspect various welds on the main reactor cooling gas ducts
- ❑ Removing unwanted objects on the duct surfaces which hindered the inspection

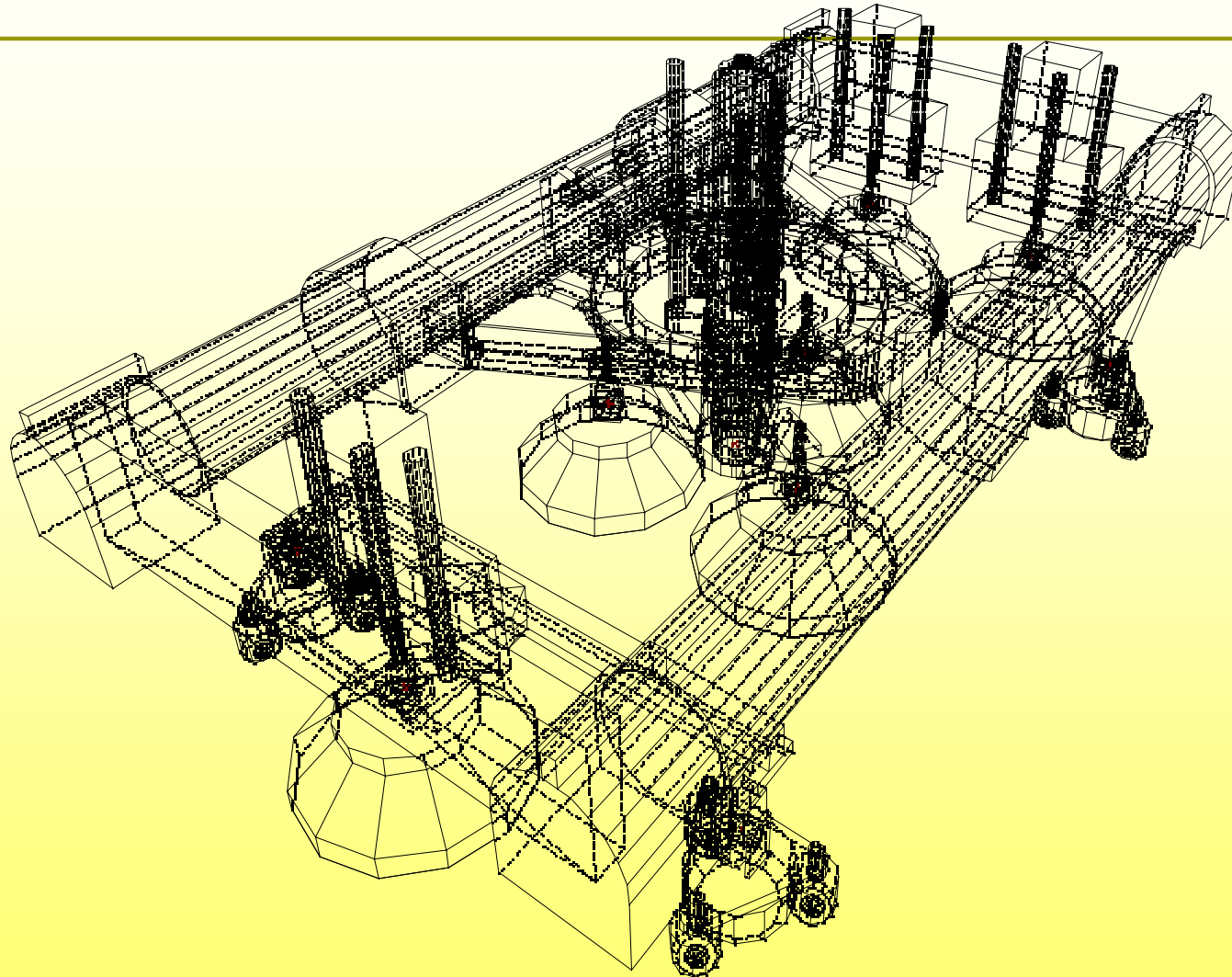
Main Difficulties

- ❑ Confined space – The robot was required to go through a small air valve
- ❑ The duct is actually connected directly to the Reactor Pressure Vessel (RPV) and hence no objects were allowed to fall into the RPV during the cutting operation

SADIE (Sidewell 'A' Duct Inspection Equipment) Robot System

- ❑ DC servo and pneumatic actuators
- ❑ Vacuum grippers for climbing wall
- ❑ Magnetic feet for safety and extra stability
- ❑ Self cleaning grippers
- ❑ Sliding frame moving mechanism
- ❑ Force controlled gripper feet
- ❑ Teleoperation
- ❑ Intelligent tool control

Mechanical Structure

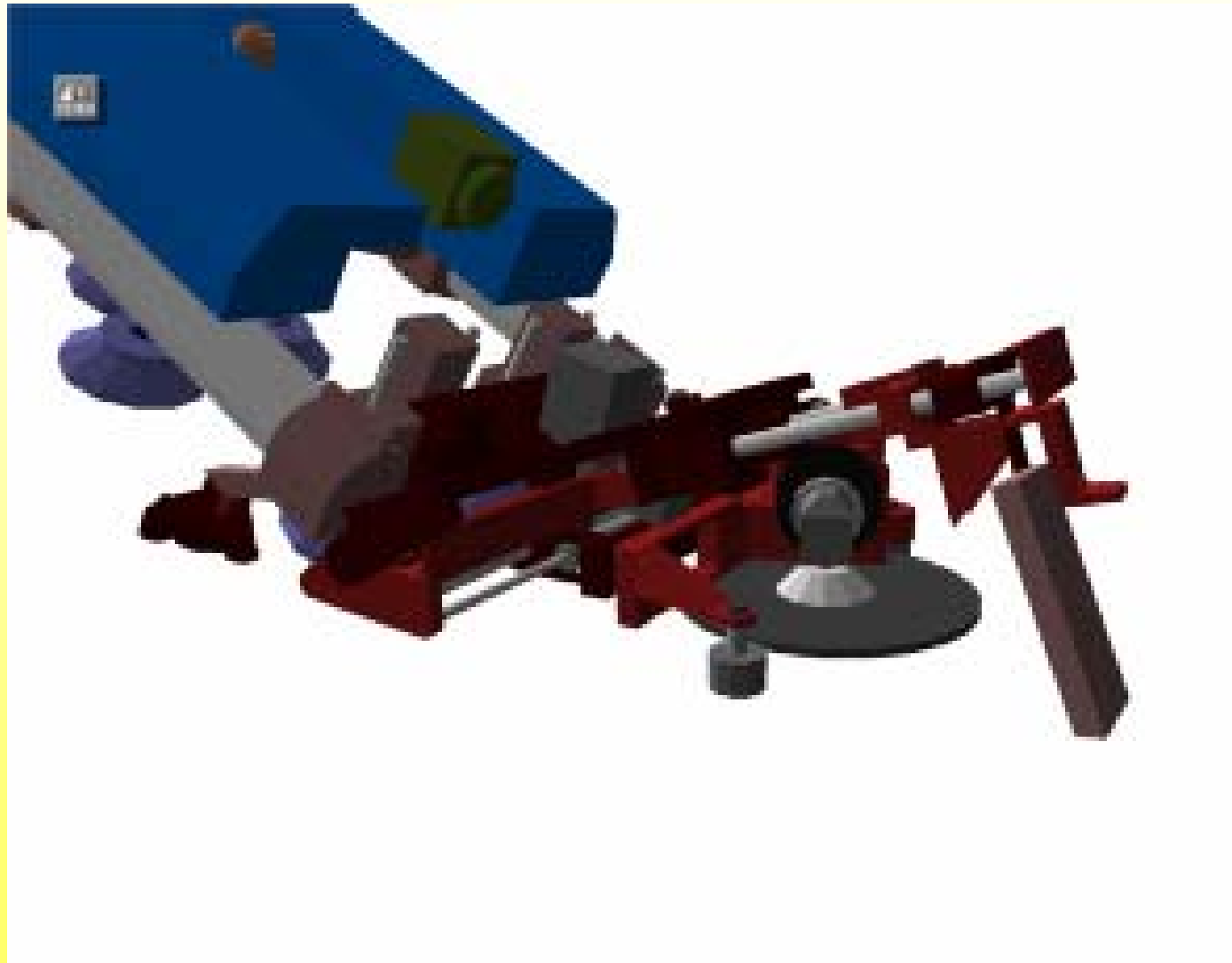


Dimension: 640mm x 400mm x 180mm

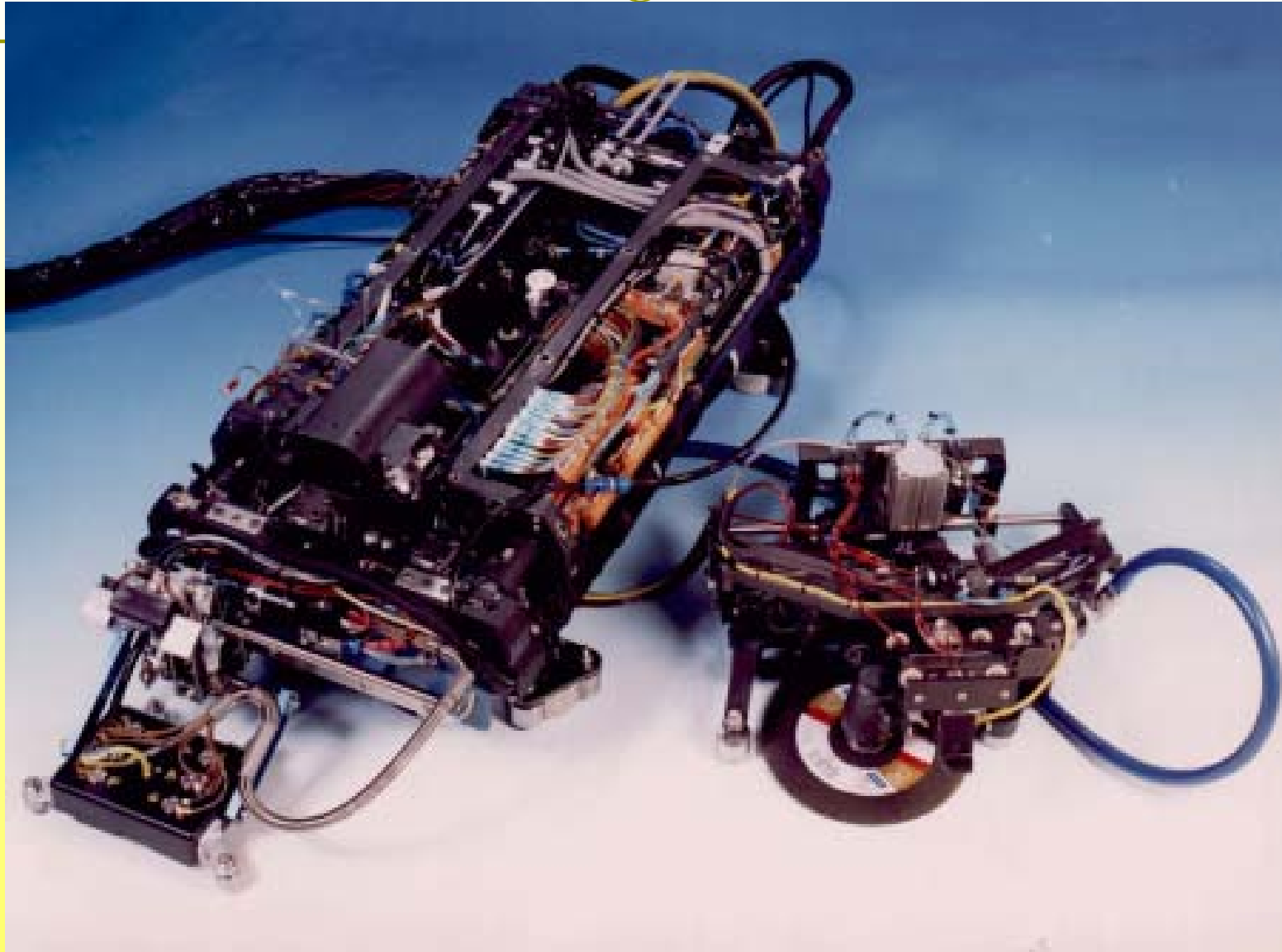
Control Console



Ladder Bracket Removal Package

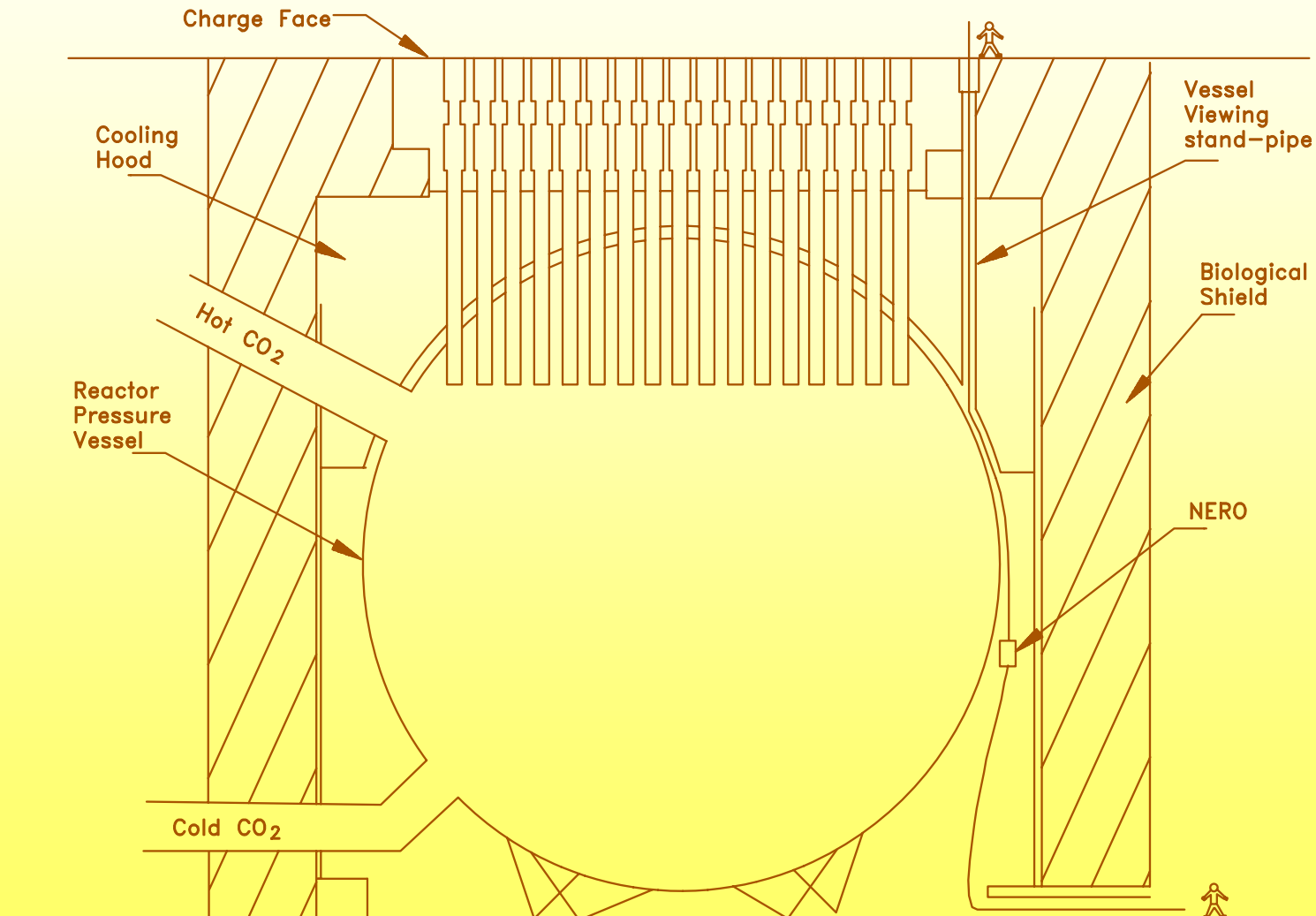


SADIE and Tool Packages



Trawsfynydd nuclear power station

- Add sensors to Reactor Pressure Vessel

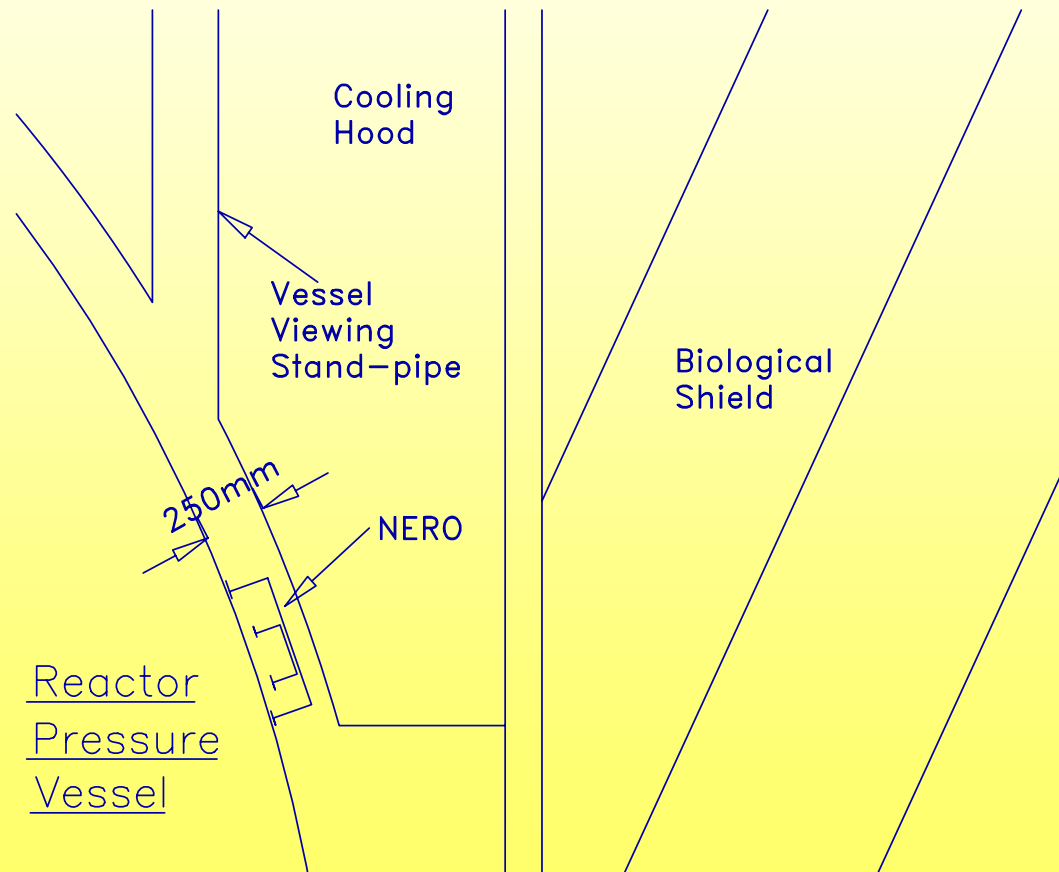


Tasks

- ❑ The original task was to install additional thermocouples onto the RPV surface
- ❑ Wire brushing – to clean the surface to ensure good contact with the thermocouples
- ❑ Metal cutting – to remove unwanted objects which hindered the installation of thermocouples

Main Difficulty

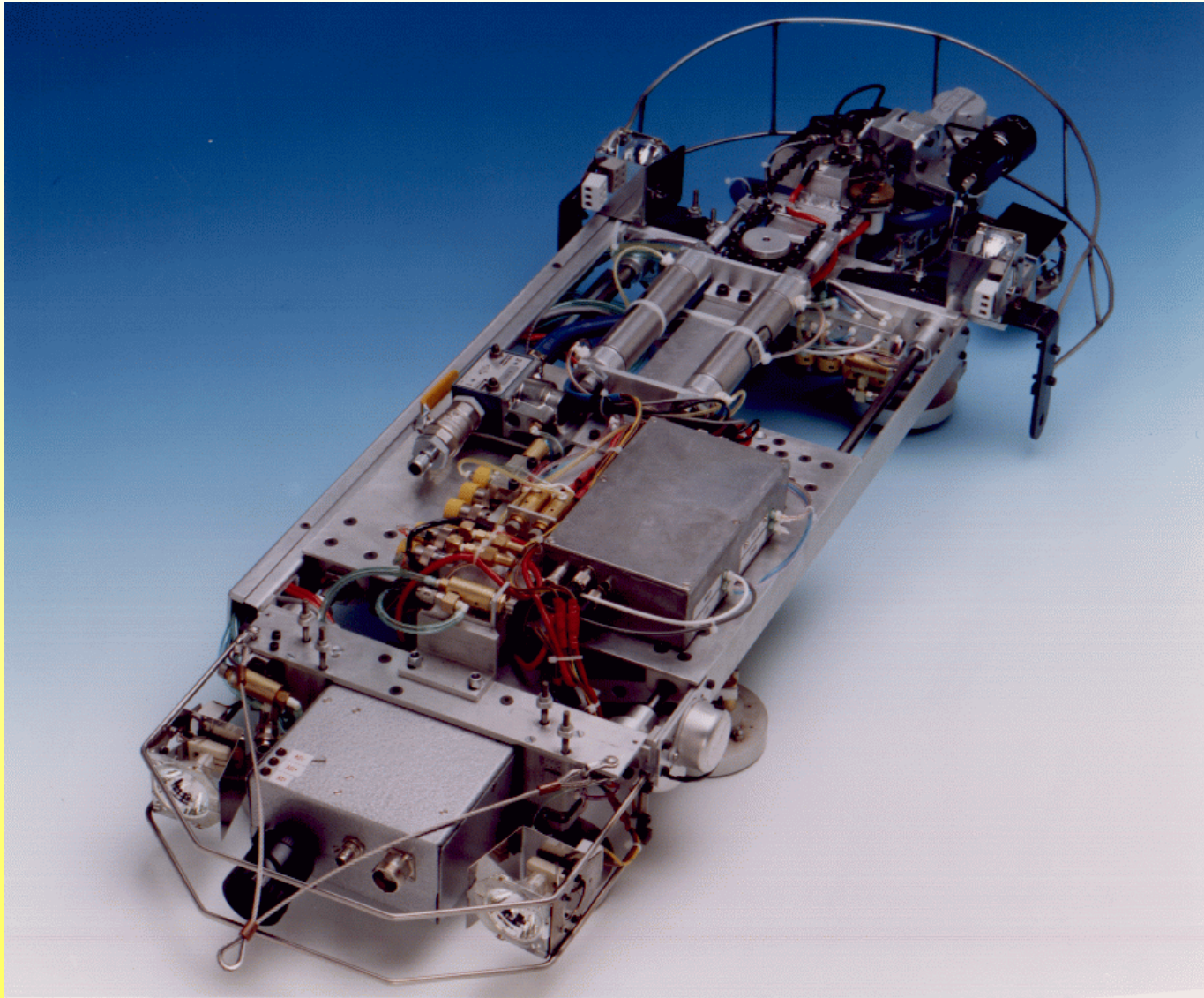
- ▣ The robots were required to work in confined space



NERO Robots

- NERO stands for Nuclear Electric Robot Operator
- Three NERO were built
 - NERO I carried a special tape feeder for installing additional thermocouples
 - NERO II had a rotating wire brush for removing loose materials from the RPV surface
 - NERO III had a 1.3HP rotary disc grinder fitted on a swing arm and was mainly used for removing unwanted studs and weld splatter from the surface.

NERO III



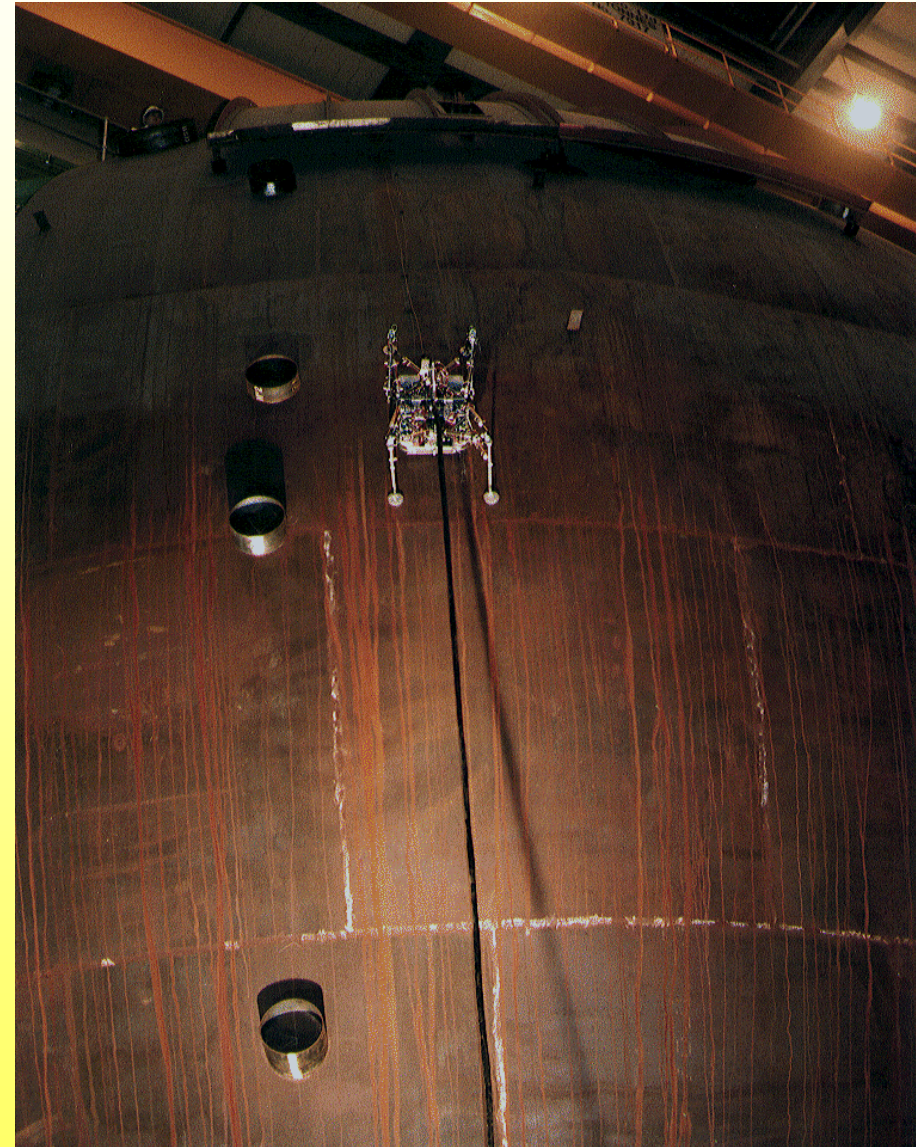
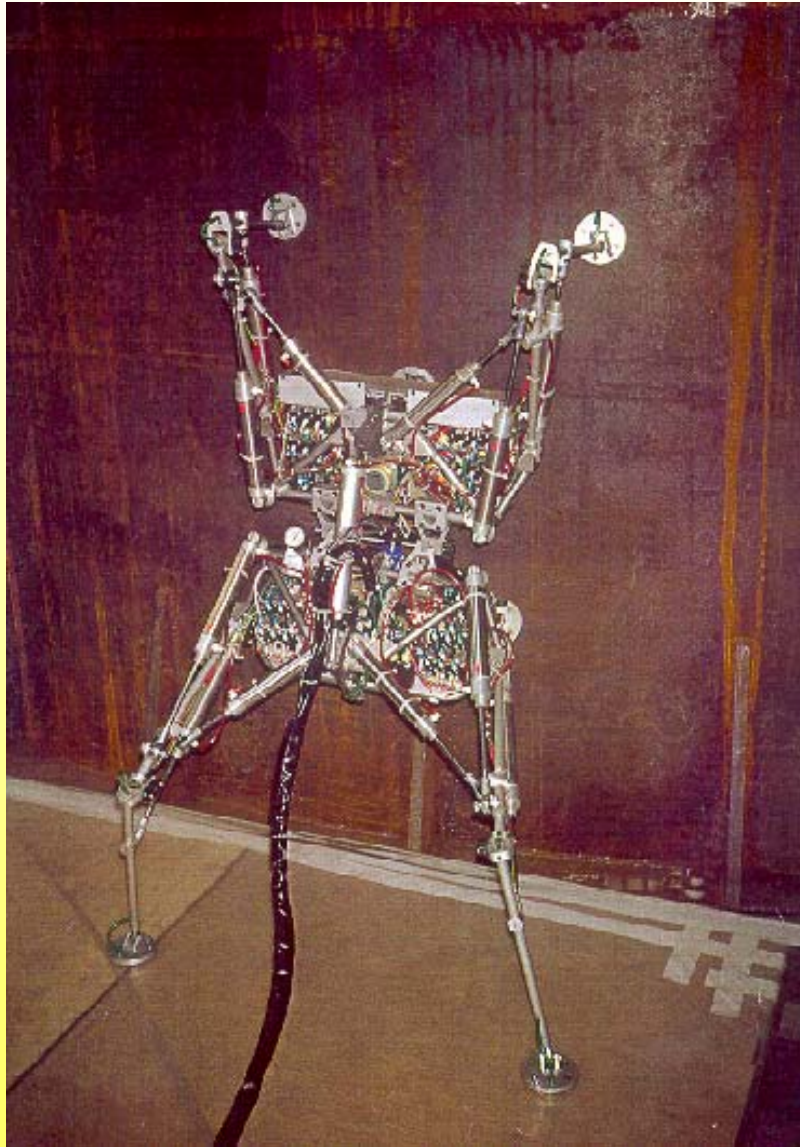
NERO III – Terminator!



Conclusions

- ❑ The robots have operated for hundreds of hours in main cooling gas ducts at Sizewell 'A' and on RPV at Trawsfynydd
- ❑ Remove many ladder brackets and unwanted objects
- ❑ Inspect many meters of welds
- ❑ Install thermocouples onto the RPV
- ❑ Prove its usefulness in remote inspection application especially in hazardous environments
- ❑ However, launching the robots onto the structures can be difficult

Robug IIs Intelligent Walking & Climbing Robot



Q & A

Thank You