FLAVIIR, AN INNOVATIVE UNIVERSITY/INDUSTRY RESEARCH PROGRAM FOR COLLABORATIVE RESEARCH AND DEMONSTRATION OF UAV TECHNOLOGIES

Aircraft Design, Systems & System Integration Session

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Abstract

A major research programme into advanced technologies for Uninhabited Airborne Vehicles (UAVs) in June 2004. The £6.5M, five-year project represents a major investment in aerospace technology for BAE SYSTEMS and their partner, the Engineering and Physical Sciences Research Council (EPSRC).

The focus of “FLAVIIR” is to develop technologies which support low cost (to acquire and operate) UAVs, together with the broader goal of improving the exploitation and hence impact of the research work completed through closer management of the research team. The project involves ten universities working together at two levels: inter-university collaboration within disciplines and inter-disciplinary collaboration both within and across university boundaries. This aspect makes the project particularly challenging for Cranfield, as it is managing the complete project (with BAE Systems) and is to deliver the benefits of these joint activities. This work leads to the integration of the technologies into a sophisticated flying demonstrator UAV which is scheduled to fly in 2009. A particularly challenging requirement is that the vehicle should demonstrate an entire flight cycle, without the use of conventional flap-type control surfaces.

The project now has more than 35 researchers working in subject areas ranging from novel aerodynamic techniques to develop control forces, novel flight control systems, to hybrid laser techniques to ‘write’ sensors and actuators directly onto carbon composite structures.

The paper gives a description of the new technologies being developed, their integration into a number of demonstrations and the plans for their culmination in the Demon flying demonstrator vehicle, which will be based on the Eclipse Vehicle. The paper will also discuss the equally important issues of integrating, a multi-university/Industry research team.

Background to the programme

Several years ago, BAE Systems made the strategic decision to focus it's University funding and support on a limited number of Universities (just 10 in the Aeronautical Engineering domain). It was also a strategic decision to get all of these Universities to work together through Cranfield University as a single 'Strategic Partner'.

This choice followed decades of collaboration between the company and Cranfield University, in research and education. The main educational activity is the Cranfield part-time MSc in Aeronautical Engineering for which BAE Systems has been the principle sponsor. This has produced more than 100 graduates, engaged at many levels within Companies. These courses have led to the design, production and flight testing of a number of piloted aircraft and UAVs as described in Ref. 1.

Figs 1 and 2 show the Eclipse and Kestrel jet-powered UAVs, which have been developed as part of this process.

Fig 1: Eclipse Jet UAV

Fig 2: Kestrel BWB Demonstrator UAV

The University, in conjunction with its own company, Cranfield Aerospace Ltd, have also produced a wide-range of UAVs.

These activities were important precursors to the FLAVIIR programme, because of its' emphasis on the important emerging subject area of UCAVs (Uninhabited Combat Air Vehicles).

The decision to include so many Universities in a collaborative programme was a bold step, in that for success, this relied on extensive collaboration between often competing Research Teams. It did recognise that it is usually impossible to get all the expertise in a single place and that collaboration is almost always a key success factor within Aerospace Companies.

The objective of this research programme is to develop technologies which would support the design of low cost (both to acquire and operate) flapless UAV's. Work includes fundamental aerodynamic research to provide control forces without the use of conventional flaps, coupled with developments in the areas of control systems, manufacturing engineering, structural engineering, the electromagnetic behaviour of these structures, and design optimisation. Additionally, the research programme includes demonstration of its' new technologies, ranging from simple bench tests through model aircraft flights to sophisticated autonomous flying vehicles. These demonstrations not only provide performance data of the new technology but also valuable research into the integration process itself and ensure that different University groups have a focus for serious collaboration. A total of fourteen research groups at ten Universities are involved in the five year programme, which has a total value of £6.5M ($11.7M). Two thirds of this funding comes from BAE Systems and one third from EPSRC and the programme will last 5 years (June 2004 to June 2009).

Stake Holder Benefits

BAE SYSTEMS has identified aeronautical engineering as an important area for the company, implying investment in research and skills to gain the necessary business returns. Almost all predictions of the UAV market potential are large, with rapid growth expected as the regulatory authorities allow greater freedom for autonomy. The Company has recently released information on some demonstrator UAVs. They started with the joint BAE SYSTEMS/Cranfield University KESTREL and then followed with the RAVEN/CORAX and HERTI vehicles. UAV applications will be diverse and varied and as such, any company wanting to exploit this market needs to be at the forefront of technology, with a flexible skill set and the ability to rapidly integrate new technologies into products. This has led to the 'Grand Challenges' laid down to the FLAVIIR programme:

Challenge #1 - To develop technologies for a low cost, maintenance free UAV without conventional control surfaces and without performance penalty'.

Challenge #2 - 'Significant research impact through effective academic/industry management and exploitation of large scale integrated academic research'.

BAE Systems is thus expecting that the FLAVIIR programme will deliver new technologies with significant market advantages and that, although the programme is unclassified, BAE Systems (and its suppliers linked with FLAVIIR) will be in the best position to exploit these developments quickly and effectively.

EPSRC sees FLAVIIR as an innovative research programme that will act as a prototype for large multi-University/Industrial collaborations. The individual technology areas will yield considerable innovative research, but their integration should produce a 'whole that is greater than the sum of the parts'.

It will also provide research into the ways in which Universities and Companies may collaborate more effectively.

The Universities' students and staff will gain considerable benefits from the FLAVIIR programme. They receive financial support for the employment of research staff and students. They also have the benefits of closer links with other Universities and BAE Systems, with potential spin-off programmes. They will obtain credit and profile from working on such a high profile and challenging project. Additional funds are available for short term related research topics under the 'Seedcorn' funding stream (see below). As the programme is partially funded by EPSRC, it also benefits from a significant number of Doctoral Training Accounts (DTAs), which further amplify research resources.

Programme Leadership and Management

To meet Grand Challenge #2, the management of the programme becomes very important. It has been recognised from the start that the whole programme is flexible. Any part of the programme can be stopped or re-directed if it is considered that either the research is unlikely to deliver or that it does not any longer meet BAE Systems or EPSRC objectives. This flexibility is not looked upon as a negative- rather it is seen as a positive ability for the researchers themselves to explore the latest thinking and pursue new collaborations within the programme. Encouraging new thinking and the ability to explore new ideas is seen as such a key criteria for success that there is £500,000 of seedcorn funding to be allocated across the network as the programme develops. This is a novel idea, certainly to EPSRC, allowing the management team to allocate a percentage of the total grant without further formal peer review. This has already provided successes and has allowed early model flights of flapless technology to take place at Manchester University (initially in June 2005).

The FLAVIIR programme is run by a Technical Director (a Professor at Cranfield), and a Technical Project Manager (from BAE Systems). It is overseen by an Independent Steering Group made up of senior figures from academia and industry. It is monitored by a Technical Committee (consisting of BAE Systems staff and representatives from each of the partner Universities).

A key aspect of FLAVIIR is to engage and involve potential suppliers to BAE Systems in the eventual exploitation of any new technology. As such, suppliers (and larger collaborators) have the ability to join the FLAVIIR network, where it is mutually beneficial.

The partner Universities are:-

- Cranfield University
- Imperial College of Science, Technology and Medicine
- The University of Leicester
- The University of Liverpool
- The University of Manchester
- The University of Nottingham
- The University of Southampton
- The University of Wales Swansea
- Warwick University, Warwick Manufacturing Group
- The University of York

Research Themes

The scope of aeronautical engineering is large and complex. Within FLAVIIR, the technical areas have been split into the seven themes shown in Fig 3.

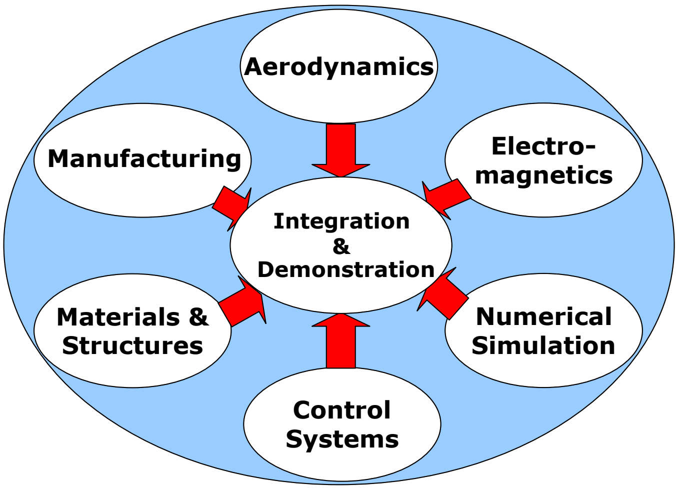

Fig 3 Research Themes

Aerodynamics: Here, research is being conducted into means of novel (flapless) control. In particular, at Manchester University research is being undertaken on circulation control and thrust vectoring (Fig 4).

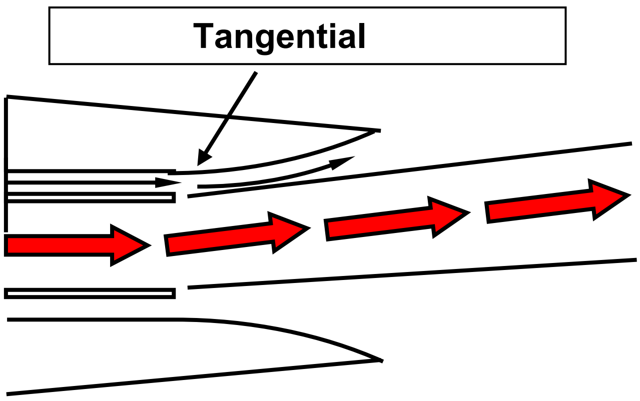

Fig 4 - Flapless Controls

A parallel study by Cranfield University has demonstrated thrust vectoring on a representative small UAV jet engine (Fig 5).

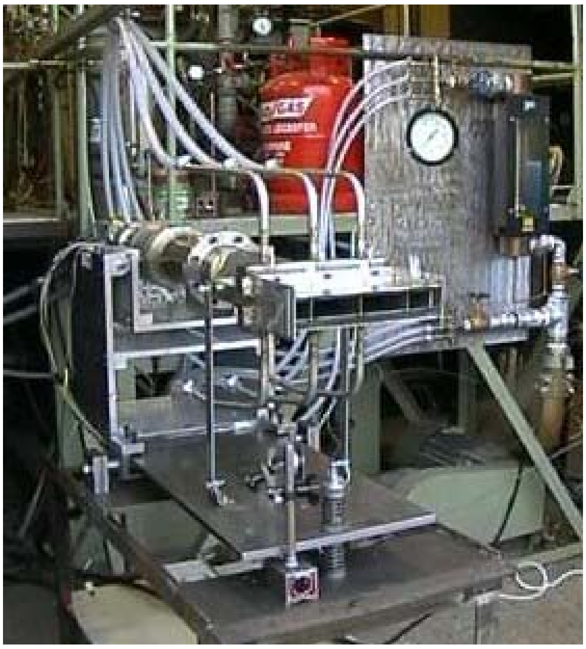

Fig 5

Coupled with these flapless devices needs to be the ability to control the aircraft and hence flight dynamics research is being undertaken. In particular, experimental facilities are being used at Cranfield and Manchester, together with evolving vehicle models.
Other flapless devices are also being investigated. In particular synthetic jets are being studied numerically by Imperial College, to determine fundamental physics and design parameters. Similar to synthetic jets, active dimples are also being researched. In this case, a depression in the surface is covered with an electro-active polymer which can oscillate from flush to the surface to a part spherical depression.

Electromagnetics: Here, predictive codes being developed by the Universities of Nottingham and Swansea. These will enable the rapid prediction of electromagnetic scattering and electromagnetic compatibility (EMC) issue to be explored. Verification of these predictions is being underwritten by detailed experiments at York University (Fig 6).

Fig 6 - Electromagnetics

Control Systems: Novel means of path planning and path following are being researched that will result in greater manoeuvrability and provable stability. Additionally, robust adaptive control is also being developed that will be resistant to damage and system wear by Leicester University and Imperial College (Fig 7).

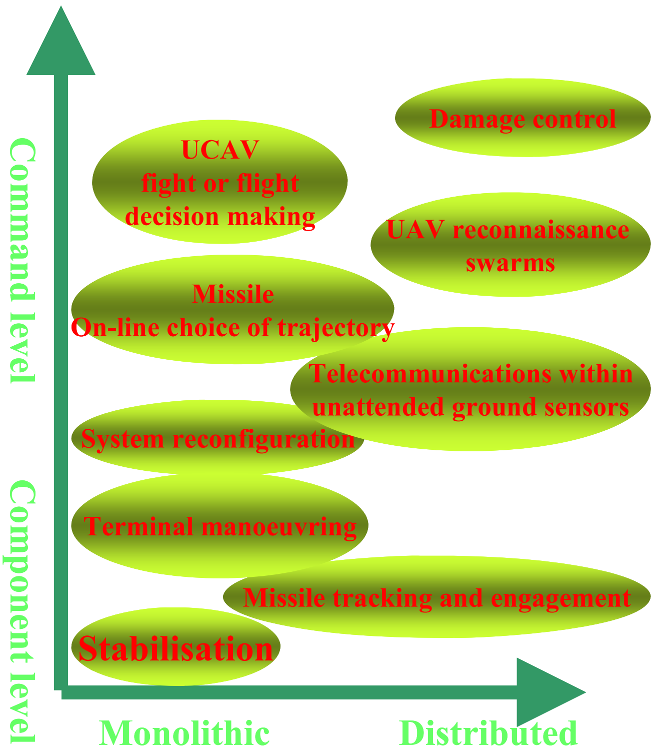

Fig 7

Manufacturing: Here the main focus is on methods to reduce the cost of the platform in areas such as adaptive and flexible tooling, low cost materials and manufacturing methods and methods that will give rise to very much less maintenance during the life of the aircraft. Collaboration is being achieved by teams at Warwick, Cranfield and Liverpool Universities. Fig 8 shows typical metal deposition work being performed by the latter University in conjunction with BAE Systems Advanced Technology Centre.

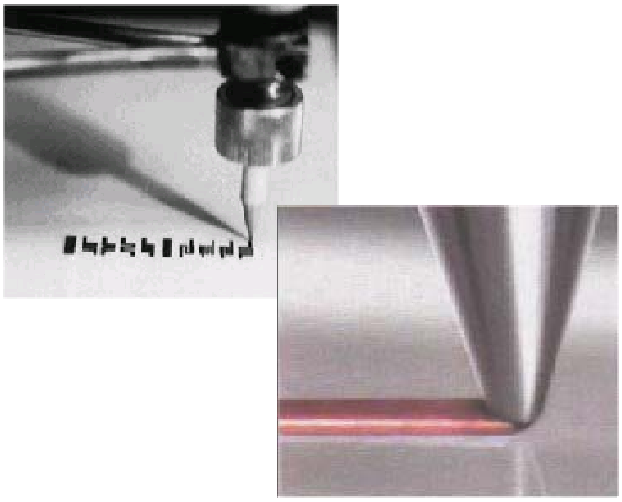

Fig 8

Materials and Structure: The main thrust in this area is the development of Imperial College's predictive tool for delamination and failure prediction within composites to thus create a virtual test facility (Fig 9).

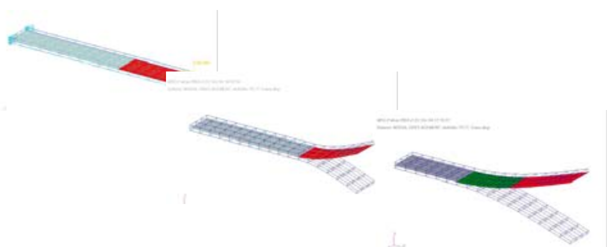

Fig 9

Numerical Methods: This area, lead by Southampton University, concentrates on the production of a concept design tool and framework based on geometry, and incorporating some cost modelling, especially with regard to the cost of integration, certification and the cost of unproven technology.

Integration: This area is treated as a research area in its own right. Within the programme it is generally added together with *demonstration* since this is usually where integration takes place. This is described in more detail below.

Integration and Demonstration

Clearly all the individual technologies being researched within FLAVIIR are new, exciting and could potentially deliver benefit to Stake Holders. However, there are a number of programmes that offer this (in other areas) already. What is novel about FLAVIIR is that it emphasises the integration of these technologies to form a usable system. Hence not only are the Universities asked to come up with clever ideas in their own fields they are also asked to demonstrate that they work together as a system – in this case a flying demonstrator.

This integration is important for BAE Systems since often good technologies fail to get developed due to lack of understanding of how they fit in with other systems. Furthermore, this integration can be expensive and time consuming if the integrators have not been involved in the technology development. Getting the University researchers to think about integration issues during development and ensuring that they perform realistic (flying) demonstrations solves many of these problems.

But how do you get 10 competing Universities to suddenly work together with a common aim? In the first instance, these Universities have been chosen carefully – for their high class technical skills in complementary areas and also for their record of being flexible and willing to collaborate. However, there remain many areas of expertise overlap, as indeed there should be to ensure rigorous questioning of approaches.

Cranfield University is leading a series of demonstration activities, ranging from computer models for individual technologies, test-bench hardware, flying models, an 'iron-bird' systems rig and ultimately, the representative flying demonstrator. The latter will incorporate as many technologies as possible, but these need to create a vehicle that is safe to fly means that some more radical technologies will have insufficient readiness for this vehicle. It has therefore, been decided that two further demonstrators will be developed. These are the ground-based technology demonstrator and a virtual demonstrator. These should lead to future programmes.

The culmination of the current programme, however will be the flight of the Demon 'flight demonstrator vehicle'. This is an extremely challenging task, as the aim is to demonstrate flapless flight from take-off to landing!

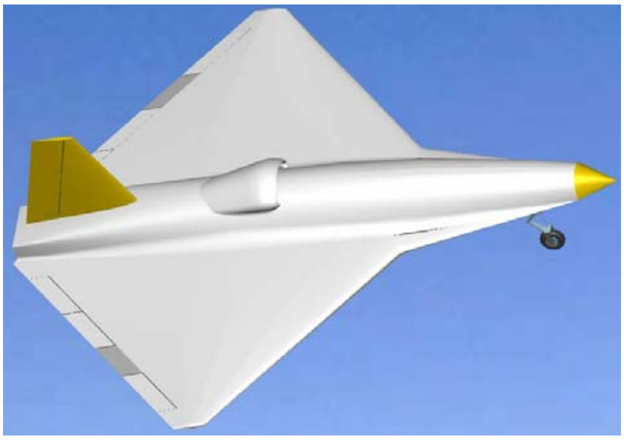

Fig 10

Fig 10 shows the initial configuration of the Demon jet-powered flying demonstrator aircraft, incorporating thrust vector and circulation control. This is being developed from the design of the Eclipse vehicle, but will be a new aircraft, incorporating space, mass and power provision for new technologies.

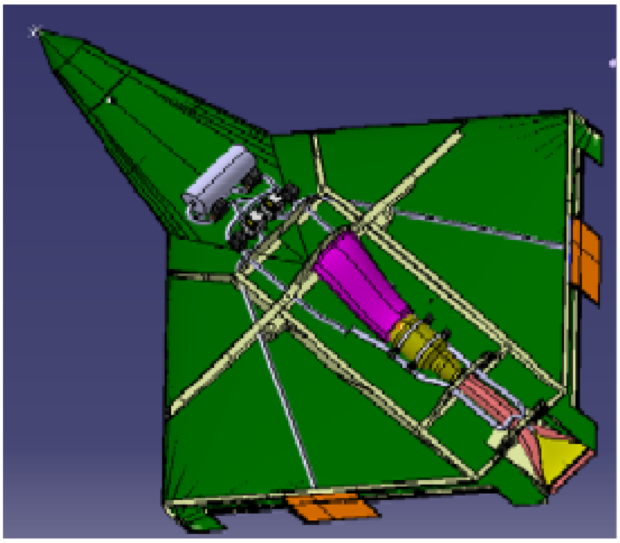

Fig 11

Fig 11 shows initial positions for the fluidic thrust vectoring and circulation control systems. The aircraft has a representatively challenging configuration and will utilise many features of modern UAVs. This vehicle has significant inertia, and an installed jet engine, with consequent temperature and vibration issues. The vehicle is being designed to be flexible so that it can incorporate newly-developing technology within and beyond the FLAVIIR programme. Fig 12 is a schematic indication of the main integration activities that will be demonstrated in the flying demonstrator, but the list is growing.

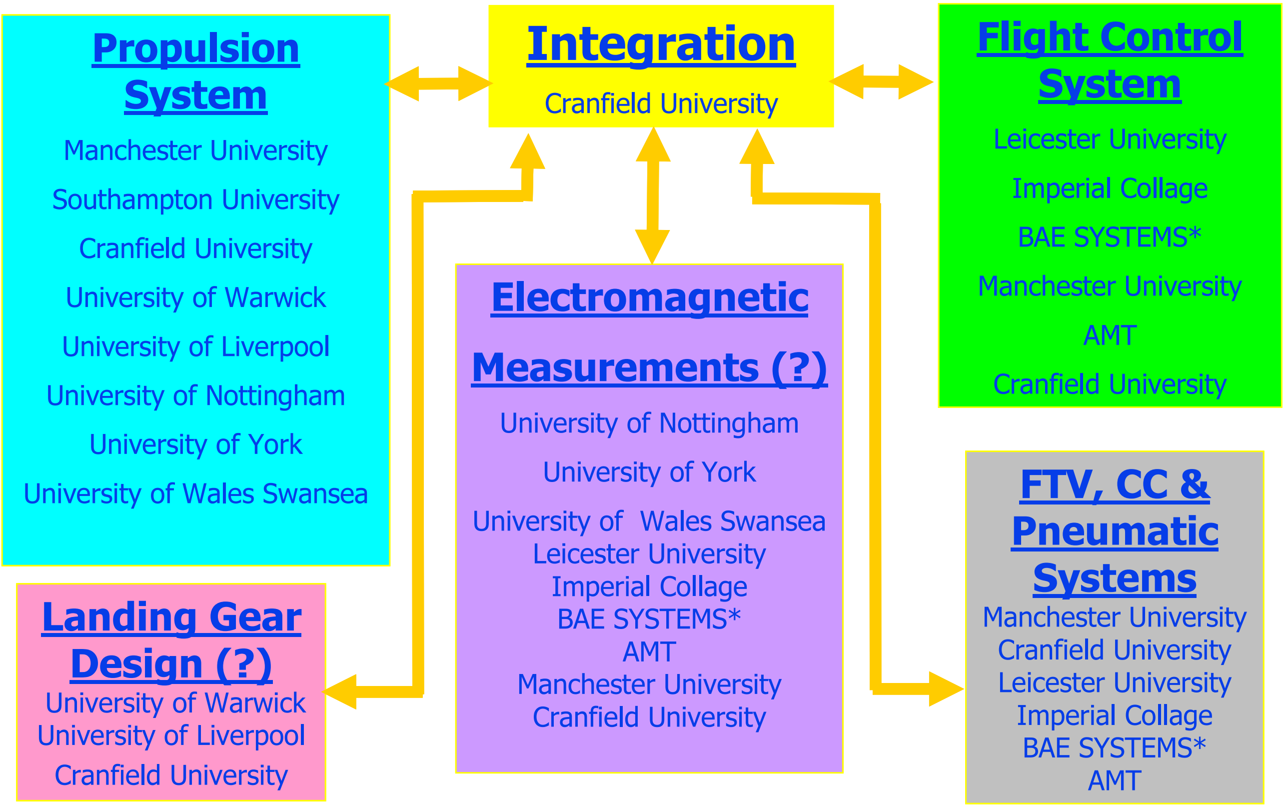

Fig 12

The Demon has had it's concept review and work is proceeding towards the Preliminary Design Review (PDR). It is hoped to perform instrumented flights of the Eclipse vehicle in the near future. This will provide important data for the partner Universities working on the flight control systems.

The overall objective is something that has to be put together by more than one University making integration essential. In addition, there is so much publicity and credit given for integrated technologies that there is a healthy competition amongst researchers to ensure that their particular work area is seen on the demonstrator. Couple this with the seedcorn and DTA funding which is heavily biased towards collaborative studies and there is very little of the FLAVIIR programme that remains in isolation.

Conclusions

After much background work, the FLAVIIR Programme was started on June 1st 2004. After more than 2 years there has been significant progress, aided by three conferences and many integration visits. The original Academic Technical Director made the following observations (Ref. 2):-

> 'The project is still very much in its infancy, but we have already made progress in developing both the framework for the research and the project team. Although a new concept, and audacious in its goals, this demonstrator led project represents a new model for future research which has a very good chance of success. This is in part because the strength of the team which has been assembled ensures that the research delivered by the team will be of a very high standard. The 'glue' that binds the project

together is the flying demonstrator which is providing a goal for the academic team and a physical demonstration of the readiness of the technology for the industrial partner'.

Subsequent work is confirming these predictions.

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