

Project GREENGLOW Its origin & further work

By Ron Evans

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First of all, I wish you all a very happy New Year for 2021.

I must thank Tim Ventura of American Antigravity for suggesting that I should give a presentation about the origin of Project Greenglow. I've also taken the liberty of adding some further ideas.

Slide descriptions

SLIDE 1

I joined British Aerospace, or BAe, in 1978 as an expert in fluid mechanics. But, as a mathematician working in industry I was required to work on other subjects, too. When I retired from BAE Systems in 2005 it was as a mathematical factotum.

The BAe gravity study began with my investigation of gravity as a possible disruptive technology. As the study grew and became Project Greenglow it collected a small band of BAe engineers interested in the idea of a breakthrough in gravitational physics. The work on Greenglow was a part-time activity for all of us.

The senior management had opposing views about allowing the work to proceed. On the one hand it appeared to be linked with anti-gravity, which, they worried, might open up BAe to ridicule. On the other hand it showed that BAe was looking into the distant future. Both sides agreed that the subject was in the province of university research departments. But, could BAe stimulate interest in the gravity study with some small amount of funding?

In fits and starts the BAe gravity programme developed. As it did so it began to take up a lot of my free time, too. And it still does. But I find it a fascinating subject, as you watching this presentation must find it, too.

SLIDE 2

Mathematicians love patterns. Analogues in physics are helpful in spotting what is missing in different phenomena.

The left hand column shows fluid dynamics. At the top is a static source with streamlines pointing outwards. On a streamline the fluid has velocity \mathbf{v} . There is also a sink, where the streamlines point inwards.

The line vortex is surrounded with streamlines around it with velocity \mathbf{v} . Grip the vortex with your right hand so that your fingers curl round in the direction of the fluid velocity. Your thumb points in the direction of the vortex core. This is called the curl of the velocity shown by the mathematical symbols at the top of the vortex. Note that there is no vorton current. If you stretch the vortex it gets stronger and the streamlines speed up. If you compress the vortex the streamlines slow down.

We also have a vortex ring with streamlines passing through it, forming a virtual source on one side and a virtual sink on the other.

The central column shows electromagnetism. For static electricity we have positive and negative charges. For magnetism we have positive and negative magnetic poles which always appear together.

A straight line of moving charges, forming an electric current i , creates a circular magnetic field around it. The curl of the magnetic field is as shown.

A ring current creates an electromagnet with a pair of virtual positive and negative magnetic poles.

The column on the right is for gravity. Positive mass is a gravity sink. We don't know whether real negative mass exists. Nor are we aware of gravitomagnetic poles. Following the pattern with electromagnetism suggests that a mass current I creates a

gravitomagnetic field around it. We are not aware of it. Leibniz introduced vis-visa, or mass times the velocity squared. Half of vis-visa is kinetic energy. Using kinetic energy we can describe mass dynamics without using gravitomagnetism. But the energy contained in the gravitomagnetic field is equal to the kinetic energy of the moving mass.

A changing magnetic field creates an electric field. This suggests that a changing gravitomagnetic field creates a gravity field. To understand how to control gravity we must investigate gravitomagnetism. Examining the gravitational analogue with electromagnetism might provide us with some clues leading to ideas for experiments.

SLIDE 3

As a research fellow at Leeds University I had been modelling vortex separation from wings under a contract from RAE Farnborough. So I had hoped to work with the Computational Fluid Dynamics Group at BAe Warton working on modelling air flows around aircraft.

However, I started work in the Performance and Propulsion Group. The Group Leader was a former Leeds University graduate. I became a member of the Drag Section, where I was primarily involved with wind tunnel data analysis.

SLIDE 4

In 1979 a photo of a UFO flying over the North York Moors was sent to the Publicity Department at BAe Warton. “Is it one of yours?” they wanted to know. No one at BAe knew what it was.

The next year the Chief Aerodynamicist attended a briefing at RAE Farnborough, where he learnt about the F117 Stealth Fighter. Now we knew what the photo of the UFO was.

As a mathematician I had studied electromagnetism, so I was chosen to investigate stealth features and provide an update for the Aerodynamics Office. I formed a Stealth Programme and arranged for the development of a mathematical model to provide radar signatures.

I soon learnt that in the 1950s the UK was a leader in stealth technology. Bombers in particular had been treated for radar stealth. I met Grant Dawson in London, who had led the MoD “Low Radar Echoing Area” programme.

I visited the EMI scale model radar range, near Bristol, to learn about the radar signature of aircraft. The lead researcher was Sid Woolcock and the lead mathematician was Dudley Bird. The intake duct was the largest radar reflector.

The Tornado aircraft was intended to ground hug and fly under radar surveillance. So, stealth had not been a major factor. I remember climbing inside a Tornado duct to see where we could stick radar absorbing material (RAM) to reduce radar reflections.

I visited the Plessey Company to learn about RAM. The lead researcher was Bernard Wickenden, who had visited Germany in 1946 to see how the Germans made RAM for use on their submarines and night-fighter aircraft.

1982 was a busy time for Plessey as they were providing RAM for ships of the Royal Navy fighting the Falklands war.

SLIDE 5

In 1983 I was told by phone that I was to be transferred to the Advanced Technology Group (ATG) as they needed someone to sort out their millimetre radar data.

I went to see the Chief Aerodynamicist to say that I didn't want to go. He said that BAe had plenty of managers, but not enough mathematicians. I would have to go and he would appoint a new manager for the Stealth programme that I had set up.

The ATG Chief was Tom Smith. He led the MUSTARD UK space programme in the 1960s. There is a model of it in the Smithsonian in Washington. The programme stopped when the UK Government withdrew its support. Later, in the 1980s, he led the HOTOL space plane programme.

I was required to analyse the ATG millimetre wave radar data and make it compatible with radar data collected by other companies in the UK and the US. The aim was to be able to identify the radar signature of enemy tanks. I obtained a RSRE Malvern contract to do the work. During this time I took part in low flying trials over Norwegian forests collecting more radar data.

I completed the radar data analysis and provided a means of making all data compatible. I was then employed on several other studies on-going in the ATG.

In 1986 I went to the ATG Chief and suggested that low radar signature technology might be countered in the future by using mass signature technology. He gave me permission to carry out a study and report back on my findings.

SLIDE 6

In December 1986 I visited Professor Laithwaite at Imperial College in London. I wanted to know his opinion about the analogue between gravity and electromagnetism. He was fully aware of the analogue and thought that the movement of a gyro might be explained in this way. He was also interested in the idea of using inertial thrust machines for propulsion. A number of patents already existed for such machines.

Earlier, in 1974, he had faced a barrage of criticism at a lecture at the Royal Institution in London when he had made some of his ideas public. The lecture was not published by the RI, but many of his ideas were given in his book.

We discussed the GEM equations containing the curl terms missing in Newtonian mechanics. Earlier both Maxwell and Heaviside had considered the GEM equations.

Assuming low mass velocities the GEM equations can be derived from Einstein's equations for general relativity.

Gravity is equivalent to acceleration. Both are vectors. But gravity possesses a field property, while acceleration does not.

A spinning flywheel creates a gravitomagnetic field. However, externally the induced gravitomagnetic field is tiny because the gravitomagnetic permeability of space is so small. The spinning flywheel also has an angular velocity. An induced gravitomagnetic field is equivalent to an angular velocity. But angular velocity does not possess a field property. Its effect must be imposed by direct contact. The movement of the gyro is the result of two vectors in contact. I think that this is what led Professor Laithwaite astray.

SLIDE 7

In late 1989 we had the opportunity to investigate Sandy Kidd's Inertial Thrust Machine. It was much in the news at the time and had been under test at Dundee University.

The tests were carried out by wind tunnel instrumentation engineers. The machine was suspended on bungee cord and connected to a load cell. The device underwent large vertical accelerations, but whether it changed weight was inconclusive. During a second series of tests in July 1991 one test seemed to show that device changed weight. But it was not repeatable and was put down to an instrumentation glitch. Unfortunately, July 1991 was not a good time for BAe to be seen doing anti-gravity tests.

SLIDE 8

In August 1989 I visited Dr Bob Forward at his holiday home on the north coast of Scotland. Dr Forward had worked with Professor Joseph Weber on detecting gravity waves.

In a paper published in 1961 he showed that using a toroidal winding with a changing current created an electric dipole field. Therefore, based on an analogue between gravity and electromagnetism, it ought to be possible to generate a gravity dipole field, too. In fact, since electrons have charge $-e$ and mass m_e , then creating an electric field \mathbf{E} must combine with creating a \mathbf{g} field, too.

In his paper he gave an approximate value for the strength of the \mathbf{g} field. Since it depended on the gravitomagnetic permeability, η , of free space he concluded that the idea was unworkable.

In free space the relative magnetic permeability of most materials lies between 0 and 1. For mu-metal the relative magnetic permeability is about 50.000. Bob Forward worked at the Hughes Research Laboratory. Did they develop a material with an extremely high gravitomagnetic permeability to make Forward's toroid device a feasible gravity dipole? Such a device would provide propulsion.

SLIDE 9

Tom Smith retired in 1990. The new Chief of the ATG decided on Future Business Strategy as a new name for the group. I was allowed to continue with my gravity study as plans had already been made for a meeting with several university groups.

We met in March 1990 and I wrote up a report of the meeting. The details of what were talked about are on the slide. I spoke about the GEM equations and Faraday's gravity experiments done between 1849 and 1859.

The BAe Warton Library put my report on the exchange list with NASA reports.

I was surprised that the Technical Director took an interest in my report. But, he was a nuclear physics graduate.

SLIDE 10

There was a close link between Salford University in Manchester and BAe as BAe apprentices studied there.

The Technical Director was about to change jobs and become the Director of Strategic Projects. He was invited to become the Visiting Professor of Aerospace at Salford University. This required him to give an inaugural lecture. He decided to base his lecture on my gravity study.

He arranged for an engineer in the Future Concepts Department to design an anti-gravity stealthy fighter aircraft. As you can see, it was a hybrid design with an enclosed gravitational lift engine, based on Forward's toroid, and two conventional jet engines for forward thrust. A BAe artist then painted a picture of the aircraft. The Director said it didn't look very futuristic. He suggested adding some green rays to simulate an anti-gravity effect.

I was sent to the Salford University to explain the GEM equations to them. Once they were satisfied with the theory the Director felt safe to give his surprise lecture, entitled "Anti-gravity! The end of Aerodynamics?"

The Director was very pleased with the response to his lecture, which he repeated elsewhere. Then he was interviewed on the radio. This led to press headlines stating that BAe had an anti-gravity programme.

When Nick Cook, of Jane's Defence Weekly, contacted BAe to write an article about BAe's gravity programme he was passed on to me. The Director had had his fun. Later, Nick Cook wrote his successful book, *The Hunt for Zero Point*, investigating whether the Germans developed gravity propulsion during the War and whether the USA had obtained the technology.

SLIDE 11

The start of the 1990s was a difficult time for BAe. At one time it looked like BAe might be bought by GEC. By then I had been running a small group called Exploratory Studies in the Advanced Technology Department. We even had a small 4-legged robot walking around the Department. This was frowned on by some, given the difficult times. Then the redundancies came. My small group was closed, with most members accepting redundancy.

I survived by moving to the Strategic Liaison Office where I looked for links between University research programmes and BAe. It didn't last long before I was told that I was to be made redundant. I contacted the engineer who had taken over as manager of the Stealth programme and he found me a job.

By the late 1990s things had become steadier. The role of mathematician is not considered to be that of an engineering specialist. However, I was made an Adviser in the new Technologist Career structure.

In 1980 BAe HQ, in London, had stripped BAe Warton of much of its research money and passed it to the former Dynamics (Missile) research centre in Bristol, which became the BAe research Centre. I was interested to learn that the Warton Technologists had been granted a small amount of their own money for funding research.

SLIDE 12

In 1997 I arranged for John Allen, formerly the Chief Future Projects Engineer at BAe Kingston, to give a talk about the long term future of Aerospace to the BAe Warton Future Concepts engineers.

John had a long interest in the possibility of gravitational propulsion.

I arranged for John to produce a report investigating the design changes in military aircraft resulting from the availability of an anti-gravity drive.

Faraday searched for a link between heat and gravity. I persuaded Professor Phil Bissell of UCL to carry out a small experiment looking for a link between magnetism and heat. It turned out that such an effect had been discovered in 1887 by Leduc, but not for the reasons we expected.

In July 1997, along with Walter Johnston from Operational Analysis at Warton, I visited the Gravitational Physics Group at Lancaster University led by Professor Robin Tucker. We discussed the idea of setting up a gravitational physics programme with shared funding.

I submitted a request to the Technologists' research panel for funding a gravity research programme jointly funded by Lancaster. It was approved under the name Project Greenglow. Professor Tucker was the Academic Adviser and Professor Allen agreed to be the Design Consultant.

The programme started in November 1997. We also arranged a gravity lecture series, the first one being given by academics from Greece. The EW &TF (Electronic Warfare and Test Facility) at BAe Warton set up a Greenglow website which was quickly swamped with requests for information worldwide.

In January 1999, on advice from the MoD, we added the study of a photon drive to the Greenglow programme. The work was done at

Dundee University by Dr Paul Smith and Professor Sergei Vinogradov and was based on earlier Soviet research. Testing was done at Strathclyde University by Professor Alan Phelps.

In November 1999 we began funding a part-study of the Podkletnov effect. Dr Evgeny Podkletnov, a Russian scientist, suggested that a spinning superconducting YBCO disc might provide a shield from gravity. In the absence of negative mass gravity shielding is not theoretically possible. Dr Podkletnov gave a lecture at Sheffield University about his work. Also, with MoD permission, I arranged for him to visit the BAe Warton site.

The Sheffield research work was led by Dr Clive Woods. No effect was detected. But, look at the Podkletnov device. Is it a version of Bob Forward's toroid? Podkletnov said that greatest change in weight of the test mass above the spinning YBCO disc was during YBCO disc braking, when the currents to the 3 solenoids were changing. Does superconducting YBCO have a high gravitomagnetic permeability?

SLIDE 13

November 1999 saw the formation of BAE Systems and with it came redundancies. During 2000 all research funding of the merged companies was frozen.

All company research came under the jurisdiction of the former two company research centres, now referred to as Advanced Technology Centres, with Dr Brian Wardrop as the Chief ATC scientist.

The ATC requested that a Goals & Metric study should be carried out for Project Greenglow. This was done by Glasgow University; the study being funded by BAE Systems and Rolls-Royce. The study proposed that more emphasis should be given to investigating quantum effects of gravity, particularly Zero Point Energy of the vacuum and its link with inertia. This was an idea proposed by Hal Puthoff and his colleagues.

The ATC agreed to provide funding support for Project Greenglow for 3 years.

In terms of quantum effects associated with gravity, I persuaded Dr Clive Speake, at Birmingham University, to carry out a study of the Casimir effect.

Professor Robin Tucker and a small team from Lancaster University travelled to the University of Canterbury, in Christchurch NZ, where the World's largest Ring Laser Gyroscope UG-1 is sited. They were looking to detect the Earth's gravitomagnetic field.

In September 2000 Marc Millis brought his NASA BPP team to BAE Systems Warton and we discussed our joint gravity programmes.

In January 2001 I attended the 1st Field Propulsion Conference at Sussex University. It was organised by Graham Ennis. It was attended by many well-known scientists presenting their own speculative ideas on means of field propulsion.

SLIDE 14

In 2002 I wrote a report suggesting that we should carry out a modified repeat of Faraday's 1st gravity experiment. But the budget for Project Greenglow was fixed and there was no way of funding further experiments. Project Greenglow closed at the end of 2004. I retired from BAE Systems in February 2005.

Although Greenglow had not led to any breakthroughs in the understanding of gravitational physics, I thought that we had run an interesting programme. I wrote the book to leave a record of what we had done.

Soon after publication I was contacted by Steve Crabtree, asking whether I would be willing to participate in a BBC Horizon documentary about Project Greenglow. I said yes. I had been contacted twice before by previous Horizon editors, but declined their requests because I knew senior BAe managers would complain.

BAE Systems HQ placed an embargo on any BBC filming on their sites. I enjoyed taking part in the making of the programme. Topics covered are given in the slide, which included visiting Porton Down, the MoD's scientific research centre. The voice-over was done by Peter Capaldi, the 12th Dr Who, from a popular science fiction TV programme in the UK. Although the documentary was based on my book, there was no mention made of it in the programme, nor in the end credits.

I'm now in the finishing stages of publishing another book. It's entitled Gravitomagnetism. I think that once we have got to grips with gravitomagnetism and can detect it in a laboratory on Earth it will open up the way to gravity control and, among other things, will lead to a means of gravity propulsion.

SLIDE 15

You will recognise most of the methods used to detect a magnetic field. I will say more about Faraday rotation later.

Angular velocity is equivalent gravitomagnetism. Although spinning bodies have a gravitomagnetic field, the property is not used to detect rotation. Direct contact is used, instead.

The axle of a free rotating flywheel remains pointing in a fixed direction in space. But viewed by an observer fixed on the rotating Earth the axle direction rotates, thus detecting the Earth's rotation.

Angular velocity is a vector. Vector addition is used to determine the movement of a spinning flywheel when rotated about another axis. So movement of the flywheel axis detects the presence of an applied rotation.

The Ring Laser Gyro uses the Sagnac effect. Reflected laser light in a rectangular cavity forms standing waves. Movement of the nodes passing a peep-hole detects rotation of the Ring Laser Gyro.

The Fibre Optic Gyro detects its rotation by detecting the phase shift between counter-rotating coherent light beams.

Finally we can use the gravitomagnetic field of a spinning body to detect an external gravitomagnetic field in space. This is analogous to placing a search coil in a magnetic field. A spinning body has a gravitomagnetic dipole moment \mathbf{k} . Placing a suspended spinning body into a gravitomagnetic field \mathbf{h} it will experience a couple $\mathbf{k} \times \mathbf{h}$ forcing its axis to turn.

We could replace the spinning body with a Ring Laser Gyro in space. If fixed on the Earth the Gyro would detect the Earth's angular velocity $\mathbf{\Omega}_E$ combined with the gravitomagnetic field \mathbf{h}_E due to the rotation of space around the stationary Earth. Trying to separate \mathbf{h}_E from $\mathbf{\Omega}_E$ is exceedingly difficult.

SLIDE 16

The model of the gravitomagnetic field of the Earth is based on a spherical mass separated into spinning discs, each forming a gravitomagnetic dipole. Summing the results gives the Earth's gravitomagnetic field \mathbf{h}_E . In the NASA satellite experiment a spinning mass, the size and shape of a table tennis ball, is placed in the Earth's field \mathbf{h}_E and the resulting couple causes the axis of the spinning mass to change. The effect is tiny.

The NASA experiment was the first to detect gravitomagnetism and space-time warping by the mass of the Earth. The latter effect is non-linear and is not predicted by the GEM equations. The experiment took 40 years to complete and cost \$750 million. Eighty students gained PhDs working on the experiment.

Because the gravitomagnetic permeability, η , of space is so tiny, it is impossible to detect the interaction between two spinning masses, both the size of table-tennis balls.

Professor Tucker visited the UG-1 Facility in NZ and tried to separate \mathbf{h}_E from $\mathbf{\Omega}_E$, but without success.

The external induced gravitomagnetic field of the Earth is very small.

SLIDE 17

We know that a mass falling in Earth's gravity field is weightless. But to cancel the Earth's gravity field requires another gravity field in the opposite direction.

Since the gravitomagnetic permeability of free space is so small it suggests that the eta-value inside the falling mass must be large.

Unfortunately, a falling mass is an unsteady problem which is difficult to model in terms of gravitomagnetism.

SLIDE 18

We start with an infinite line-mass moving with a steady velocity \mathbf{v} .
And we concentrate on an element of mass M and length ℓ .

This is the gravitational analogue of the moving line charge.

The values of the steady gravitomagnetic field are analogous to those given by the Biot-Savart law in electromagnetism.

The induced external gravitomagnetic field is zero, while the strength of the internal induced gravitomagnetic field is equal to v divided by the radius R . That's large, but how to measure it?

Relativity must be observed in trying to detect the steady gravitomagnetic field. There must be movement between the moving mass and the sensor.

SLIDE 19

Faraday discovered Faraday rotation in 1845. When vertically polarised light is shone along the linear magnetic field created by a solenoid the light polarisation rotates. This effect is shown in the slide.

With a current in a linear conductor the magnetic field is circular. Using a fibre optic coil around the conductor polarised light runs in line with the magnetic field. The degree of rotation θ of the polarised light is given approximately as $\theta = V H L$. Once the strength of the magnetic field H is known, the current can be determined from the Biot-Savart law. This idea is due to Boeing. It was used at BAE Systems Warton to determine current flows in structures during artificial lightning strikes.

We assume that the gravitomagnetic field exists in a fluid flowing in a tube, as given by the gravitational analogue of Biot-Savart. Can a thin fibre optic cylinder (thin, so as not to disturb the flow) be used with Faraday rotation to determine the mass current? If so, we can start to investigate gravitomagnetism.

Like gravity, it is assumed that gravitomagnetism cannot be shielded against. Consequently, can the fibre optic cylinder be attached to the outside wall of the tube, or must it be placed within the fluid?

Gravitomagnetism can exist without magnetism. The generation of magnetism through the movement of charge means that gravitomagnetism is also present. Is it possible to separate them? If so, by varying the magnetic field within an earthed conducting cage is it possible to generate an external varying gravitomagnetic field and, consequently, a gravity field. This has links with Bob Forward's toroid.

SLIDE 20

This slide describes my idea for a modified repeat of Faraday's 1st gravity experiment of 1849. Basically, the idea is to use a fibre optic coil, or cylinder, and use Faraday rotation to search for the tell-tale rotation of the plane of polarisation indicating the presence of a gravitomagnetic field.

The first experiment might be to drop a large fibre optic coil on its own, as it has its own mass. Its fall may need to be guided.

The second experiment might be to attach a thin fibre optic cylinder to a long mass cylinder and allow it to fall. There is no relative movement between the fibre optic cylinder and the mass, so I'm not sure whether the added mass will make any difference.

This idea and some minor variations is what I described in my BAE Systems report in 2002. As far as I am aware, no one has taken any interest in the idea. The ATC near Bristol closed in 2015.

In my frustration, in August 2017 I discussed the proposed experiment with Dr Frank Kvasnik, a retired Senior Lecturer from UMIST (University of Manchester) and with an ex-BAE Systems colleague. Frank is knowledgeable about fibre optics and is hands-on. I wrote a report of our meeting which described the experiments, the apparatus required, some of the difficulties that might be encountered and an estimate of the cost.

But I couldn't see how to proceed. In August 2020 I sent a copy of the meeting note to a researcher at Birmingham University, who had taken part in the Greenglow programme, but received no reply.

I am hopeful that someone watching this presentation with access to a laboratory might take an interest in the proposed experiments. Success would be the first detection of gravitomagnetism in a laboratory on Earth. Then we can probe gravitomagnetism.

SLIDE 21

We need to discover the gravitational analogue of Oersted's experiment.