

# SPARK

The Official Newsletter  
of the  
UK Pyrotechnics Society



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The **UK Pyrotechnics Society** is the only independent UK organisation that exists to represent the heritage, science, history and art of pyrotechnics in the United Kingdom.

The society was officially formed in 2006, and consists of industry professionals, academics, and enthusiasts of the general public.



We are not a trade association, but represent the interests of a very wide ranging, vibrant membership. If you are not already a member, we invite you to read the newsletter, visit our webpage:

<http://www.pyrosociety.org.uk>

and perhaps even consider joining our organisation?

Steve Miller MIEpE. UKPS Chairman

Some of the information published in Spark is of a technical nature. While the UKPS make every effort to ensure published information is correct, we cannot be held responsible for accidents or injuries occurring through use of any information published in the magazine.

Opinions expressed are those of the authors and not necessarily those of the UKPS.

The UKPS does not approve of or encourage any illegal activities connected with the construction or use of fireworks.

*Front Cover - Fireworks from the good old days...*

*Photograph Phil Dunford*

# SPARK - Issue 12

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## From The Editor:

The AGM now seems a distant memory! If you did not manage to make it this year, you can see what you missed in Paul's report.

The consensus is that a central venue is best for most people, so we will be looking for somewhere suitable for next year. We'd also be interested to hear your opinion on what you would like to see and do at the next AGM. Time for a change maybe?

I'm delighted to have articles from 2 new sources in this issue, thank you Ian and Roger – I think you will find them all of interest. Of course I am now looking for more good articles for the next issue...

I've had positive reports on the combination of professional printing and online availability for Spark, so that's the way we will be publishing in future.

We have several events in the pipeline, these include:

A fusing day at Steve's House.

A pyro day in a field!

A visit to a place of interest – possibly Waltham Abbey.

These are all in preparation. Please keep your eye on the website and forum for full details.

We would also love to see more local get togethers – to fire a few fireworks, have a chat, have a pizza – whatever. The getting together is more important than the nature of the event. Could you organise something in your area?



Phil Dunford Editor & Vice Chairman

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# Greener fireworks in more ways than one

*by Ian Williams*

## Introduction

Fireworks today are not perceived as the most environmentally friendly of entertainments. I am aware of at least one multinational company that will no longer conclude their corporate events with a firework display for environmental reasons.

Obviously, fireworks do contain toxic components that can range from perchlorates through to heavy metals. However, less toxic replacements for these compounds and other firework ingredients are beginning to emerge, so greener fireworks could be on the horizon.



Of course, the environment would benefit from cleaner, greener fireworks and it is the military that is driving this research forward. The armed forces are particularly heavy users of pyrotechnics; signals, illuminations, decoys and smoke screens are all used for training and on the battlefield. Within the military though, there are growing concerns for the potential health issues that may arise from repeated use of pyrotechnics.

More environmentally friendly pyrotechnic research is being undertaken in the United States largely due to America having a combination of strict environmental controls and a strong tradition of military Research and Development. While the armed forces will be the first to benefit from this work, military funded research into cleaner pyrotechnics is starting to filter through into civilian fireworks.

## Smoke gets in your eyes

Until recently the basic components of a conventional firework hadn't changed much over the years. A carbon based fuel is mixed with a metal salt that acts as the oxidant and in many cases the flame colourant. In other formulations metal fragments and powders such as magnesium and titanium are used as the fuel, which results in a brighter burning firework. However, once the firework is lit, the underlying energetics of the reactions remain the same.

One of the most obvious problems with fireworks is smoke generation. Smoke is a by-product of the incomplete combustion of the carbon based components. It is also produced by the combustion of metal fuels producing metal oxide particles. This can be a nuisance and obscure the view of the spectator or in more serious cases, reduce visibility in the surrounding area due to drift.



Other intermittent problems are the lacrimating effects smoke can have on eyes and the respiratory discomfort it causes when inhaled.

About ten years ago a research team at the Los Alamos National Laboratory (LANL) in New Mexico investigated the use of high nitrogen compounds as explosives. One of their most interesting and useful developments was the preparation of tetrazoles. These molecules are five-membered heterocyclic rings consisting of four nitrogen atoms and one carbon atom. The research team noted that the tetrazole compounds they produced ignited with little or no visible smoke. This is a property that has obvious potential benefits for pyrotechnics.

Another advantage of fireworks with low smoke levels is that less colourant is needed to produce the same level of brightness as there is less smoke to obscure the light source. When the metal in question is barium, a green light emitter, that is a significant bonus. The development of bis-tetrazole based compounds at LANL able to complex the metal in question has also reduced the amount of metal required due to the more uniform dispersion of the metal compound throughout the pyrotechnic formulation. These compounds may also replace perchlorates in some cases. (See later :- Replacing perchlorate).

## Boron may get the green light

Another potentially useful development is the possibility of replacing barium altogether and instead producing a green flame based on boron. Anyone who has prepared trimethyl borate from boric acid, methanol and a little concentrated sulphuric acid will know that it burns with a green flame; the green colour being due to light emission from the excited  $BO^*$  intermediate species produced. Initial tests by US Army researchers using an amorphous mixture of potassium nitrate and boron produced the green light emitting boron oxide but unfortunately, the combustion was far too quick to be of practical use. The team looked at other boron

compounds and came up with boron carbide as a candidate.

The normally inert boron carbide will react with oxygen at elevated temperatures to produce boron oxide, the desired green light emitter. Work carried out by the US Army in collaboration with the Ludwig Maximilian University of Munich (LMU) showed that a mixture of potassium nitrate oxidiser and boron carbide fuel held together with a polymer binder produced a long lasting very bright green pyrotechnic. Although the mechanism for the reaction is not yet fully understood, it works!

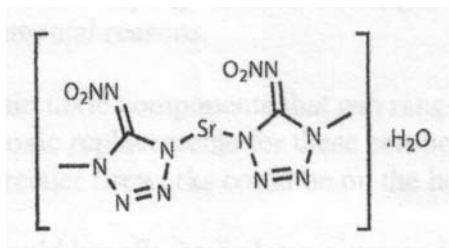
From a military perspective, attempts are being made to replace the potassium nitrate not because potassium is toxic but because it is a red light emitter and reduces the colour intensity of the flare. Any coloured light source seen from a distance tends to look white to the naked eye so colour purity is important. Currently a boron based oxidiser is being developed by researchers at LMU. This should increase the colour purity and also the intensity of the flare.

## Replacing perchlorate

Perhaps the biggest targets for removal from firework formulations are the perchlorate salts. Perchlorate was once considered the ultimate oxidant. Applications ranged from solid rocket fuels (See SPARK Issue 10 The World's Largest Core Burner by Bob Twells) through to fireworks and other pyrotechnic devices. Perchlorate has the advantages of stability, low cost, low hygroscopicity and a particularly large oxygen balance. Perchlorate is a very atom efficient ion with respect to oxygen because, when it burns it releases four oxygen atoms for every molecule of perchlorate. However, environmental concerns are mounting; perchlorates are water soluble and can accumulate in the ground potentially affecting drinking water supplies.

The perchlorate ion is a suspected teratogen. It has been linked with birth defects and can also impact thyroid function. Despite the obvious challenges, perchlorate free pyrotechnic formulations are starting to emerge. The key to this process has been the experimental use of high nitrogen compounds as fuels. Using high nitrogen fuels means that the amount of oxygen required can be dramatically reduced. High nitrogen compounds produce far fewer oxides than conventional fuels during combustion enabling oxidisers with a lower oxygen balance, such as nitrates to replace perchlorate with no loss of performance.

A high performing, perchlorate free, red light emitting flare has been produced thanks to the successful preparation of a bis-tetrazole based high nitrogen strontium compound (See structure below). In addition to giving more energy the gasses produced tend to have the effect of expanding the flame which makes the flare look brighter.



strontium bis-(1-methyl-5-nitriminotetrazolate) monohydrate

## The future

The driving force at present comes from the military but once good reliable greener, cleaner pyrotechnics have been successfully produced it would be seen a logical step to use such advances in civilian pyrotechnics and fireworks. However, the cost of these new pyrotechnic materials may initially limit their use to stage and theatrical special effects where the advantage of a cleaner burning product would tend to outweigh the cost to some extent. Eventually though, the goal would be to have more environmentally friendly, smokeless firework displays at an acceptable cost.

## References :

J Mitchell Crow, Chemistry World, (2012), Vol 09, No 01, 46-49

JJ Sabatini et al, Chem. Eur. J., (2011), DOI: 10.1002/chem.201102485





# Details of a real prosecution

*Foreword by Phil Dunford*

Roger Ashwood passed me the following (with permission to publish) at the last AGM. I'm very grateful to Roger, as it gives a fascinating insight into how the law can work.

Roger was being prosecuted for making a firework in 2011. For some reason, the act used was Section 4 of the 1883 Explosive Substances Act. Not MSER 2003. There is a statement from the forensic expert (actually Sidney Alford) and then the judges summing up to the jury, stating why the case collapsed.

There is much that could be of interest to the UKPS, not least the judges comment that "...defendant was making a firework... Well it is not in itself unlawful to make such a firework... In some circumstances you may need a licence etc".

IN THE CROWN COURT AT GUILDFORD

BETWEEN REGINA V ROGER ASHWOOD

FORENSIC EVIDENCE

## POINTS OF AGREEMENT

1. All unmixed substances were available from legitimate retail outlets.
2. The defendant's storage of the chemicals was basic but adequate.
3. The storage of containers of incompatible substances in close proximity to each other as shown on page 34 of the photographs taken during the search is not recommended for safety reasons but is unlikely to be the cause of unintended reaction between the substances.
4. The pyrotechnic compositions i.e. mixtures of the substances as within both the devices and some of the storage containers present no

particular danger of spontaneous flammability.

5. Sodium chlorate mixed with sulphur poses a danger and could ignite spontaneously. This mixture was found within one of the containers of DGKJ6 and in part of DGK/40. However the presence of a large proportion of sodium chloride within both of those exhibits would reduce the probability of spontaneous combustion significantly.

6. The risk of spontaneous explosion of the compositions is negligible.

7. If there were to be a fire in the premises which ignited the compositions it would be no more significant than a fire involving household substances such as lighter fuel, oil paint and petrol.

## Devices

8. Paper Maché was traditionally used by firework makers and was used by commercial manufacturers of fireworks until replaced by plastic approximately 30 years ago.

9. The term IED does have specific meaning in a military or terrorist context. In this case it relates simply to the fact that the devices were homemade.

10. All could cause injury in the same way as commercially available fireworks particularly DGK17 which has a wooden case but even that device would not be expected to have any lethal potential. DGK/40 includes a poorly conceived homemade rocket which would probably not function as a rocket although the presence of a stick and exhaust hole adjacent to the stick indicate that it was intended to function as a rocket. The use of copper tubing is inappropriate and without detailed knowledge of the composition the behavior of the rocket would be unpredictable.

## Judges summing up

JUDGE ADDISON: I am sorry you were kept so long, members of the jury, but, as you know, I have been discussing the law with counsel. The prosecution case is now closed and one of the functions that I have is

to consider at the close of the prosecution case whether at that stage, assuming no further evidence were called, there is sufficient evidence on which you could properly convict on all or any of these counts.

The long and short of it is that I have decided that there is insufficient evidence and I shall explain to you what follows from that. It is only right that I should tell you, very briefly, why I have reached that decision.

You may think that the evidence shows that the defendant was making home-made fireworks, that is devices so designed for the entertainment, either of himself or, possibly others, by means of making a noise or light or colours, such as normal fireworks do.

There is no evidence that they were designed to cause injury to people or to cause damage to property. Well, it is not in itself unlawful to make such a firework. In some circumstances you may need a license. If, for example, you are doing it other than small quantities or if you are selling them and of course some well-known manufacturers do have licenses to make them and to sell them.

The prosecution have not sought to prove that the defendant should have had a license in the small quantities in which he was doing it. If they thought that he was committing an offence by not having a license, well, then they could have charged him with that offence but they have not. They charged him with offences under section 4 of the Explosive Substances Act of 1883. I do not suppose there were licenses for such things in those days, back in 1883, but that is the Act under which he is charged, which says: ‘Any person who’, and I am paraphrasing, “makes or has in his possession any explosive substance under such circumstances as to give rise to a reasonable suspicion that he is not making it or has it in his possession for a lawful object, commits the offence.”

Well, it seems to me that the prosecution have not proved that. Once the facts were known and the police had been to his flat and called their expert and so on, it does not seem to me that there is any reasonable suspicion that he was having them for an unlawful object and, indeed, the evidence is clear, that he had them for what is in itself a lawful object, that is to make an ordinary firework.

But quite apart from that, the Act goes on to say that he is not guilty

if he can show that he made it, or had it in his possession, for a lawful object and it seems to me that, by what he said in his interview, he has shown that, that what he was doing was making a firework, which is in itself a lawful object. Clearly, it would not have been a lawful object if it had been designed to cause injury or damage property or something of that sort, that would have been a different matter.

The position is this: that having reached that decision, what I normally would do is to direct you to acquit because he is in your charge, but these days the prosecution in these circumstances, if a judge reaches what is called “a final ruling”, are entitled to go to the Court of Appeal and try to persuade them that my ruling is wrong and that I should not have made that ruling and that does sometimes happen. What has happened is that Miss Davies has told me — and I do not criticize her of course at all for this, she is perfectly entitled to — that she wants a bit of time to consider whether she should go and try to persuade the Court of Appeal that my direction in law is wrong and I have said that she can have some time in which to do that.

So that being the case, I cannot direct you to acquit because it is possible that there may be another trial, I suppose. What I do is to simply discharge you from giving a verdict. If then the prosecution do not appeal or appeal unsuccessfully, then the defendant will be automatically acquitted. But if they were to be successful, then of course there might have to be a retrial and so, although I discharge you from giving verdicts, I do ask you not to discuss the case with other people for the time being, just in case there is another trial.

I am sorry about it, you have heard a lot of stuff about chemicals and I hope you have not found it totally uninteresting or boring, but there it is, that is the rather unsatisfactory result of it, you will not have to make a decision and so I shall discharge you from any further consideration in this case and after you leave court you will be told what your next duties may be. All right, thank you very much. If you would like to leave now, please.



# UKPS AGM 2013

*by Paul Dack*

Those that made it through the adverse weather to this years AGM found their efforts well rewarded.

The opening business was dealt with swiftly, with the only alteration to the board being that Paul Dack has taken on the role of Treasurer which was previously occupied by Joseph Matthews.

The first of our guest speakers, Alan Morely – the President of the IExpE no less, provided us with an insight into the workings of the organisation and how to become a member.

Next up was the dedicated Mr Dunford presenting a history of fireworks throughout the years, and how they have evolved from intricate large lanceworks and set pieces, taking thousands of man-hours to assemble, to the modern day shows.

Chris Clarke from Sonning Fireworks gave an excellent presentation that went into reasonable depth on the design of pyromusicals including how to avoid common mistakes and give your shows a professional touch. Our Chairman Steve Miller then expanded on this showing



Chris Clarke



Paul Dack

how with just careful planning, a portfire and a stopwatch you can achieve great results without expensive firing systems.

Paul Dack then gave a very brief overview of the FireOne system used in the show later that day, and demonstrated by running through a show script.

Last but not least Chris Clarke presented an explanation of different firing system types and how you can use different wiring and RF topologies to your advantage.

Overall there were some interesting presentations, possibly the best AGM so far.

Over the next couple of hours whilst the sun set there was plenty of time for people to socialise or for those that wished, help set up the pyromusical display. It was bitterly cold that day, so I hold no grudge against those that stayed inside!

The day concluded with a short but rather dramatic display by Dean Graham (who braved the cold all day in order to make it possible), and Paul Dack of Fuse Fireworks, with equipment on loan from Phil Cooper and fireworks from Steve Miller.

I'm sure everyone will agree that this years AGM was a very enjoyable day, and would like to thank everyone that made it possible.



# The Fenny Poppers

*By Ian Williams*

Every 11th November an unusual custom takes place in Fenny Stratford, Milton Keynes. The events of the day celebrate the life of eminent physician Dr Thomas Willis. He was a founding member of the Royal Society and also had the honour of being interred at Westminster Abbey.

Thomas Willis practised in the St Martin-in-the-Fields parish of London and regularly attended the church. He lived at St Martins Lane and died on St Martins Day 11th November 1675, leaving a considerable amount of money and various properties in the Fenny Stratford area. His estate was eventually inherited by his grandson Dr Browne Willis. This eccentric historian was famed for his unkempt appearance and for providing funds to build a new parish church in the village. The church was dedicated to St Martin in memory of his grandfather.

In addition to dedicating the parish church, Browne Willis also devised several activities to celebrate St Martins day and, to some extent, himself it would seem. Celebrations begin with the reading of a sermon at St Martins church in the village, the preacher receiving a fee of one guinea. After this, at various times throughout the day, Fenny poppers are fired. The poppers are described as ceremonial cannons that resemble large iron beer mugs. The day concludes with a turkey dinner at the near by Bull tavern which is attended by local dignitaries and originally Browne Willis himself. These traditions continue to this day together with the more recent Fenny Poppers Festival.

## The Poppers

There are six poppers in total and the originals are believed to date from 1740 when it is thought they were first fired. They eventually deteriorated and one cracked so all were re-cast at the Eagle Foundry, Northampton in 1859. They have recently been examined by x-ray to ensure that there are no cracks or fissures and it is these cannons that remain in use today.



The Poppers

## Charging and firing

The poppers each weigh approximately 8.5kgs. The bore is 152mm x 44mm and will take a charge of one to four ounces of black powder which is plugged with well-rammed news paper. They are fired three times on St Martins day; at noon, 2.00pm and 4.00pm precisely. If 11th November falls on a Sunday then the poppers are fired on Saturday 10th November. There is of course, no connection with remembrance day which also falls on 11th November. The poppers are occasionally fired to commemorate other significant events, most recently on 5th June 2012 to celebrate Queen Elizabeth II Diamond Jubilee. All six were fired, starting at 2.00pm.



Charging

Over the years, the firing has supposedly caused some collateral damage to the fabric of the church and the roof of the near by Bull tavern. This has resulted in the use of alternative local venues.

Currently the battery of poppers are fired at the Leon recreation ground. The end of a 12 foot long metal rod is heated in the church furnace (brazier) and then used to touch off each cannon. Traditionally, the vicar of St Martins has the honour of firing the first popper. The rest are fired by other notable town folk, each receiving a certificate to confirm their participation.

Quite why Dr Browne Willis chose these rather bizarre ways of celebrating the life and work of his grandfather is unclear. However, a series of loud bangs and a hearty meal followed by a glass of wine or a few pints of ale does seem quintessentially British and a lot of fun!



Firing





# Dissecting a 25mm candle

*By Practicus*

This month, I'm looking at the construction of a typical CAT4 25mm Roman Candle.

There are quite a few interesting features, and they are certainly made in a very different way to traditional candles.



The unit is wrapped in polythene for protection against damp (intended to be left in place when firing) and has a quick match leader.



First slight surprise is that the first 1/3 of the tube is empty. The arrow shows where the composition starts. It's clear that some trouble has been gone to in order to ensure that the stars all reach the same height.

This empty space gives the first star enough time under pressure to accelerate. It also makes the device look bigger than it is, but not for once, to fool the buyer!

Incidentally, the cap is a loose fit, with a bulge for the quickmatch fuse. Again, it's intended to be left in place, keeping out rain or damp and being blown off when the device is fired.





The cutaway reveals the construction of the candle.

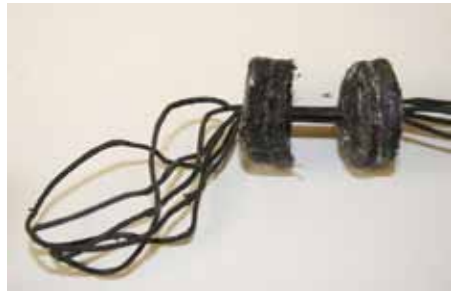


Six black match strands (which communicate with the quick match fuse) thread through several felt washers and wrap around the star. Fire will first be communicated to the star & thence to the lift charge beneath. The star is a poor fit in the tube but the felt washers will compensate for this, giving compression to the lift charge and

allowing the star to accelerate up the tube.

You can see here that the match passes straight through the washers and that no delay is incorporated,

The lift charge is contained in a small plastic bag, which melts instantly from the heat of the burning star above it.



Removing the charge from the bag, shows it to be a good quality, medium mesh grain powder.





Pulling all the units apart reveals the story so far.



Next we have a new unit, a delay. In 'traditional' candles, the delay would be provided by 'dark fire'. A black powder composition designed to burn with as little light as possible. The problem as candles get larger is that quite a large volume of this composition is required. This both adds to the cost and to the smoke produced. The fact that the composition burns away completely also means there is no 'plug' above the next star to provide compression, so the fit of the star in the tube needs to be much tighter in order to

achieve a good height.

This unit uses felt washers to achieve the compression. There is a hole down the centre through which a piece of Chinese delay fuse is fitted. The length of 30mm corresponding to a delay of just over 1 second. The top is heavily primed with a black powder slurry in order to guarantee fire being transferred from the lift above.



Although an excellent system in many ways, the big down side of such a candle is the amount of debris it produces. Anyone who has fired on a site that has to be left clean, will rue the demise of Dark Fire!



We can now see the complete chain down to the first delay unit. After this, the sequence repeats – Star – Lift – Delay/Compression, for the eight shots of the candle.

As I mentioned earlier, some trouble has been taken to ensure uniform height of star projection.

I said that the chain repeats, but there is one difference as we go further down the candle. The lift charges are graded. The size of the charge reduces, the lower down the candle we go. This is because lower stars travel further along the 'barrel' and thus would accelerate more (and progressively reach greater heights). Reducing the charge a little for each star gives a very uniform performance. I have no idea if there is a formula for this, or if the charge is determined empirically. I have tabulated the weights (along with other useful data in the following table.

# Details of 8 Shot Candle

Candle Length	75cm
Internal Diameter	25mm
External Diameter	35mm
Length of empty space	28cm
Size of star	20mm diameter x 20mm long
Weight of star	11g
Lifting charge star 1	3g
Lifting charge star 2	2.5g
Lifting charge star 3	2.2g
Lifting charge star 4	2.1g
Lifting charge star 5	2.0g
Lifting charge star 6	1.9g
Lifting charge star 7	1.8g
Lifting charge star 8	1.7g



## UKPS Address

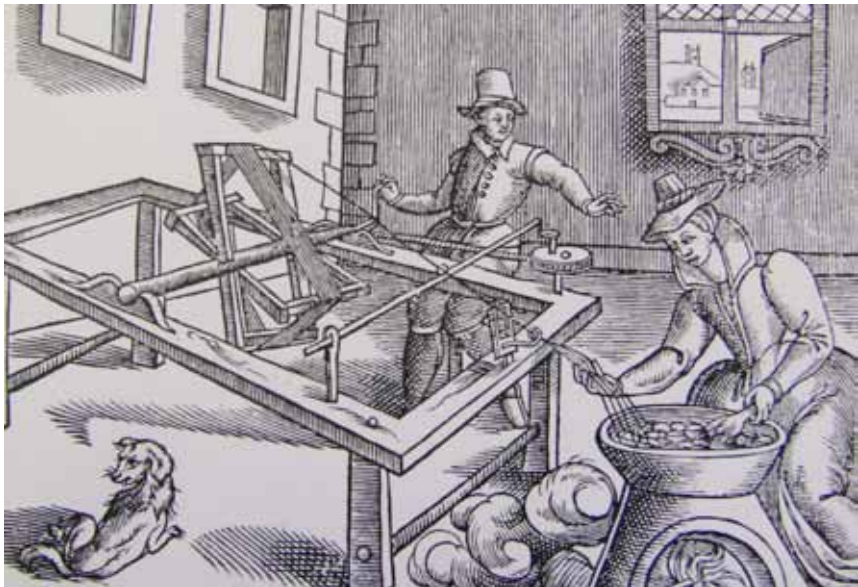
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Luigi gets his wife and hound working on the black match



## *Firework Quote:*

“Fireworks had for her a direct and magical appeal. Their attraction was more complex than that of any other form of art. They had pattern and sequence, colour and sound, brilliance and mobility; they had suspense, surprise, and a faint hint of danger; above all, they had the supreme quality of transience, which puts the keenest edge on beauty and makes it touch some spring in the heart which more enduring excellences cannot reach.”

— Jan Struther, *Mrs. Miniver*





We welcome any firework related articles for publication.

Please send to:  
editor@pyrosociety.org.uk

Remember to visit the Website and Forum for up  
to date information

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