To the deflection of Asteroids in the diameter range of 5 to 200 km

(→ includes feasible deflection strategies)

14.1.2014 - by Harry K. Hahn / Germany

…..CNN Breaking News : A newly discovered asteroid seems to be on a collision course with our planet. A large C-type asteroid with a diameter of approximately 60 to 70 km and an orbital period of > 250 years was discovered by an automatic survey telescope. A first analysis of the available observation data of this asteroid turned out be bad news for mankind ! The probability that it will hit our planet was calculated to be higher than 90 % according to astronomers who carried out the analysis. Unfortunate circumstances and a very low albedo of the asteroid of only 0.03 are the reasons why it was discovered relatively late. The time period until impact was calculated to be around 13 months from now. The UN Security Council will meet for an emergency meeting this afternoon ……

Are there any strategies how we could save our planet Earth in such a situation ???

Do we have sufficient defence capabilities, and suitable equipment ready for use ??

…..CNN News Update : In a press conference after the UN Security Council meeting the Secretary-General said that the situation doesn't look good for mankind. The astronomers are still working on more precise analyses of the asteroid's trajectory, but the probability would be very high that this asteroid will impact on our planet in around 13 months time. He said that it is very sad that we have more than 17000 nuclear weapons stored here somewhere on our planet Earth to destroy ourselves, but not one nuclear weapon placed in space, somewhere close to the approaching asteroid, where we most urgently need it !! We are all to blame for this carelessness he said. And the Secretary-General explained that we would be able to deflect the asteroid away from Earth if we would have placed just half a dozen of our powerful nuclear weapons close to the asteroid in this moment. But because the asteroid is approaching so fast, and by the time we would have our weapons in space and finally arrive at the asteroid, that we would then need many many times more nuclear bombs to deflect it. And therefore he said in all probability a succesful deflection of the asteroid will not be possible anymore !! However the scientists and engineers will do everything possible to prevent the imminent catastrophe. And he said that it would be very important that we all strictly follow the instructions of our governments from now on ……..

…….With the help of a small number of Asteroid Deflection Units (ADUs), equipped with nuclear explosive devices, already located at positions close to the Earth-threatening Asteroid, at the time of it's discovery, a collision could have been avoided !!!……...

This is the important message and advice from this possible (realistic) story !!

And it is the purpose of the following study to act as an eye-opener, so that the real dimension of the threat can be better understood and the necessary decisions can be made to initiate the development of suitable technology to protect our planet Earth !

<u>As motivating factor</u> : There are very valuable asteroids which can be moved in an orbit around Earth with the same technology for mining !!
→see weblink: Asteroid - 3554 Amun and Floating mines in outer space

Two small asteroids of a few meters diameter entering our atmosphere with high speed !!

Just imagine their diameter would be 1000 to 10,000 times bigger !! Any plans for defense ?

The **"Chelyabinsk"** Meteorite → On 15 February 2013, an asteroid of approximately **17m diameter** and a weight of 10000 T entered Earth's atmosphere over Russia at about 03:20 UTC with an estimated speed of 18.6 km/s (over 41000 mph or 66960 km/h), almost 60 times the speed of sound at that altitude) and quickly became a brilliant superbolide-the "**Chelyabinsk Meteor"** The dazzling light of the meteor was brighter than the sun, and bright enough to cast moving shadows during the morning in Chelyabinsk. It was observed over a wide area of the region and in neighbouring republics. Eye-witnesses also felt intense heat from the fireball.

Due to its enormous velocity and shallow atmospheric entry angle, the asteroid exploded in an air bust at a height of about 23.3 km (14.5 miles, 76000 feet). The explosion generated a bright flash, producing many small fragmentary meteorites and a powerful shock wave. The atmosphere absorbed most of the object's energy, with a total kinetic energy before atmospheric impact equivalent to approximately 440 KT (kilotons of TNT equivalent)

Wikipedia Info : http://en.wikipedia.org/wiki/Chelyabinsk_meteor

Info about Meteorite Fragments : Meteorite Database

Movies : General Info about the Meteor ; the Meteor Fall : Movie-1, Movie-2, Movie-3
the shockwave : shockwave ; NASA movie : The Aftermath : NASA-movie

The **1972 Great Daylight Fireball** (or **US19720810**) → an Earth-grazing meteoroid that passed within 57 kilometres of Earth's surface on August 10, 1972. It entered Earth's atmosphere with a speed of 15 km/s over Utah, USA and passed northwards leaving the atmosphere over Alberta, Canada. It had a **diameter of 3 to 14 m** (depending on it's compound). It was an Apollo asteroid in an Earth-crossing orbit. Photo and movie made by James/Linda Baker at Jackson Lake (CA). From there it could be seen for 101 seconds. The visible track was more than 1000 miles long !!

Wikipedia Info : http://en.wikipedia.org/wiki/1972_Great_Daylight_Fireball

Here the weblink to the **original movie** from 1972 : to the movie → clic on 3812ko !!

The main goal of this study was to answer the following questions :

Is there currently an increased probability for large impact events on Earth ? **The answer is : Yes**

Considering an advance warning time of ≤ 2 years , what maximum asteroid diameter could we currently deflect from Earth with conventional deflection techniques if it would be on a direct collision course ? **The answer is : ~ Ø 10 km**

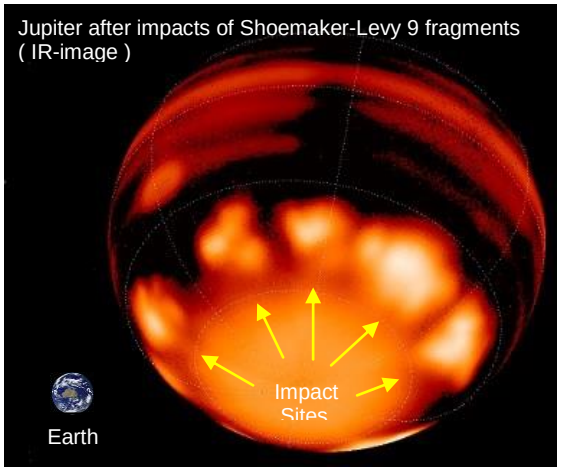
With better preparation, e.g. with the help of special Asteroid Deflection Units (ADU's) already placed on certain locations in space and ready to go, what maximum asteroid diameter could we then deflect ? **The answer is : ~ Ø 20 km**

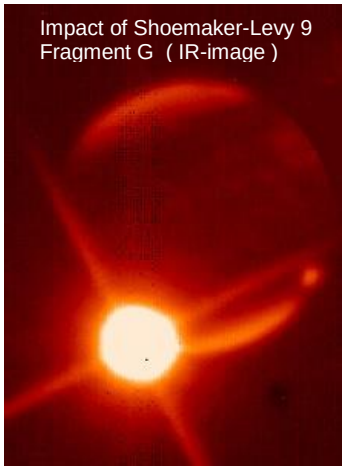
Is there any way to prevent a collision with an asteroid in the diameter range Ø 20 km to Ø 200 km ?? **The answer is : Yes there is one way to do that !!**

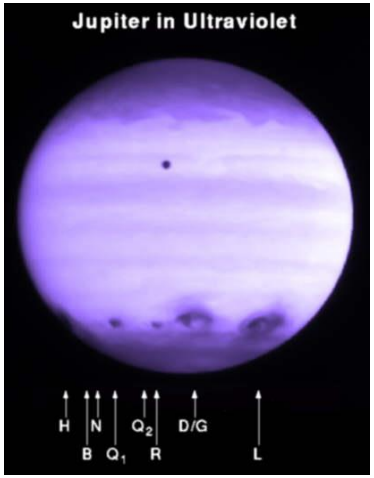
What's the most important message from this study ??? :

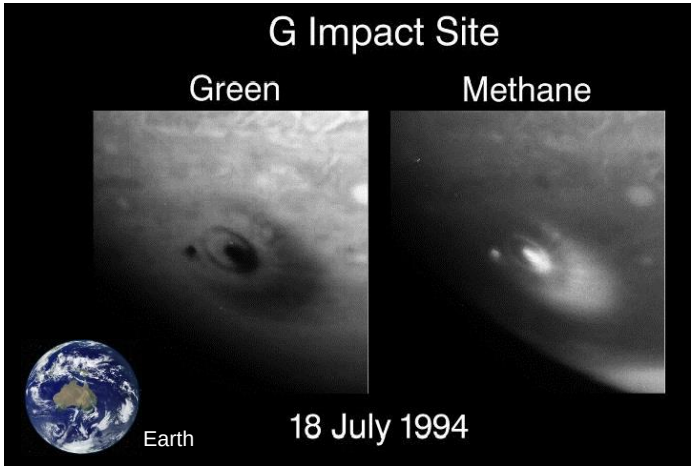
Currently we are not able to prevent impacts of large asteroids ≥ Ø 10 km or comets ≥ Ø 18 km, if they are on direct collision course with our planet Earth, and if we consider an advance warning time of ≤ 2 years !! We don't have a suitable defense system in place, no proper action plans, no experience or expertise to deal with such a collision scenario. We not even have any suitable defense equipment which could be launched quickly ! We currently live in an extinction period with increased risk of large impact events !! There are **> 10000 Asteroids of Ø 10 km** in our solar system and **many billion Comets (!!) with diameter ≥ Ø 20 km in the Oort-Cloud.** Every one of these asteroids or comets has the potential to end mankind's history if it would impact on Earth !! Comet Hale-Bopp (C1995/O1) with a nucleus Ø ~ 35 km could as well have been on a direct collision course with our planet Earth in the year 1997. In the case of an impact it would have wiped out > 99% of mankind !! → All these reasons should be more than enough motivation to come up with a proper defense system for our planet Earth !! (with a number of ADU's already placed on defined positions in space and ready to go !!) → This may cost a few billion Dollars. But if the money would be raised by all members of the UNO it should be relatively easy to get the money together !! It should be in every nation's interest to set up a proper defense system for our planet Earth !!!

As explained in this study : **There are ways to even deflect asteroids ≥ Ø 200 km. But to be able to do that, we need suitable equipment and experience !!!**









Comet Shoemaker–Levy 9 (formally designated **D/1993 F2**) was a comet that broke apart and collided with Jupiter in **July 1994**, providing the first direct observation of an extraterrestrial collision of Solar System objects. This generated a large amount of coverage in the popular media, and the comet was closely observed by astronomers worldwide. Over the period of 6 days, 21 distinct impacts of comet fragments were observed, with the largest on July 18 when Fragment-G struck (→ **Diameter Fragment-G approx. 1 to 2 km**) This impact created a giant dark spot over 12000 km across, and was estimated to have released an energy equivalent to **6,000,000 MT TNT** (**600 times the world's complete nuclear weapons arsenal !!!**). Impacts continued until July 22, when the last Fragment-W struck Jupiter. → more information on Wikipedia site : **Comet_Shoemaker_Levy_9**

Movies about the impacts : Have a look at this !! : → short documentation : movie 03 ; News : movie 01 ; Impact Fragment-G : **movie 02** ; documentation + impact animations : movie 04

Introductory Explanations :

To the increased probability of large impact events on Earth :

There is clear statistical evidence for a 62-million year cycle in bio-diversity (fossil diversity) on Earth. Currently we live at the end of the declining phase of such a 62-Myr cycle. The declining phase of this cycle should better be called an extinction period !!
If we look at the diagram which shows the bio-(fossil)-diversity on Earth (Diagram 1), it is evident that there are abrupt and deep cuts into the bio-diversity within each marked extinction period ! This is the case for each of the last eight cycles (500 million years). Another Diagram (No. 3) which shows the percentage of extinct marine species clearly indicates that during each of these eight cycles always at least 40% of all marine species became abruptly extinct !!! The only cycle which doesn't show (or which haven't had !) such a deep cut in the bio-diversity on Earth is the current cycle !!

But because the 62-million year cycle is strongly confirmed by statistical evidence we must anticipate that also the rule of the abrupt cuts in bio-diversity (a cut of at least 40% in marine species) proves to be correct ! Therefore we must expect that a comparable sharp and steep cut into bio-diversity on Earth will happen within the next 3 to 5 million years !!
That immediately implies that the probability for an extreme decline in bio-diversity is logically 10 to 20 times higher within the next 3 to 5 million years than it was during the last ~ 55 to 60 million years where no decline at all in the bio-diversity occurred !!!

At the moment we can only speculate what the true cause for these periodic occuring deep and sharp cuts into bio-diversity on Earth could be. But because the 62-Myr cycle is so strong and distinct, it seems to be driven by a robust long-periodic physical process

In **Diagram No.2 & No.3** further below there is clear indication that the extinction cycles seem to be linked to large eruptions and/or large impact events, which are either confirmed or where there is diagnostic evidence available for these impact events.
It must be noted here that large eruption events (> 150 km) can also be caused by large impact events ! (see e.g. → Addams Crater on Venus, or Orcus Patera Crater on Mars → Orcus-Patera -1 & -2. (see also **Appendix 1**) Therefore there is strong reason to believe that the sharp and steep cuts in bio-diversity are caused by large impact events ! A further indication is the good agreement with the extinction of marine species on Earth which also seems to be clearly linked to large impact events on Earth.

In the article "Cycles in Fossil Diversity" in the -Nature- magazine a number of possible causes for these cycles are listed. However because of the obvious connection of the bio-diversity cycles with large impact- & (impact)-eruption events, I only want to mention here two possible periodic physical processes which I believe could be the trigger of periods with large impact events. The first is a possible external process (or cause) which could heavily influence our solar system from outside.This is the periodic passing of our solar system through the galactic plane, which may be full of dense gas-, dust- and asteroid-accumulations which could be the cause of heavy impact periods on Earth

And the second process is a possible internal process within our solar system, caused maybe by a cyclic behaviour of our Sun (e.g. cycles with extreme Solar Flares and CME's), which could trigger considerable periodic disturbances of asteroid- or comet-orbits. And this could then lead to periods of excessive impact events on our planets.

→ Please see further explanation to these two processes on the next page !!

Feasible deflection strategies for asteroids with diameters 5 to 200 km :

The main goal of this study was to find feasible methods and strategies for the deflection of large asteroids in the diameter range of 5 to 200 km.

For the deflection of asteroids in the 50 - 200 km range only one feasible way was found, which is an indirect but extremely powerful technique !! → see explanation further below ! (→ **Deflection Strategy 3**)

But to begin with, at first the following basic assumption was made :
An asteroid of a certain diameter is on a direct collision course with our planet Earth, and our advance warning time of the possible impact on our planet is less than two years.

Then a first assessment of our ability to deflect an asteroid of a certain diameter was carried out. It was considered that only existing and proven technology and a powerful direct deflection method (an explosion on or close to the surface of the asteroid) would be used for this task. Due to the shortness of the available time for a successful deflection of the asteroid, it was further considered that only high performance rocket engines would be used in the Deflection Units which are sent to the asteroid.

And for the deflection measures itself only proven nuclear weapons with a high yield-to-weigth ratio were considered. The explosive yields of the following nuclear weapons (developed in the USA) were used as a reference for the calculations :
→ B41 (max. explosive yield : 25 MT), → B83 (max. explosive yield : 1.2 MT) and the →W76 (max. explosive yield : 100 KT) , see also : Nuclear Weapon Yield

Please find the detailed explanation of the general conditions which were considered for this assessment further below (→ assessment of **Deflection Strategy 1 & 2**). To keep the calculation effort to a minimum, mainly kinetic energy considerations & -calculations were performed to determine the required energy (amount of NED's) for the deflection.

The result of this assessment is presented in the form of a table. This table shows the minimum amount of NED's (Nuclear Explosive Devices) which is required for the deflection of an asteroid with a given diameter, so that it just misses our planet Earth.
Here it was considered that either the maximum explosive yield (Deflection Strategy 1) or only a small defined fraction of the explosive yield (Deflection Strategy 2) of the used NED's is transformed in work (kinetic energy) which is usable for a direct change of the trajectory of the asteroid at a given distance to Earth (→ of either 250 or 500 million km)

The numbers in the table clearly show how difficult (or impossible) it is to deflect large asteroids (or comets) by direct deflection methods if there is only limited time for this task.

→ As the imaginary Secretary-General in the possible future scenario said : It is careless not to prepare for such an event !!! Because the fate of our whole planet would depend on just a handful of NED's which are either already close to the Earth-threatening asteroid in the moment of it's discovery or which are far away !!! This difference would be crucial !!!

Here the important message is as follows !!! : For every halving of the distance (to Earth) were the deflection measure takes place, **the required amount of energy** (amount of NED's) for a successful deflection of the asteroid **must be quadrupled !!!!!**

→ This interdependence is described by the kinetic energy formula. ($E_{kin} \sim V^2$)

What must be done ??!! (→ Please read this work instruction after you have looked through the presentation !!)

Scientific research is required to find the cause of the distinct 62 +/- 3 Myr bio-(fossil)-diversity cycle :

There are especially two physical processes which should be investigated as possible causes of the 62 +/- 3 Myr bio-diversity cycle !! :

Possible Cause 1: The periodic passing of our solar-system through the galactic plane of our galaxy

An examination of the galactic plane should be carried out (especially the area on the galactic plane where our solar system passed through during the last 3 million years) regarding possible gas-, dust- and asteroid accumulations.

And it should be simulated what effect different gas-, dust- and asteroid-accumulations would have on the Oort Cloud & on our planets, if our solar system would pass through them.

A more extensive and more precise diagram to the age and size of large impact events & large eruption events on Earth with information to "age tolerances" must be produced !!

Possible Cause 2: Longterm physical processes in our Sun

In principle only the sun qualifies as source for an internal process within our solar system which could lead to periods with considerable increased numbers of large impact events on our planets. In order to produce strong disturbances of asteroid- or comet- orbits a powerful trigger is required.

Therefore it should be examined / simulated: to what extent e.g. strong changes in the Solar Wind Flow and in Flare Activity over longer time periods (millions of years) could cause disturbances (changes) in asteroid- or comet- orbits, which then could lead to an increase in large impact events.

→ An estimation shows that a strong solar flare releases an amount of energy which would be comparable to around 4.5T TNT equivalent per square kilometer on the surface of an asteroid in a distance of 2.5 AU to the sun. Thousand strong solar flares would have the same impact on an asteroid as the radiation yield produced by a **W76**-explosion

→ see e.g. : Solar Flare and Carrington Event

The helium enriched plasma of solar flares is a strong indication that solar flares are closely linked to the fusion process in the core of the sun, and that they are a direct result of changes in the sun's fusion zone. Therefore long-periodic variations in the sun's fusion zone may be the cause of periods with excessive and powerful solar flares !!

→**Please see Appendix 2 : "To the origin of solar flares"**

What practical measures must be taken ??

A first experimental ADU should be built for the controlled explosion of one NED close to a large asteroid, and another NED during the controlled impact of a Sub-ADU on the asteroid with defined impact speed

The main goal is to find out how the real explosion result matches with pre-calculated predictions regarding the change of the trajectory of the asteroid and the efficiency of the explosion etc.

We need to get practical experience in deflecting asteroids or comets with the help of ADU's and NED's !

It must be examined what types of NED's are required for different deflection tasks and –strategies. Computer simulations of asteroid deflections referring to the described deflection startegies 1 - 3 must be carried out
A database of asteroids with inclinations ≥25° is required

After this first series of practical experiments and computer simulations a first prototype of a standard production model of an ADU should be developed, built and then tested on different selected asteroid types.

Then a first effective Defense System comprising a number of ADU's must be realized. The ADU's should preferably be placed on strategical positions in our solar system, e.g. in wider orbits around the planets Venus, Mars and Jupiter, and on defined positions on the orbits of Mars, Venus and Jupiter → e.g. on trojan orbits on these orbits.

It must be the goal to have a number of ADU's ready to be sent off immediately to a mission to deflect an Earth-threatening asteroid or –comet. Because it is very time consuming to reach locations far away from Earth were deflection measures must be carried out (NED explosions) for successful deflection of a large asteroid or comet, the ADU must already be located close to the location were it is required in the moment of the discovery of a large Earth-threatening asteroid/comet.

Computer simulations must be carried out to find out were the optimum locations for ADU's in the inner solar system would be, considering all possible trajectories of approaching asteroids and comets.

Additionally a number of ADU's and launch rockets must be kept in store on Earth and ready to go at all times !!!

Design requirements for the described ADU's :

For maximum range and acceleration- and deceleration capability the weight of the ADU should mainly come from the fuel tank mass and the mass of the NED units. All other components must be kept as light as possible !

The control system must have a very redundant design

Only reliable and well tested components should be used for the design of the ADU. The design should be kept as simple and reliable as possible !

The life expectancy of the ADU should be ≥ 30 years !!

The ADU must have a heavy micro-meteoroit protection (the ADU may be exposed to a comet tail or to other areas with yet unpredictable accumulation of dust etc.)

ADU's should be able to communicate with each other & should be equipped with a very reliable power supply

To the financing of an effective Defense System :

As described before it is very important to be prepared for the deflection of a large Earth-threatening asteroid or comet. The goal of the short story at the beginning of this presentation was to point out, that having an ADU available close to a new discovered Earth-threatening asteroid or comet could make the difference between life and death !! The survival of mankind and the fate of our Earth could depend on just one ADU which was already placed somewhere in space as a matter of prudence !!

And therefore we need to develop and build a certain number of ADU's and place a defined minimum number of ADU's on strategical locations far away from Earth.

And we need well trained experts which are prepared for a possible "worst case collision scenario" in order to be able to successfully deflect a large Earth-threatening asteroid or comet (→ Deflection Strategy 3) !!!

It must be in the interest of all countries of the world to develop and build an effective defense system for our planet Earth which can successfully deflect large Earth-threatening asteroids or comets !!!

Therefore the longterm financing of such a Defense System should not be a big deal. Ideally the UNO should organize the financing of this Defence System !!
And as a **motivating factor** : There are very valuable asteroids which can be moved in an orbit around Earth with ADU's for mining ! →see weblink: Asteroid - 3554 Amun

Evidence that we are still within an extinction cycle with possible large impact events

There is strong analytical evidence for a **62 +/- 3 Myr** cycle in Fossil Diversity (or Bio-Diversity). Sharp cuts into the bio-diversity on Earth clearly occur within **~ 20 Myr long periodic extinction periods**. These sharp cuts all happen within the declining phases of the 62-Myr cycle (→ see sin wave **1c**).
Currently we live at the end of an extinction period or declining phase of the 62-Myr cycle which is still going on for another 3 to 5 million years !! But it is obvious that there wasn't a similar sharp cut yet in the current cycle, if compared with the past 8 cycles !

Note that in 6 of the past 8 cycles **at least 70%** of all marine species became extinct !!! (diagram 3). And in all 8 cycles the minimum percentage of extinct species was 40 %. However our current cycle doesn't show any cut in bio-diversity worth mentioning !! Have we just been **very lucky** or is the cause of the sharp cuts in bio-diversity **just a bit late** in the current cycle which is still going on ?? Note : In cycles 5 and 8 a sharp cut occurred right at the end of each cycle ! (corresponds to eruptions & craters in Diag. 2)

There are indicators in diagram 2 & 3 that the sharp cuts in bio-diverstiy may be caused by periodic occuring large impact events. Note in **Diagram 2** the 5 large eruption events (which could also be caused by impacts) which occurred within or very close to cycles 1 & 5-8 , and the two large impact events in cycle 5 & 8. → also see **Diagram 3** !!
It would be important to produce a more extensive and precise diagram to the age and size of large impact events & large eruption events with information to age tolerances !

The most plausible cause for such periodic big impact events could be either a **periodic behavior of our sun** (e.g. sharp rises and drops in the Solar Wind Flow & Flares) at some stage, which may disturb asteroid- & comet orbits, or the **periodic crossing of the galactic plane** by our Solar System, which may be heavily crowded with asteroids (debris) similar to the Saturn ring-plane. The **62 +/- 3 Myr** Bio-Diversity cycle is in good agreement with the **66 +/- 6 Myr** period for the vertical oscillation of our Solar System about the plane of our galaxy ! Note that it seems the last crossing of the galactic plane occurred **≤ 3 Myr ago,** which is **5 to 7 Myr ! after mid of the extinction cycle !!** → **see weblinks :**

1.) Weblink Study 1
2.) Weblink Study 2

"Cycles in Fossil Diversity "
by Robert A. Rohde and Richard A. Muller
Weblink to Study : http://muller.lbl.gov/papers/Rohde-Muller-Nature.pdf

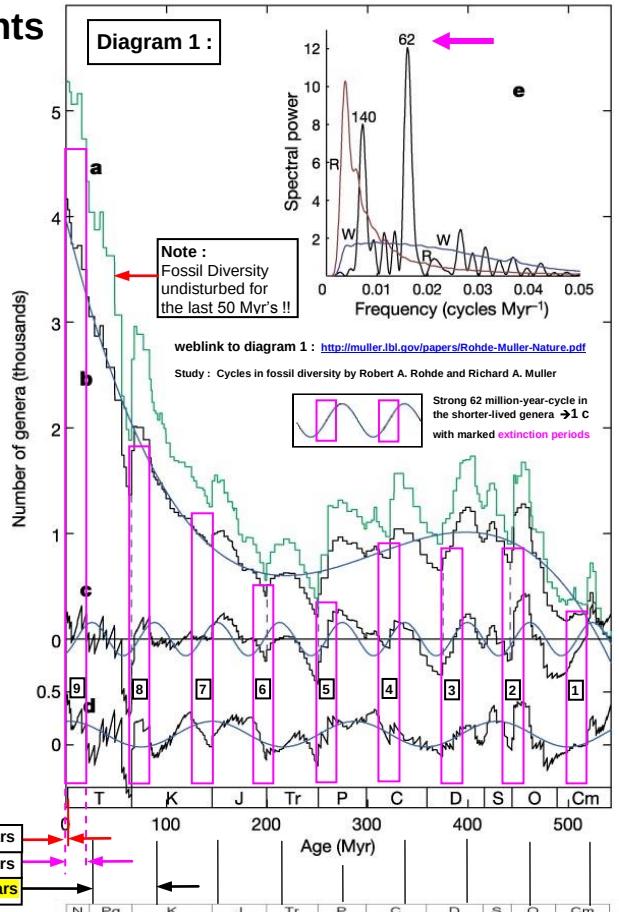
Diagram 1e : Shows the Fourier Spectrum of the short-term variations of the bio-diversity on Earth. The Fourier Spectrum is dominated by a **strong spectral peak with period 62 +/- 3 Myr.**
The **sin wave** corresponding to this cycle is shown in **Fig. 1c** where it accounts for 35% of variance.

Diagram 1e also shows a second spectral peak with period 140 +/- 15 Myr.

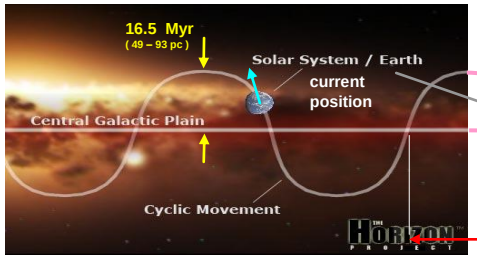
The 62-Myr cycle is very significant.
By contrast the 140 Myr cycle can plausibly result from random processes.

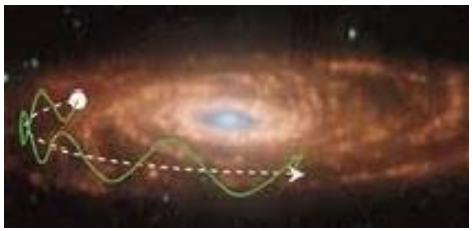
Although no explanation exists, the 62-Myr cycle is not a subtle signal. It is evident even in the raw data (Fig. 1a), dominant in the short-lived genera (Fig. 2) and strongly confirmed by statistical analysis. It implies that **an unknown periodic process** has been **having a significant impact on Earth's environment** throughout the Phanerozoic. The author considers the following physical processes : periodic comet showers triggered by a companian star or a planet X or by the oscillations of our solar sytstem up- and down the galactic plane every 52-74 Myr or by periodic crossings of spiral arms, or periodic mantle plume cycles & volcanism cycles, or longterm solar cycles.

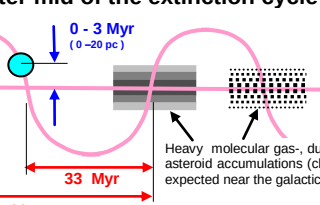
Diagram 1 :



3 - extinction period left ~ 3 - 5 million years
2 – extinction period approx. 20 million years
1 - fossil diversity cycle 62 +/- 3 million years

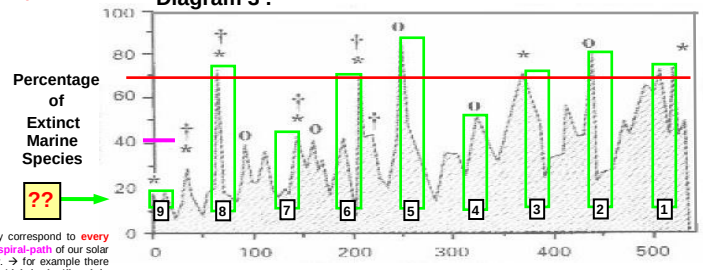






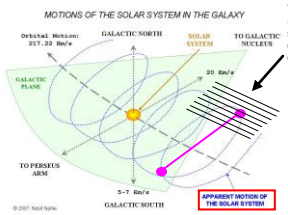
Large well-dated Impact Craters
Diagnostic evidence of Impact
documented Iridium Spikes

Diagram 3 :

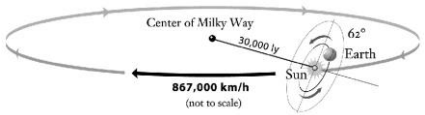


weblink to diagram 3 : Weblink Diagram 3

Study : Impacts and Mass Extinctions by Michael R. Rampino :
Weblink : http://adsabs.harvard.edu/full/1996EM%26P...72..441R

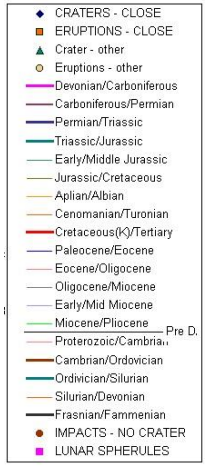


The logical reason why large impact events mainly correspond to **every second crossing** of the galactic plane could be the **spiral-path** of our solar system on it's way around the center of our galaxy. → for example there could be **a "heavy dust- or asteroid accumulation (debris ring)" mainly on one side of the spiral path and less on the other side !** (see image)

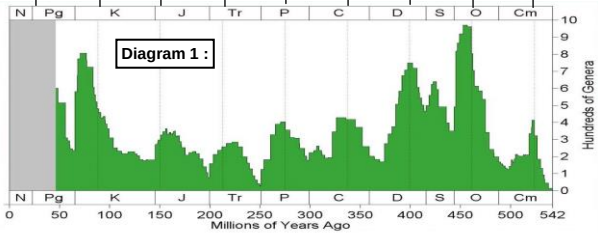


prepared by Harry K. Hahn , 29-9-2013

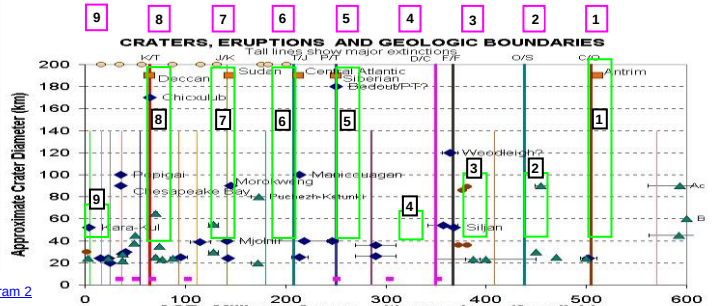
Diagram 2 :



weblink to diagram 2 : Weblink Diagram 2



Fossil Diversity. All 13,682 short-lived (< 45 Myr) genera listed by Sepkoski are plotted. The dotted lines are spaced 62 Myr. (Rohde & Muller, Nature, vol 434, 208-210, 10 March 2005)



Graph by Michael Paine. Thanks to Andrew Glikson, Franco Pirajno and Dallas Abbott. Updated March 2001

Assessment of our ability to deflect large Earth-threatening Asteroids (or Comets) at short notice :

This assessment shall provide a first overview of our technological ability to prevent the collision with a large **Earth-threatening Asteroid or Comet**

Basic assumption for assessment : We have to deal with a **newly discovered asteroid** and we only have an **advance warning time of ≤ 2 years**

And the result of this assessment is clear !! : With direct deflection techniques we can't prevent collisions with such asteroids ≥ Ø 20 km !

For the deflection of the asteroid it was considered to use the most powerful NED's (nuclear eplosive devices) available. And it was further considered that the action to change the trajectory of the Earth-threatening asteroid (explosions of NED's on or near the asteroid) would be accomplished in a distance of either 500 Million km or 250 Million km before the collision (which is currently not achievable considering the short warning time !). Then the amount of required NED's (B83 or B41) was calculated to deflect the Earth-threatening asteroid in such a way that it just misses Earth. Two Deflection-Strategies with different efficiencies ($\eta_1 = 1$, $\eta_2 = 0.065$) of the used NEDs were considered. **Result: The pure number of NED's** required and the difficulty of the short warning time would make it impossible to avoid a collision with asteroids **> Ø 20 km**. **Note:** a 20 km asteroid would be comparable to **Comet Hale-Bopp** which nearly passed Earth's orbit 1997.

Case 1: Action to change the trajectory of the asteroid carried out **500 Million km before Impact :**

Asteroid Diameter in km	Volume in m^3	Mass in kg	Work (Kinetic Energy) in J required to induce a lateral velocity of 0.66 m/s into the asteroid to avoid a collision	Deflection Strategy 1 (technically extremely difficult to achieve max. explosive yield !!!) Required amount of NEDs if max. explosive yield is considered in calculation		Deflection Strategy 2 (relatively easy and save to achieve ! (assuming ADU's can be applied fast !)) Required amount of NEDs if only effective radiation yield is considered in calculation	
				B41 - type	B83-NEP	B41 - type	B83-NEP
150	1.767 * 10^15	5.83 * 10^18	1.27 * 10^18	12	253	190	3795
100	5.236 * 10^14	1.73 * 10^18	3.76 * 10^17	4	75	56	1124
50	6.545 * 10^13	2.16 * 10^17	4.70 * 10^16	1 (0.45)	10	7	141
20	4.189 * 10^12	1.38 * 10^16	3.01 * 10^15	1 (0,03)	1 (0,6)	1 (0,45)	9
10	5.236 * 10^11	1.73 * 10^15	3.76 * 10^14	1 (0,004)	1 (0,08)	1 (0,06)	2 (1,1)
5	6.545 * 10^10	2.16 * 10^14	4.7 * 10^13	1 (0.0005)	1 (0.01)	1 (0.007)	1 (0.14)

see explanation further below !

Comparable to Hale-Bopp :
Considering a nucleus diameter of 35km and a density of 0.6 T/m^3 for Hale-Bopp, then the resulting mass of 1.3 * 10^16 comes close to the mass of a 20 km asteroid with a density of 3.3 T/m^3 (average orbital speed ~ 30km/s)

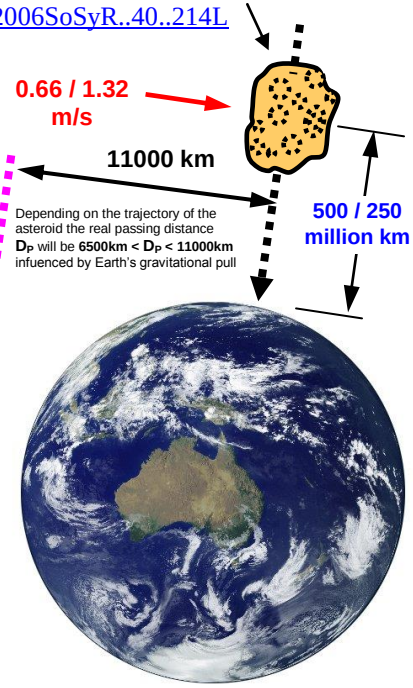
Case 2: Action to change the trajectory of the asteroid carried out **250 Million km before Impact :**

Asteroid Diameter in km	Volume in m^3	Mass in kg	Work (Kinetic Energy) in J required to induce a lateral velocity of 1.32 m/s into the asteroid to avoid a collision	Deflection Strategy 1 Required amount of NEDs if max. explosive yield is considered in calculation		Deflection Strategy 2 Required amount of NEDs if only effective radiation yield is considered in calculation	
				B41 - type	B83-NEP	B41 - type	B83-NEP
150	1.767 * 10^15	5.83 * 10^18	5.08 * 10^18	48	1012	760	15180
100	5.236 * 10^14	1.73 * 10^18	1.51 * 10^18	15	300	224	4498
50	6.545 * 10^13	2.16 * 10^17	1.88 * 10^17	2 (1.8)	38	28	563
20	4.189 * 10^12	1.38 * 10^16	1.20 * 10^16	1 (0,11)	3 (2.4)	2 (1.8)	36
10	5.236 * 10^11	1.73 * 10^15	1.51 * 10^15	1 (0,02)	1 (0,3)	1 (0,23)	5 (4.5)
5	6.545 * 10^10	2.16 * 10^14	1.88 * 10^14	1 (0.002)	1 (0.04)	1 (0.03)	1 (0.6)

The following assumptions were made for this assessment :

It was assumed that the approaching asteroid has an average speed of 30 km/s and that it would hit planet Earth directly in the center. To compensate for the influence of Earths gravitational field on the asteroids trajectory, a simple target distance of 11000km was defined between Earth and the asteroid, for the planned passing of asteroid and Earth, which must be achieved through a lateral acceleration of the asteroid at the given distances (250 & 500 million km's) with the aid of the deflection measures. For the mass calculations a density of **3.3 T/m^3** was used (→ M-type Asteroid)

→ see : http://adsabs.harvard.edu/abs/2006SoSyR..40..214L



technically in the long term impossible

technically in the medium term impossible

technically just possible with many ADU's in place **Deflection Strategy 2**

technically relatively easy with ADU's in place **Deflection Strategy 2**

technically possible with B83's (even at a distance of only 50 - 100 million km)

Note : For every halving of the interference distance, the required amount of NED's must be **quadrupled !!!** e.g. for an interference distance of 125 million km 4 times more NED's are required then in **Case 2** !! And at only 62.5 million km → 16 times more NED's !!

prepared by Harry K. Hahn

Creation of a defence system with the aid of Asteroid Deflection Units (ADU's) in the solar system

To make it possible to deflect very large **Earth-threatening Comets or Asteroids** coming from the outer solar system (e.g. from the Oort Cloud) it is imperative to have a number of **Asteroid Deflection Units** (**ADU's**) already in place on strategical advantageous locations in the solar system.

Possible parking spaces for such ADU's :

1.) Orbits around the planets Jupiter, Mars, Earth & Venus

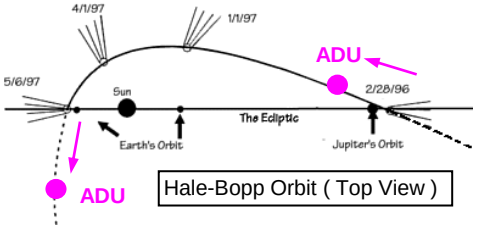
This would allow to quickly get the ADU on the right trajectory with a gravity assist maneuver and save time & valuable fuel.

2.) Trojan Orbits near the L-Points L4 & L5 of these planets

→ For an even distribution of ADUs over the orbits of the planets (some of these ADU's could then be applied by planet fly-bys)

The principle idea is to build an inner- and outer defence ring around Earth which allows an early deflection of objects like e.g. comet Hale-Bopp no matter what trajectory they have !

For example : To make it possible to deflect a comet like **Hale Bopp (C/1995 O1)** , which is on a direct collision course with Earth, an early intervention is imperative !



Hale-Bopp Orbit (Top View)

Note the extreme inclination of Hale-Bopp's Orbit, and that it nearly crossed Jupiter's orbit just 7 months after it's discovery !!

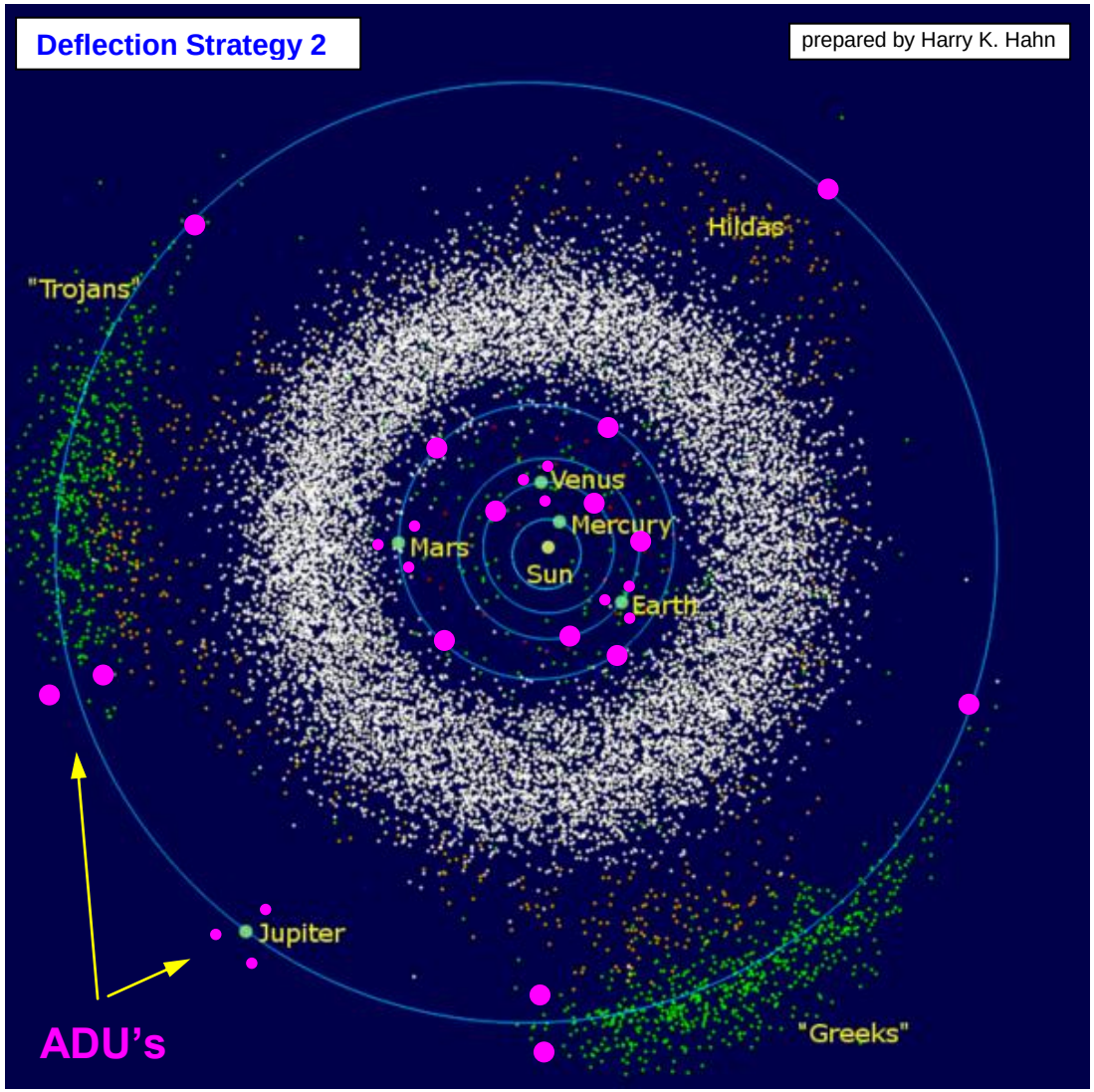
Inclination of Hale-Bopp's orbit : **89.4°**

Orbital Period : **~ 2530 years**
Perihelion : **0.914 AU**
Nucleus Ø : **~ 30 – 40 km**

In order to make it technically possible to prevent a collision with such a large object (diameter 30km or bigger !), special Asteroid Deflection Units must already be in place on strategical important locations in the solar system at the time when such an earth-threatening object is discovered !

(Note: The time between Hale-Bopp's first discovery and it's closest approach to Earth was just 1 year and 8 months !!)

An intervention to slightly change the orbit of such a large object, (→ so that it just misses Earth !), should be done when this object is still at least 200 to 500 million km away from the calculated collision point !!!



Inner solar system (Asteroid Belt) shown with possible park positions for the Asteroid Deflection Units, also shown the Trojan asteroids (coloured green) in front of and behind Jupiter along its orbital path, and the asteroid belt (white) between the orbits of Mars and the Hilda family of asteroids (brown).

Principle Design Concepts for powerful Asteroid Deflection Units (ADU's) :

The described **ADU's** can either be used for **Deflection Strategy 2** or **Deflection Strategy 3** or these ADU's can also be sent to a direct collision course with the Earth-threatening asteroid with the explosion triggered just before impact. In this way a higher effective explosive yield could be achieved (similar to **HAIV**)

Concept 1

NED* used for Concept 1 :

B41 – type fusion bomb

(→ highest yield-to-weight ratio)
weight : approx. **4800 kg**

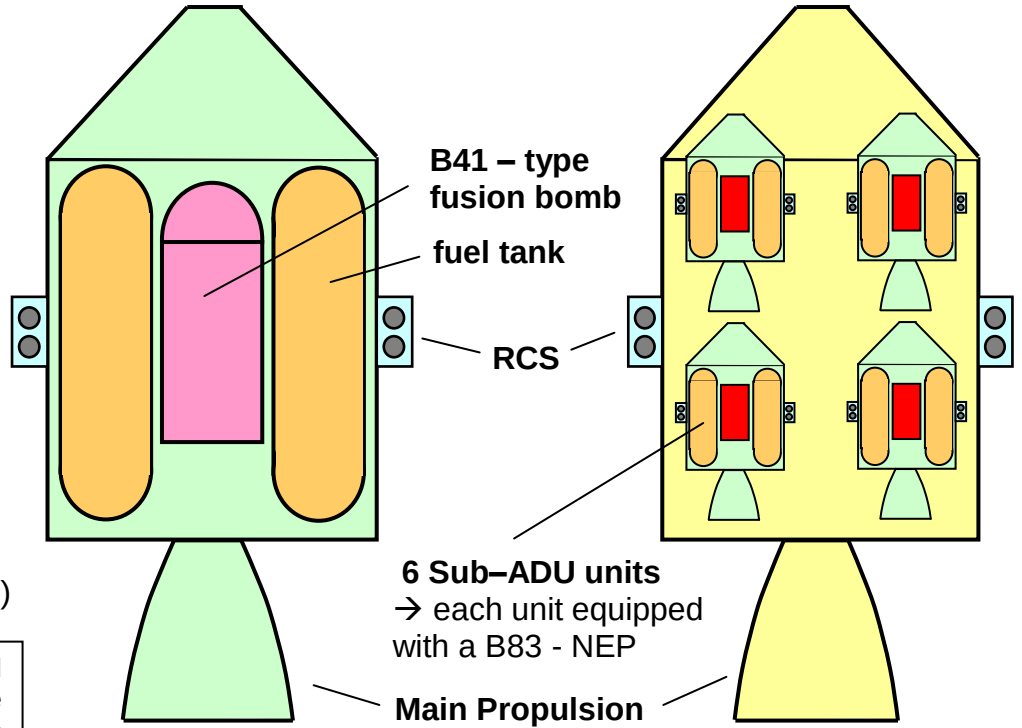
maximum explosive yield : **25 MT**

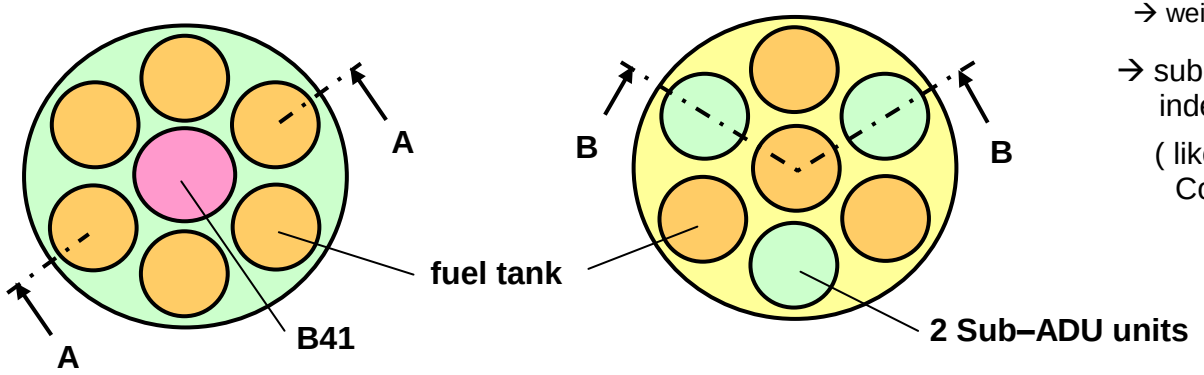
only yield produced by radiation of explosion : **~ 9 MT**

effective radiation yield : **~ 1.6 MT**
→ convertible to an (lateral) acceleration of the asteroid in order to change its path

(**NED*** = Nuclear Explosive Device)

Note : The design of the ADU's should be carried out in such a way that the ADU's have a very long service life (> 30 years) and the design should be as simple and reliable as possible !
It must iclude an extra heavy micro-meteorite protection, especially on the tip





Concept 2

NED* used for Concept 2 :

B83 – NEP of B83 nuclear weapon
(alternatively smaller **W76** can be used)

(NEP → nuclear explosive package B83)
weight: approx. **600-700 kg**

maximum explosive yield : **1.2 MT** per B83 - NEP

only yield produced by radiation of explosion : **~ 0.42 MT**

effective radiation yield : **~ 0.08 MT**
→ convertible to an (lateral) acceleration of the asteroid

The main module contains 6 Sub–ADU units :

→ each sub-unit is equipped with one **B83 - NEP** (**1.2MT**)
(or alternatively with a **W76-100 KT**)
→ weight of W76 warhead : **164 kg**

→ sub-units are detachable and independently manoeuvrable
(like a miniature-version of Concept 1)

prepared by Harry K. Hahn

Deflection Strategy 2 - Deflection through controlled nuclear explosions close to the Asteroid :

Deflection Strategy 2 considers that one or more **ADU's** are placed in defined orbits around the Earth-threatening asteroid, which are then exploded during precise maneuvres (either collision- or approach maneuvres) in order to change the trajectory of the asteroid

This deflection strategy in principle only makes use of the yield of the NED which is produced by the radiation of the nuclear explosion. The effective radiation yield of the NED which is convertible to an (lateral) acceleration of the asteroid is only a fraction of the maximum yield of the NED but this deflection strategy has a number of important **advantages :**

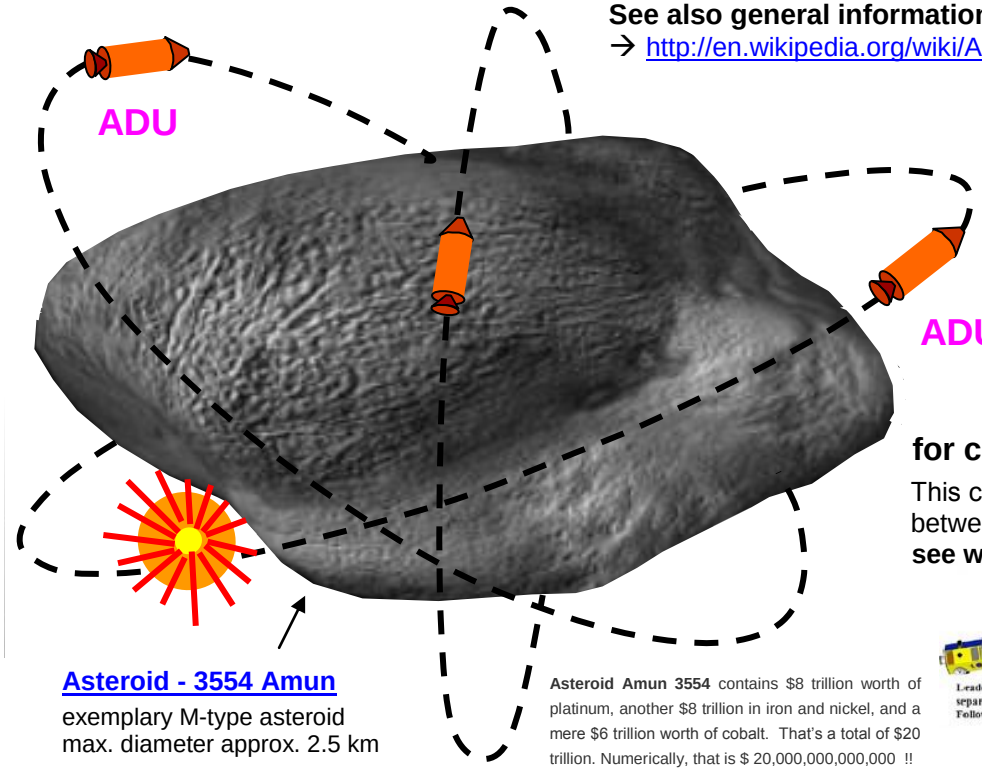
- The slow approch to the asteroid allows for a proper analysis of the topography and the physical properties of the asteroid and the definition of the optimum locations for the explosions of the NED's
- The explosions of the NED's can be precisely planed and executed (e.g. within an existing crater)
- It is a safer and more reliable concept than a very fast approach as intended e.g. with the HAIV-concept where the failure risk would be considerably higher. It also allows to properly deal with "rubble pile asteroids"
- And it is probably the only really viable concept in the case where the ADU has to catch up with an astroid or comet from a park position e.g. in the Jupiter orbit (→ see "Creation of a defence system")

In order to increase the explosive yield of the NED, the ADU can also be put on a defined and precise collision course with the asteroid, and the explosion can be executed just before impact → similar to the HAIV-concept

F_{RP} = Resulting Force produced through the Effective radiation pressure of the NED

→ considered apex angle of the spherical radiation sector (defined by conical boundary) = **120 degree**

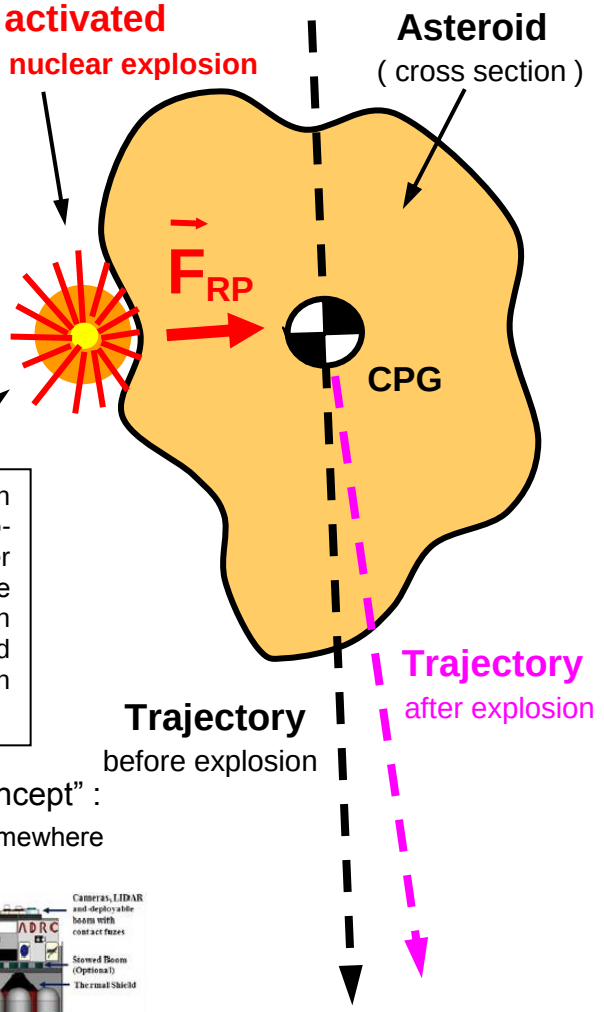
See also general information about asteroid impact avoidance :
→ http://en.wikipedia.org/wiki/Asteroid_impact_avoidance



Asteroid - 3554 Amun
exemplary M-type asteroid
max. diameter approx. 2.5 km

Asteroid Amun 3554 contains $8 trillion worth of platinum, another $8 trillion in iron and nickel, and a mere $6 trillion worth of cobalt. That's a total of $20 trillion. Numerically, that is $ 20,000,000,000,000 !!

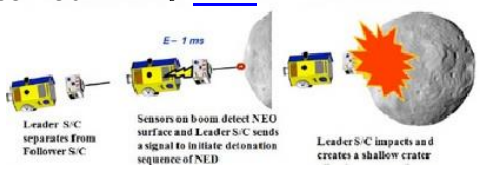
During the controlled explosion of one of the ADU's or Sub-ADU's (ADU-Concept 2) all other ADU's in an orbit around the asteroid should be located on the opposite side of the asteroid in the moment of the explosion to be safe and protected.

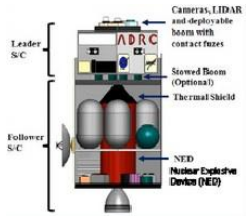


for comparison : → The "**HAIV** mission concept" :

This concept has an efficiency of the used NED's somewhere between the efficiency of Deflection Strategy 1 & 2

see weblink : → **HAIV**



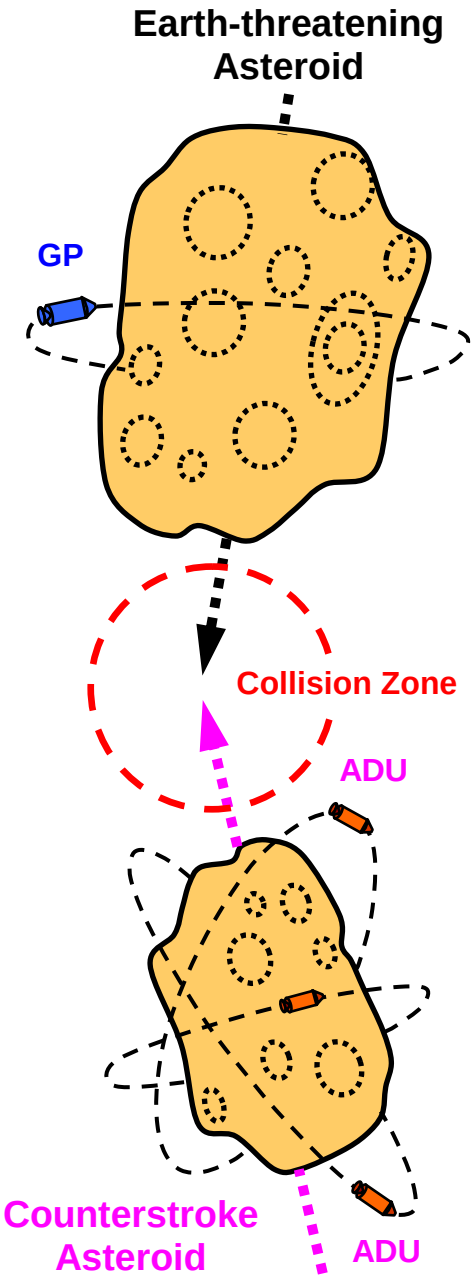


prepared by Harry K. Hahn

Deflection Strategy 3 - Deflection of an Asteroid with the aid of Counterstroke-Asteroids

→ Let's play "Asteroid-Billiard" !!! ;-)

prepared by Harry K. Hahn, 29-9-2013



With this strategy the **applied energy** (→ the energy of the nuclear explosions) **can be multiplied by a very large factor !!**

The idea is to use the kinetic energy of another asteroid to deflect the Earth-threatening asteroid !!

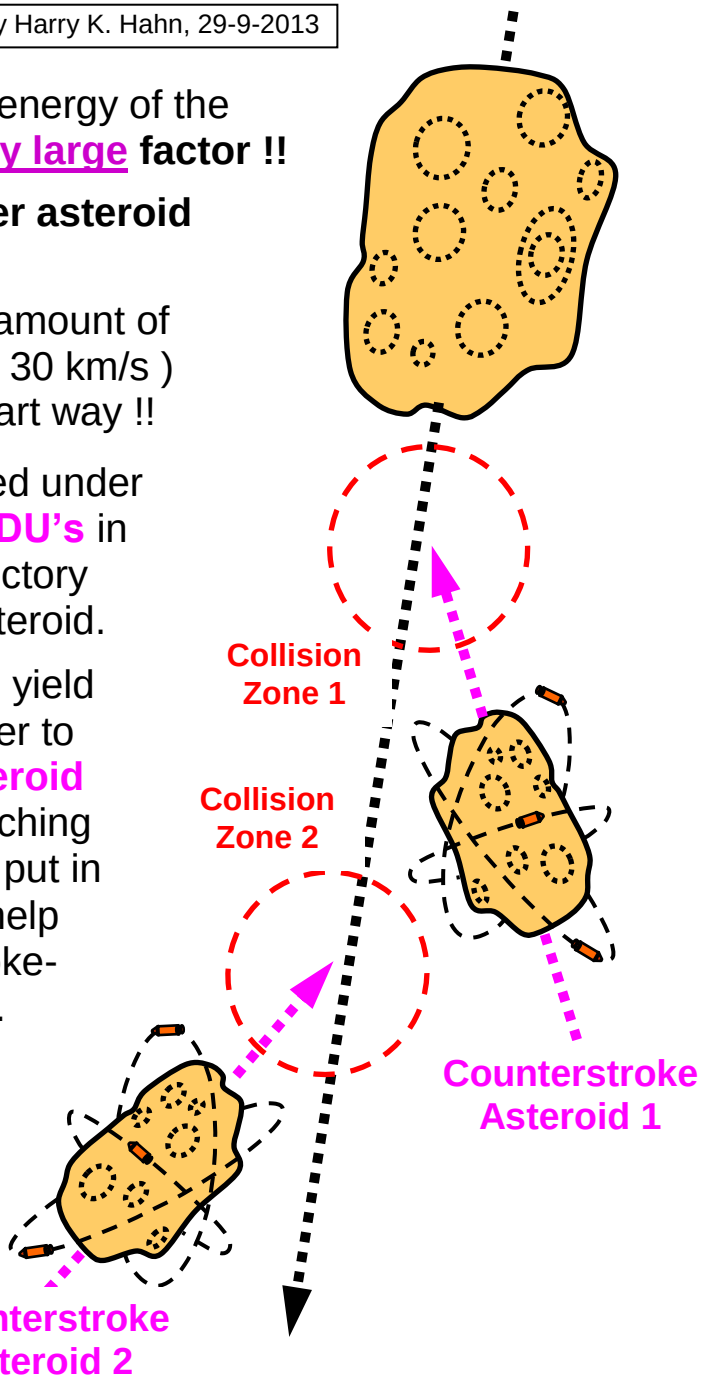
Even a very small asteroid has stored a gigantic amount of kinetic energy because of it's very high speed (~ 30 km/s) All we have to do is make use of this fact in a smart way !!

In principle we use the same strategy as described under **Deflection Strategy 2**. We place a number of **ADU's** in the orbit of a smaller asteroid, which is on a trajectory where it comes close to the Earth-threatening Asteroid.

Then we explode **NED's** with a defined explosive yield in a defined sequence, one after the other, in order to set the small asteroid → the **Counterstroke Asteroid** step by step on a collison course with the approaching Earth-threatening Asteroid. A **Guide Probe "GP"** put in the orbit of the Earth-threatening Asteroid could help us with the controlled changes of the Counterstroke-Asteroid's course and the checking of the course.

And to be on the safe side we can set more than one Counterstroke-Asteroids on course to deflect the Earth-threatening Asteroid !!

By the way, the described strategy can also be used to move big Asteroids in an orbit around Earth for mining !!



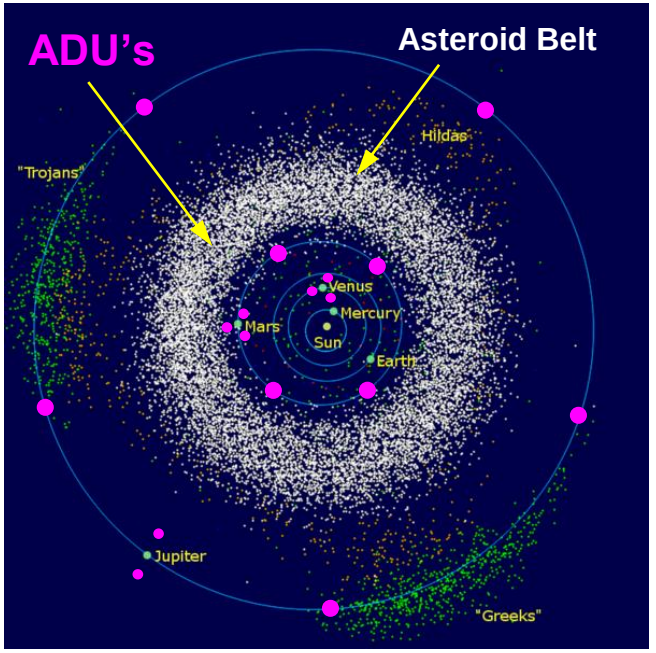
Deflection Strategy 3 - Explanation of the deflection procedure

prepared by Harry K. Hahn, 29-9-2013

As described before it is imperative to have a number of **Asteroid Deflection Units** (**ADU's**) already in place on strategical advantageous locations in space in order to be able to deflect large Earth-threatening Asteroids (or Comets) at short notice. We must be prepared ! This is important !

In order to apply **Deflection Strategy 3** quickly it would be good to have a number of **ADU's** placed close to the Asteroid Belt. This is where our arsenal of Counterstroke-Asteroids is located !! We also need a Super-Computer + Software which can determine the best Counterstroke-Asteroid

Then the optimum deflection procedure for the Counterstroke-Asteroid must be calculated. We need to kow what type of ADU we need, how many NED's are required and where on the Asteroid and when they must be exploded.



Astroid Deflection Units placed in Mars's Orbit (e.g. in stable Trojan Orbits) and in orbits around planet Mars so that they can be applied quickly

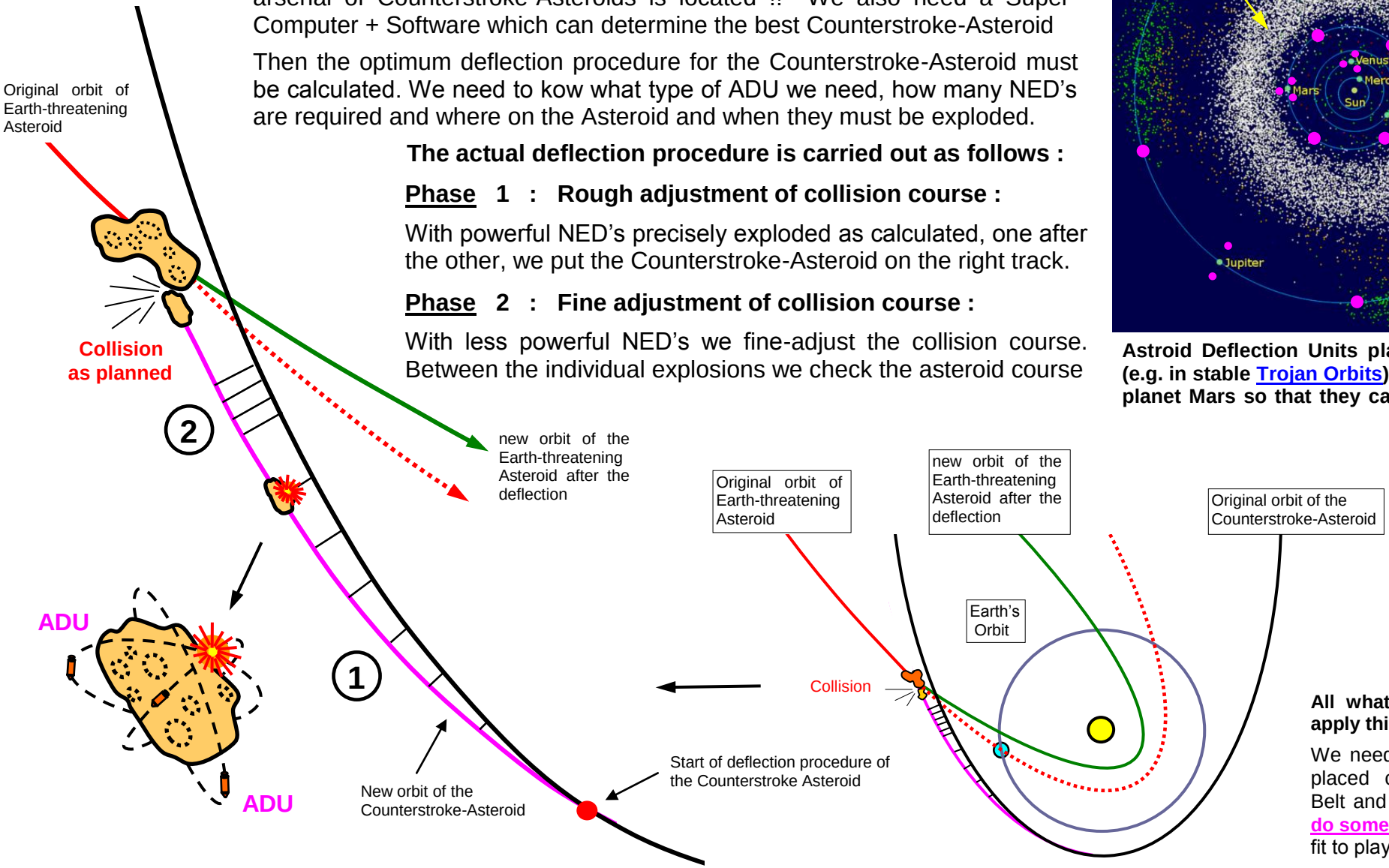
The actual deflection procedure is carried out as follows :

Phase 1 : Rough adjustment of collision course :

With powerful NED's precisely exploded as calculated, one after the other, we put the Counterstroke-Asteroid on the right track.

Phase 2 : Fine adjustment of collision course :

With less powerful NED's we fine-adjust the collision course. Between the individual explosions we check the asteroid course



All what is really required to apply this deflection strategy :

We need some **ADU's** already placed close to the Asteroid Belt and of course we **need to do some exercise** in order to be fit to play "Asteroid Billard" !! ;-)

Deflection Strategy 3 - First calculations show that Asteroids of Ø 150 km and even larger can be deflected with currently available technology !!!

A comparison of the described **indirect** **Deflection Strategy 3** with the **direct** **Deflection Strategies 1 & 2** shows that if we use the huge amount of **stored kinetic energy** in the known Asteroids of our Solar System to our favour, we are able to protect our Earth from collisions with Asteroids of up to **Ø 150 – 200 km diameter !!!** → **In this way we can multiply the energy which we put in the deflection action by a very large factor !!!**

With Deflection Strategy 3 we can multiply the applied energy (the effective yield of the used NED's) by a factor of 60,000 to 250,000 !!!

prepared by Harry K. Hahn, 29-9-2013

For the deflection again an **advance warning time of only ≤ 2 years** was considered. Further it was considered that the action to change the trajectory of the Counterstroke-Asteroid would be accomplished in a distance of either **500** or **250 Million km** before the collision with the Earth-threatening Asteroid (at least the rough adjustment of its trajectory should be finished then !!) And it was assumed that we have shifted the trajectory of the Counterstroke-Asteroid by **1 Million km** at the collision point.

Collison between **Counterstroke-** & **Earth-threatening Asteroid** to change the trajectory of the **Earth-Threatening Asteroid** is carried out around **250 Million km** before the collision with planet **Earth**. → induced lateral velocity **1.32 m/s**

Case 1: Action to change the trajectory of the **Counterstroke** Asteroid carried out around **500 Million km** before collision with the **Earth-Threatening Asteroid :**

Counterstroke Asteroid Diameter in m	Volume in m^3	Mass in kg	Work (Kinetic Energy) in J required to induce a lateral velocity of 40 m/s into the Counterstroke-Asteroid	Deflection Strategy 1 – Required amount of NEDs if max. explosive yield is considered in calculation: B41 - type	B83-NEP	W76-WH	Deflection Strategy 2 – Required amount of NEDs if only effective radiation yield is considered in calculation: B41 - type	B83-NEP	W76-WH
2000	4.189 * 10^9	1.38 * 10^13	1.11 * 10^16	1 (0,11)	3 (2,2)	27	7	33	407
1500	1.767 * 10^9	5.83 * 10^12	4.67 * 10^15	1 (0,05)	1 (0,9)	12	1 (0,7)	14	172
1000	5.236 * 10^8	1.73 * 10^12	1.38 * 10^15	1 (0,02)	1 (0,3)	4 (3,3)	1 (0,2)	5 (4,2)	51
500	6.545 * 10^7	2.16 * 10^11	1.73 * 10^14	1 (0,002)	1 (0,04)	1 (0,5)	1 (0,03)	1 (0,6)	7 (6,4)
200	4.189 * 10^6	1.38 * 10^10	1.11 * 10^13	1 (0,0001)	1 (0,003)	1 (0,03)	1 (0,002)	1 (0,04)	1 (0,4)
100	5.236 * 10^5	1.73 * 10^9	1.38 * 10^12	1 (0,00002)	1 (0,0003)	1 (0,004)	1 (0,0002)	1 (0,004)	1 (0,05)

Deflection Strategy 3 – Kinetic Energy of Counterstroke Asteroid used to deflect Earth-threatening Asteroid

Counterstroke Asteroid Diameter in m	Kinetic Energy in J which is stored in the Counterstroke-Asteroid if considered average orbital speed is 20 km/s
2000	2.76 * 10^21
1500	1.17 * 10^21
1000	3.46 * 10^20
500	4.32 * 10^19
200	2.76 * 10^18
100	3.46 * 10^17

Deflection Strategy 2

Work (Kinetic Energy) in J required to induce a lateral velocity of 1.32 m/s into the asteroid to avoid a collision	Required amount of NEDs if only effective radiation yield is considered in calculation: B41 - type	B83-NEP	Earth-threatening Asteroid Diameter in km
5.08 * 10^18	760	15180	150
1.51 * 10^18	224	4498	100
1.88 * 10^17	28	563	50
1.20 * 10^16	2 (1.8)	36	20
1.51 * 10^15	1 (0,23)	5 (4.5)	10
1.88 * 10^14	1 (0.03)	1 (0.6)	5

For comparison : This is the first table from the presentation, which shows how many **NED's** we would need if we try to deflect the Earth-threatening Asteroid directly !!

Case 1: Action to change the trajectory of the **Counterstroke** Asteroid carried out around **250 Million km** before collision with the **Earth-Threatening Asteroid :**

Counterstroke Asteroid Diameter in m	Volume in m^3	Mass in kg	Work (Kinetic Energy) in J required to induce a lateral velocity of 80 m/s into the Counterstroke-Asteroid	Deflection Strategy 1 – Required amount of NEDs if max. explosive yield is considered in calculation: B41 - type	B83-NEP	W76-WH	Deflection Strategy 2 – Required amount of NEDs if only effective radiation yield is considered in calculation: B41 - type	B83-NEP	W76-WH
2000	4.189 * 10^9	1.38 * 10^13	4.44 * 10^16	1 (0,44)	9 (8,8)	108	28	132	1628
1500	1.767 * 10^9	5.83 * 10^12	1.87 * 10^16	1 (0,2)	4 (3,6)	48	3 (2,8)	56	688
1000	5.236 * 10^8	1.73 * 10^12	5.52 * 10^15	1 (0,08)	2 (1,2)	14	1 (0,8)	17	204
500	6.545 * 10^7	2.16 * 10^11	6.92 * 10^14	1 (0,01)	1 (0,16)	2	1 (0,12)	3 (2,4)	26
200	4.189 * 10^6	1.38 * 10^10	4.44 * 10^13	1 (0,0004)	1 (0,012)	1 (0,12)	1 (0,01)	1 (0,16)	2 (1,6)
100	5.236 * 10^5	1.73 * 10^9	5.52 * 10^12	1 (0,0001)	1 (0,0012)	1 (0,016)	1 (0,001)	1 (0,02)	1 (0,2)

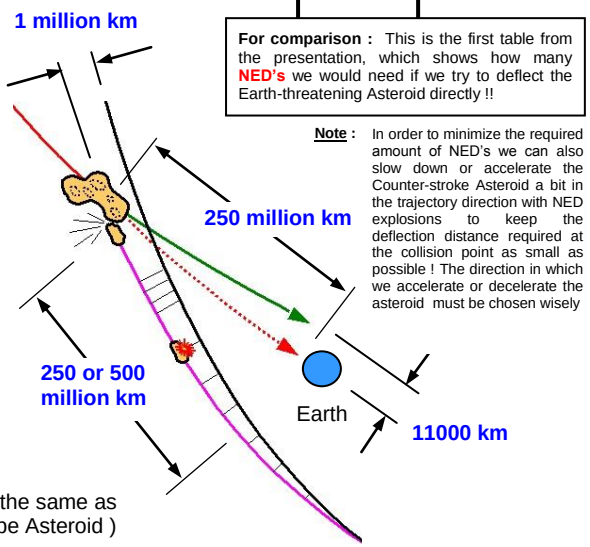
technically in the long term impossible

technically in the medium term impossible

technically just possible with **many** ADU's in place **Deflection Strategy 2**

technically relatively easy with ADU's in place **Deflection Strategy 2**

technically possible (even at a distance of only 50 - 100 million km)



Note : In order to minimize the required amount of NED's we can also slow down or accelerate the Counter-stroke Asteroid a bit in the trajectory direction with NED explosions to keep the deflection distance required at the collision point as small as possible ! The direction in which we accelerate or decelerate the asteroid must be chosen wisely

The following further assumptions were made for this assessment :

It was assumed that the Counterstroke-Asteroid moves with an (average) orbital speed of 20 km/s. The assumptions regarding the Earth-threatening Asteroid are the same as before (see assessment of the direct deflection strategies). For the mass calculations of the Counterstroke-Asteroid again a density of **3.3 T/m^3** was used (→ M-type Asteroid) → see : http://adsabs.harvard.edu/abs/2006SoSyR..40..214L

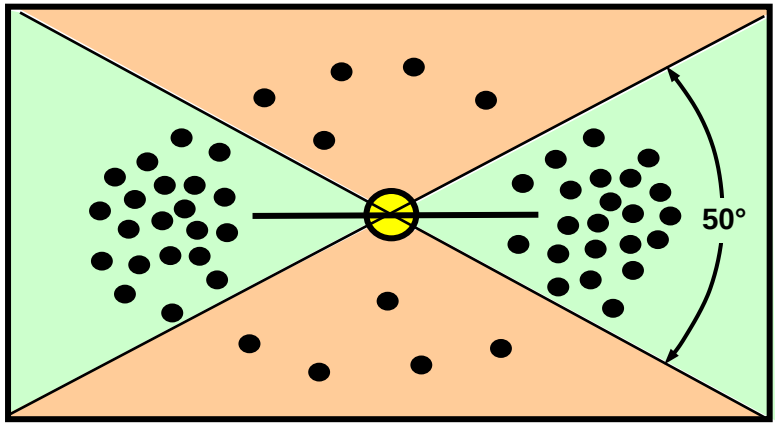
Deflection Strategy 3 - Why we need to search for small Asteroids with orbit inclinations of ≥ 25°

With **Deflection Strategy 3** it should be possible and within our capabilities to protect Earth from a large Asteroid or Comet on a direct collision course with Earth, if the approaching Earth-threatening Asteroid or Comet has an **orbit inclination of ≤ 25 degrees**

However if the approaching Earth-threatening Asteroid or Comet has an **orbit inclination of ≥ 25 degrees** then the planning, organization and execution of the deflection procedure will be much more difficult, because there are considerable less possible Counter-stroke Astroids availabe which have such inclinations.
(→ e.g. for the deflection of a **"Hale Bopp-like" Comet**)

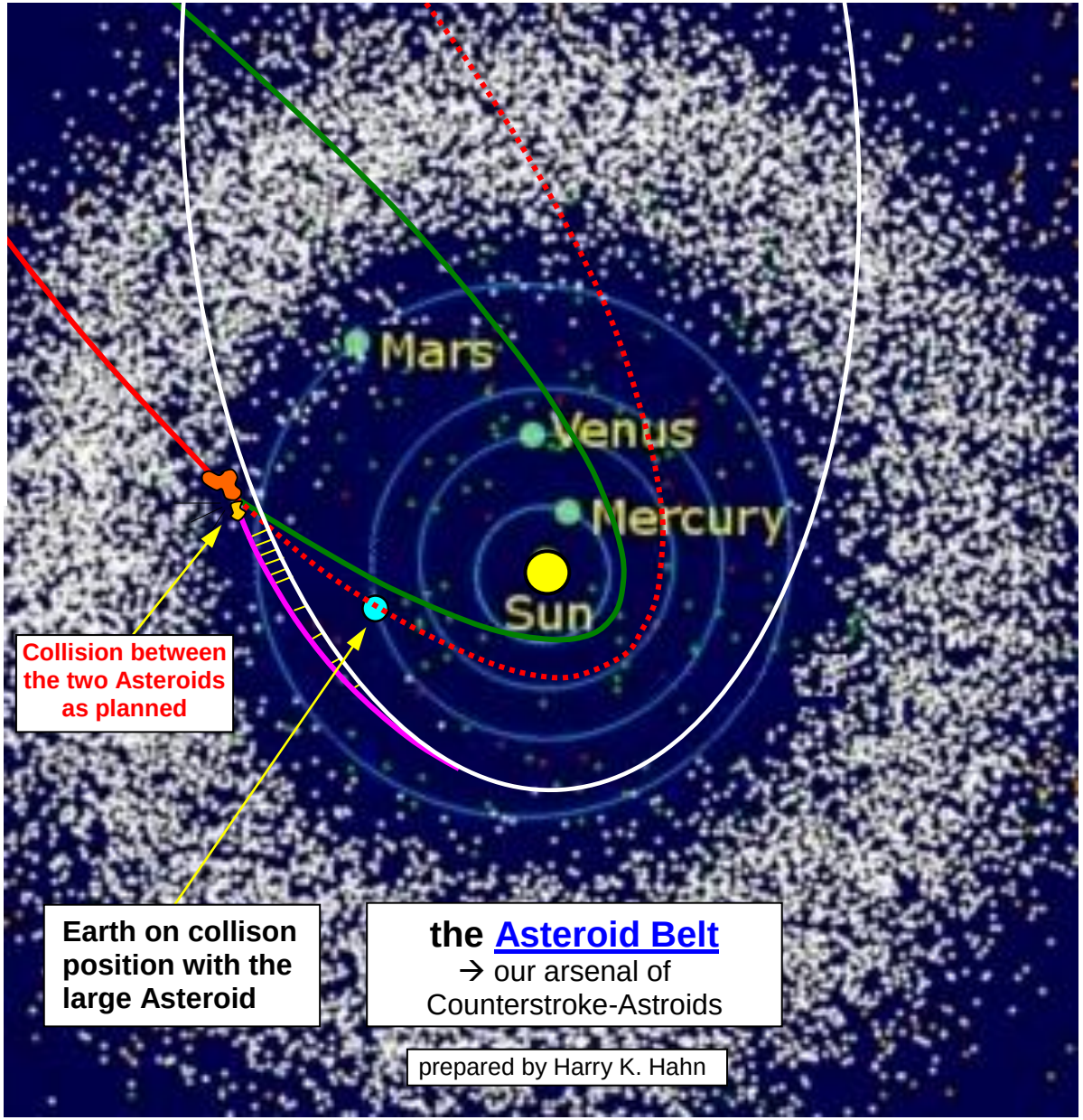
That's why it would be important to search for possible Counterstroke-Asteroids with inclinations of ≥ +/- 25 degrees and build up a special data base !

Side view of inner solar system up to the orbit of Mars with a cross-section through the Asteroid Belt



only small arsenal of Counterstroke-Asteroids available with **orbit inclinations of ≥ +/- 25 degrees**

good arsenal of Counterstroke-Asteroids available with **orbit inclinations of ≤ +/- 25 degrees**



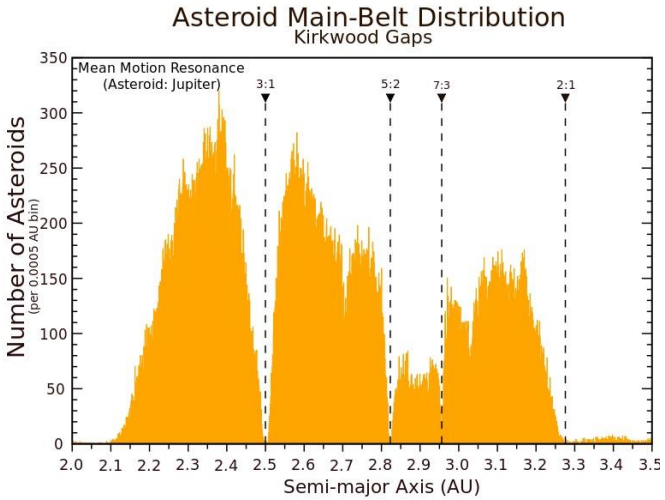
The image shows the inner solar system up to the Astroid Belt (our natural arsenal of Counterstroke-Asteroids) and exemplary the execution of Deflection Strategy 3. A suitable Counterstroke-Asteroid (white orbit) is deflected by a sequence of explosions of suitable NED's (changed orbit → pink) and collides as planned with the Earth-threatening Asteroid

Deflection Strategy 3 - Our arsenal of Counterstroke-Asteroids

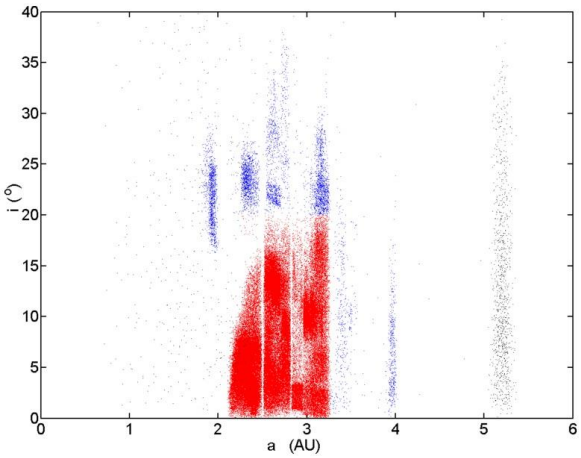
The important base for Deflection Strategy 3 is the available arsenal of possible Counterstroke-Asteroids. Here especially **the available number of asteroids in the diameter range Ø 100m to Ø 500m** and their spatial distribution in our solar system must be considered for the succesful application of the suggested **Deflection Strategy 3** (→ **deflection of large asteroids in the Ø 50km to Ø 200km range**).

The table further below shows that there are at least **2 million Counterstroke-Asteroids with Ø 500m, 4 million Counterstroke-Asteroids with Ø 300m and ≥ 25 million Counterstroke-Asteroids with Ø 100m are available for the possible deflection of large asteroids !!**

These large numbers of available Counterstroke-Asteroids should make Deflection Strategy 3 a potential and feasible deflection strategy for large asteroids with orbit inclinations of ≤ +/- 25 degrees !!



This chart shows the distribution of asteroid semi-major axes in the "core" of the asteroid belt. Black arrows point to the Kirkwood gaps, where orbital resonances with Jupiter destabilize orbits



The asteroid belt showing the orbital inclinations versus distances from the Sun, with asteroids in the core region of the asteroid belt in red and other asteroids in blue

see wikipedia : → http://en.wikipedia.org/wiki/Asteroid_belt

Approximate number of asteroids N larger than diameter D

D	100 m	300 m	500 m	1 km	3 km	5 km	10 km	30 km	50 km	100 km	200 km	300 km	500 km	900 km
N	~25,000,000	4,000,000	2,000,000	750,000	200,000	90,000	10,000	1,100	600	200	30	5	3	1

Our arsenal of Counterstroke-Asteroids

Overview of NED's :

NED type :	B83	W80	W54
max. explosive yield :	**1.2 MT**	**5 - 150 KT**	**1 KT**
only yield produced by radiation of explosion :	**0.4 MT**	**1.7 - 52 KT**	**0.35 KT**
effective radiation yield :	**80 KT**	**0.3 - 10 KT**	**0.07 KT**

ADU - Concept 3 :

This **ADU** concept could be used for the controlled deflection of small (Counterstroke) - Asteroids in the **Ø 200 - 500m** range.

The **Main-ADU Unit** is divided into different launch facilities for at least two different sizes of **Sub-ADU's**.

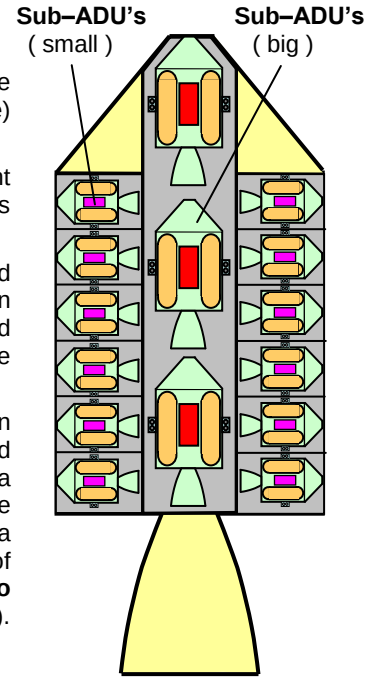
Here the bigger size ADU's are designated for the first **rough adjustment** of the collision course of the Counterstroke-Asteroid, and the smaller size ADU's are designated for the **fine adjustment** of the asteroid's trajectory.

For the **rough adustment** of the collision course of a **Ø 500m** counterstroke-asteroid approx. **3 - 10 NED's** (big Sub-ADU's) with a max. explosive yield of **100KT to 1.2MT** are required (e.g. W80 & B83 NED's), and for a **Ø 200m** size asteroid the same amount of **NED's** with a max. explosive yield of **5KT to 25KT** are required (e.g. W80 → weight 130kg).

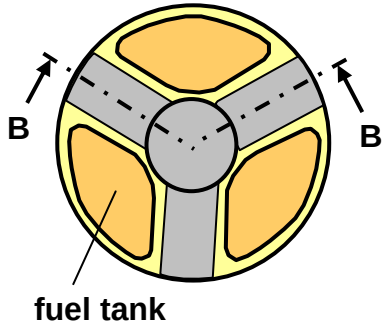
And for the **fine adustment** of the collision course of a **Ø 500m** counterstroke-asteroid approx. **10-30 NED's** (small Sub-ADU's) with a max. explosive yield of **10KT to 80KT** are required (e.g. W80 type NED's), and for a **Ø 200m** size asteroid the same amount of **NED's** with a max. explosive yield of **1KT to 5KT** are required (e.g. W54 & W80 type NED's).

(**Note** : the max. applicable explosive yield per course-adjustment-step must be kept below a certain threshold in order to avoid a possible breaking-up of the asteroid.

(**Note:** Deflection Strategy 2 considered !)



B - B



Deflection Strategy 1 - At last a few words to the Deflection Strategy 1

prepared by Harry K. Hahn

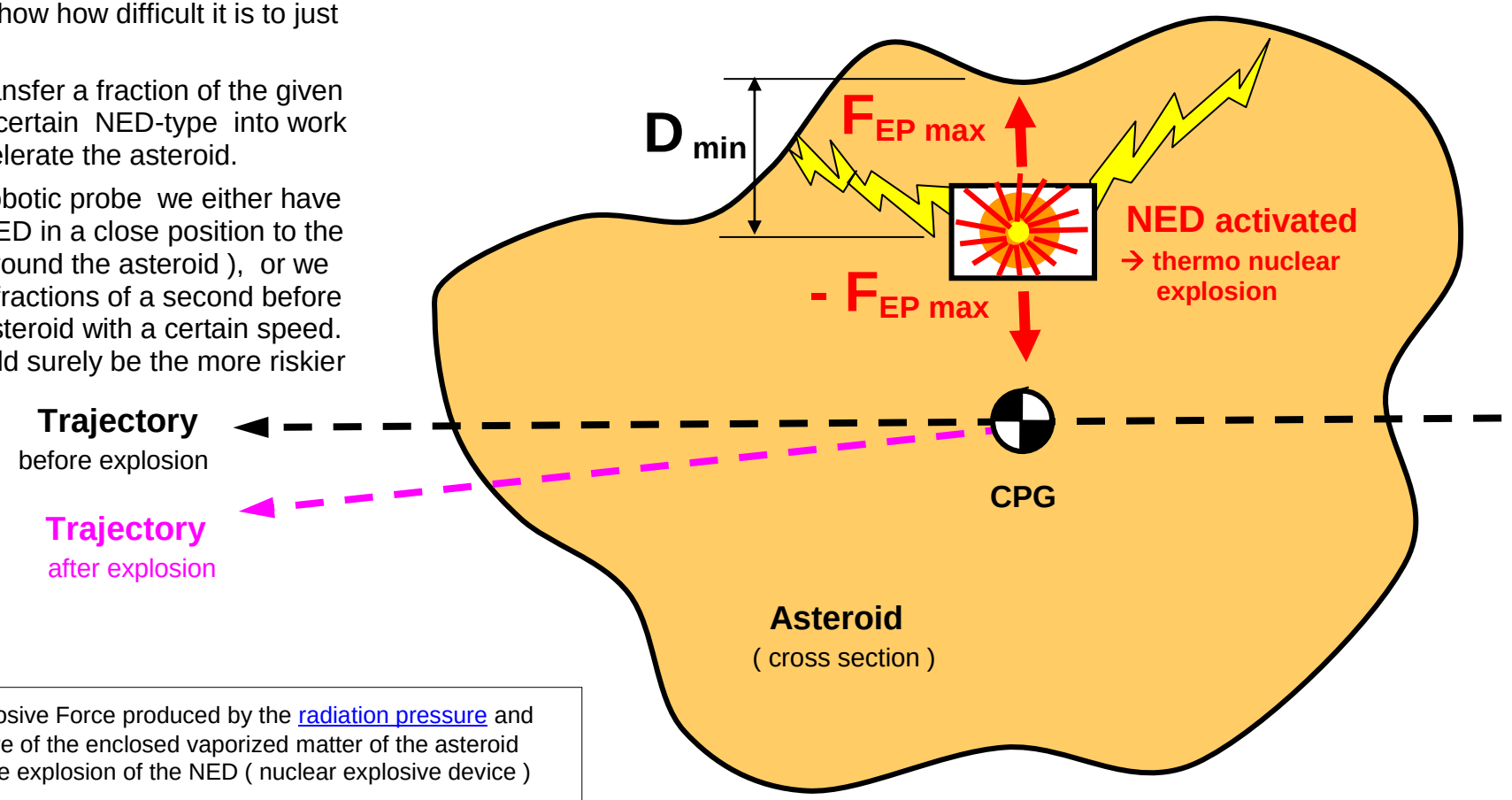
For comparison I have also calculated the required number of **NED's** for the deflection of asteroids, if we could expect to achieve the maximum possible Explosive Force F_{EP} for the lateral acceleration of the asteroid. However this would mean that we transfer the given maximum explosive yield of the NED without any losses into work (or kinetic energy) to accelerate the asteroid perpendicular to its trajectory .

But this is only possible if the NED gets precisely placed in a minimum depth D_{min} inside the asteroid before the explosion. Here the required minimum depth depends on the given max. explosive yield for a certain NED-type. The higher the given max. explosive yield, the greater the required minimum depth D_{min} must be. Obviously this is not an easy task to do in space, far away from Earth, as indicated in the movie "Armageddon"

(→ the Mars Rovers also show how difficult it is to just drill some minor holes !).

Realistically we can only transfer a fraction of the given max. explosive yield of a certain NED-type into work (or kinetic energy) to accelerate the asteroid.

With a remote controlled robotic probe we either have the option to explode the NED in a close position to the asteroid (e.g. in an orbit around the asteroid), or we trigger the explosion a few fractions of a second before the probe impacts on the asteroid with a certain speed. But the impact method would surely be the more riskier and error-prone method !

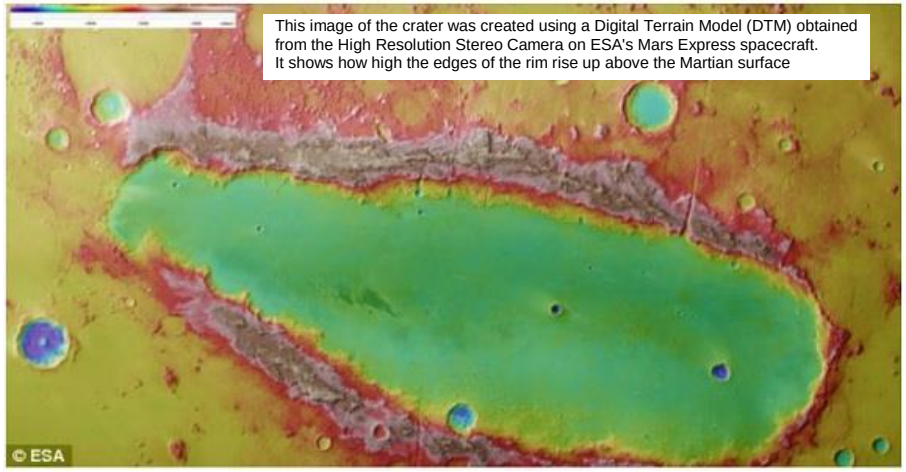


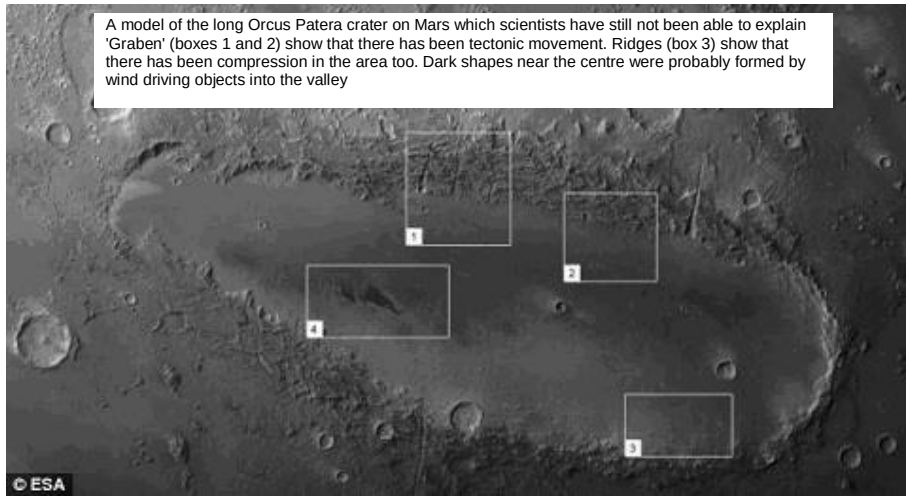
$F_{EP\ max}$	=	Maximum Explosive Force produced by the radiation pressure and the gas pressure of the enclosed vaporized matter of the asteroid produced by the explosion of the NED (nuclear explosive device)
D_{min}	=	Required minimum depth of the NED inside the Asteroid to achieve the maximum possible Explosive Force (or the maximum possible explosive yield of the NED)

Appendix 1 : Addams Crater on Venus & Orcus Patera Crater on Mars

Orcus Patera Crater on Mars

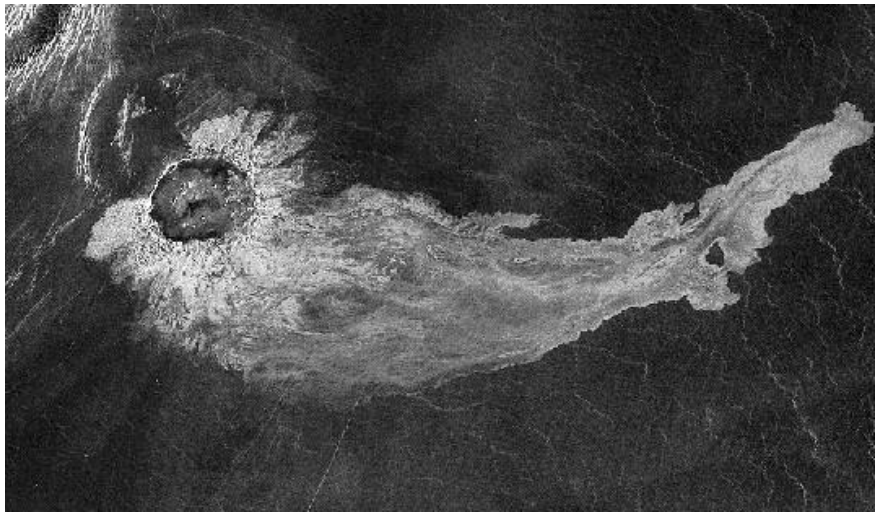
see weblink : → Orcus-Patera -1 & -2.





Addams Crater on Venus

see weblink : → Addams Crater



Addams crater is remarkable for the extensive outflow that extends 600 kilometers (373 miles) from the crater rim. Because of the high temperature and pressure on the Venusian surface, impacts produce more melt than on other planets. Outflow deposits are very thin. Their direction is controlled by the local topography.

Magellan radar image of Addams crater, Venus. The radar bright outflow associated with the 90 km crater stretches over 600 km to the east. (North is up.) The crater is located at 56.1S,98.9E in the Aino Planitia region. (Magellan C2-MIDR 60S093;202,framelets 21 and 29)

Orcus Patera crater : Scientists have been left baffled by a long strange scar on the surface of Mars, close to the planet's equator. The European Space Agency (ESA) has released new images of Orcus Patera - an elongated crater which is located between the volcanoes of Elysium Mons and Olympus Mons in the planet's eastern hemisphere. Scientists believe the most likely explanation for the crater is that it was made in an oblique impact, when a small asteroid struck the surface at a very shallow angle. The long crater is about 230 miles long and and is almost 90 miles wide and has a rim that rises up more than a mile above the surrounding plains. Its valley floor lies almost half a mile below the Martian plains that surround it. The term 'patera' is used for deep, complex or irregularly shaped volcanic craters but despite its name, scientists do not really know where Orcus Patera came from.
It may be a large and originally round impact crater, which has changed shape through compression over time. Or it could have formed after a number of different impact craters were eroded. The existence of tectonic forces at Orcus Patera is evident from the presence of the numerous 'graben', rift-valley-like structures that cut across its rim. Up to 2.5 km wide, these graben are oriented roughly east–west and are only visible on the rim and the nearby surroundings. The dark shapes near the centre of the depression were probably formed by wind-driven processes, where dark material excavated by small impact events in the depression has been redistributed.

Appendix 2 : To the origin of solar flares and the possible cause of long-periodic changes in solar flare activity

As mentioned at the beginning of this study, strong changes in the Solar Wind Flow and in Flare Activity over longer time periods (millions of years) could cause considerable changes on the orbits of the asteroids and comets (incl. the comets of the Oort cloud) of our solar system.

The fundamental cause of such a long-periodic change in Solar Wind Flow and Flare Activity, which may match the 62-Myr biodiversity cycle on Earth, could only be a long-periodic change in the sun's fusion zone or in sun's core, where all energetic processes and all solar activity originate from.

What is the important link between Solar Flares and the Sun's fusion zone ??

The answer is relatively simple : The Helium which is produced in the fusion zone of the sun !!!

There is clear evidence that Helium from the fusion process, which is ascending from the fusion zone to the surface of the sun , is the main cause of solar flares !!!

The abundance (or share) of Helium in normal solar corona is around 3 to 5 % (≈ 3 % at solar minimum (slow solar wind) ; and ≈ 5 % at solar maximum (fast solar wind))

However the abundance of Helium in solar flare plasma is in the range of up to 10 to 22 % !!!

See following scientific studies to Flares & Helium !! : → Study_1 , Study_2 , Study_3

The following logical conclusions must be drawn from this fact !! :

1.) - **Helium ascending from the fusion zone must be the main cause of solar flares !**

2.) - **Because of the unity (or close association) of solar flares and sunspots, consequently this Helium must be the main cause of sunspots too !!**

3.) - **And because of the further unity (association) of sunspots and "magnetic flux ropes", the Helium ascending from the fusion zone must also be the basic trigger of the "magnetic flux ropes" and the "coronal loops" which form the stellar magnetic field !!**

4.) - **Therefore flares, sunspots and magnetic flux ropes are a direct result of the movement of Helium from the fusion zone to the surface !!**

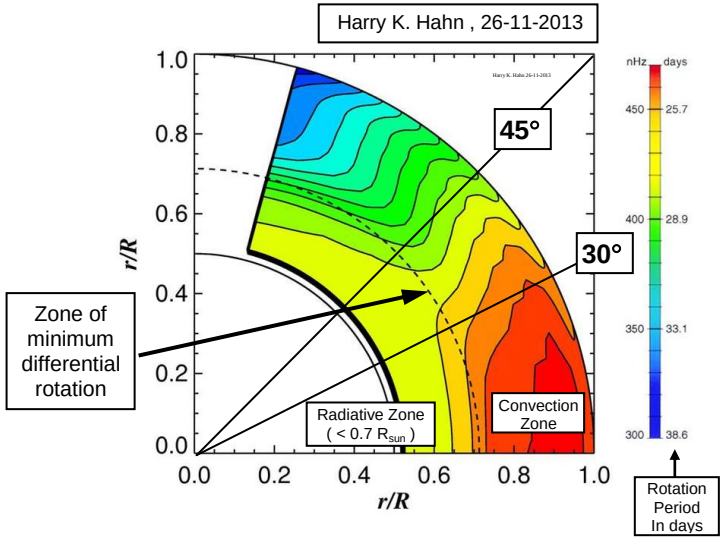
Harry K. Hahn 26-11-2013

Based on these conclusions I want to propose a new theory to explain the creation of sunspots, magnetic flux ropes and solar flares (see below) :

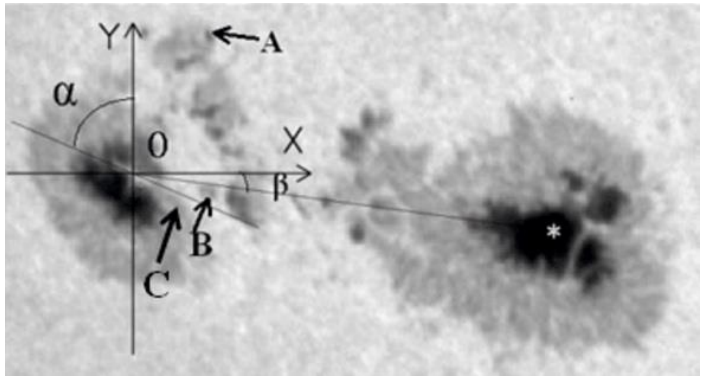
And I want to point out that we need to better understand the processes which lead to changes in the fusion zone and in the primordial magnetic field of the sun. Because these processes are responsible for the ejection of powerful solar flares (helium-enriched plasma) !!

Helium filaments start to form on the outer edge of the hydrogen-burning fusion shell, along the magnetic field lines of the primordial magnetic field of sun's core. These helium filaments together with the magnetic field lines (amplified by helium flow) slowly ascend towards the surface, mainly in the equatorial area of the sun. At a height of approx. 0.7 to 0.8 R_{sun} the helium filaments break-up to short "helium-strings" by convection and differential rotation.
Only the "helium-strings" which move up in the zone of minimum differential rotation make it to the surface where they then cause sunspots, solar flares and coronal loops etc.

→ detailed explanation of this new theory see next page !!



At the start of a sunspot cycle, sunspots tend to appear at latitudes of around 20° to 35° on the Sun's surface. As the cycle progresses, sunspots appear at lower and lower latitudes, until they average 15° at solar maximum. The average latitude of sunspots then continues to drift lower, down to about 7° and then while the old sunspot cycle fades, sunspots of the new cycle start appearing again at latitudes of 20° to 35° The movement of the sunspots is driven by convection and the differential rotation of matter in the equatorial area (red and orange marked)



Rapid rotation of a sunspot associated with flares. There is a close relationship between the sunspot rotation and the emerging kinked magnetic Ω-loops, where the flares occur.

Note : rotation of sunspot is associated with the flow of helium !

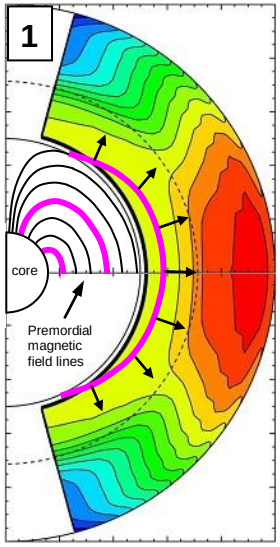
For the sunspot with positive polarity, the umbra, the penumbra, and the area near the penumbra exhibit a conspicuous counterclockwise rotation. Moreover, the velocities decrease from the umbra through the penumbra to the area near the penumbra. It is interesting that the rotation of the umbra, the penumbra, and the area near the penumbra are opposite to that of the area far from penumbra. → **weblink to study**

The Theory : Helium Filaments ascending from the fusion zone are the cause of sunspots, flares, coronal loops, sun tornados etc.

Helium filaments start to form on the outer edge of the hydrogen-burning fusion shell, along the magnetic field lines of the primordial magnetic field of sun's core. These helium filaments together with the magnetic field lines (amplified by helium flow) slowly ascend towards the surface, mainly in the equatorial area of the sun. At a height of approx. 0.7 to 0.8 R_{sun} the helium filaments break-up to short "helium-strings" by convection and differential rotation.

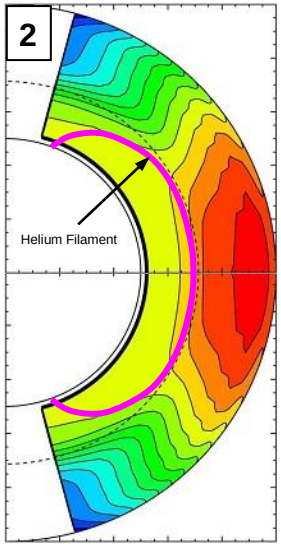
Only the "helium-strings" which move up in the zone of minimum differential rotation make it to the surface where they then cause sunspots, solar flares and coronal loops etc.

Harry K. Hahn , 26-11-2013



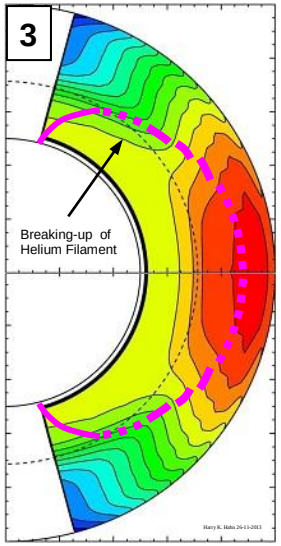
Start of the Helium filament

The trigger for the development of the helium filament is the outward flow of the primordial magnetic field lines from the core region, together with helium-rich plasma which is moving in a circumferential direction relative to the magnetic field lines → The helium plasma goes into a helical flow surrounded by primordial magnetic field lines. This process then creates the Helium filament.



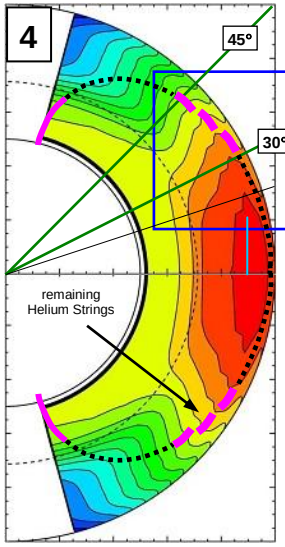
Max. expansion of filament

The helical flow of the helium-rich plasma in the filament amplifyies the magnetic field inside & outside the helical filament by two - three orders of magnitudes. This process increases stability & density of the helium (vortex) filament which allows a maximum expansion of the helium filament in the radiative zone up to around **0.7 R_{Sun}** in the equatorial area of the sun.



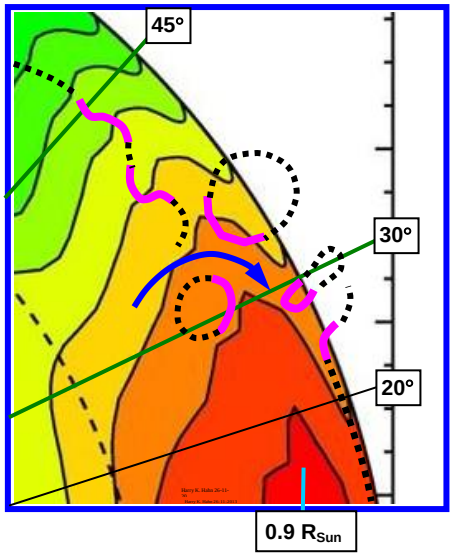
Filament breaks into strings

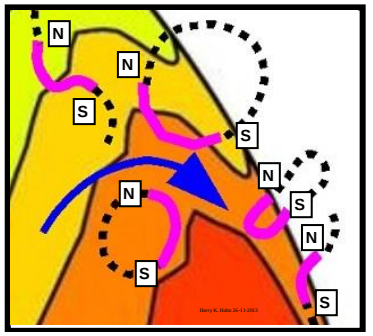
The increasing differential rotation and convection at **>0.7 R_{Sun}** starts to deform and stretch the helium (vortex) filament more and more, so that eventually it breaks up into shorter "helium (vortex) strings". This breaking-up process of the helium filament depends on the prevailing differential rotation gradient. Therefore it is more pronounced in the angle sectors ± 30° and 45° to 90°, and less pronounced in the 30°- 45° sector.



Helium strings reach surface

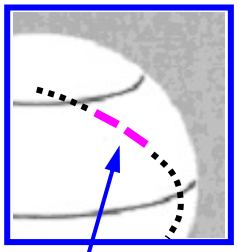
From the original filament `only the two sections which ascended in the ± 30°- 45° sectors arrive on the surface, in the form of short helium (vortex) strings. All other sections of the original filament are stripped of the helium-rich plasma, caused by strong convection and a high differential rotation gradient in the ± 30° and 45° to 90°-angle sectors (black dotted lines)





N-S orientation of strings remains

After the break-up of the original helium filament into shorter strings the magnetic orientation of the helium strings essentially stays intact. The helium (vortex) strings get more or less bended by convection currents and start to form (coronal) loops (magnetic field lines of string form a ring)



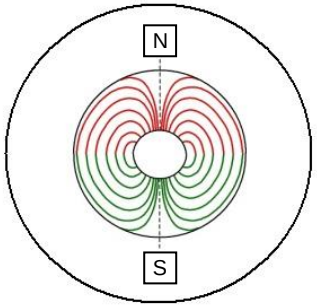
Explanation why sunspots first appear at 20° - 30° latitude

When the helium strings reach approximately a height of **0.9 R_{Sun}** they start to drift towards the sun's equator where the maximum differential rotary speed prevails at the closest distance to the surface (→ this is indicated by the curved blue arrow in the images above)..

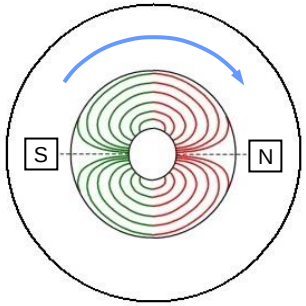
The ends of the "helium (vortex) strings" then first penetrate the sun's surface in latitudes between approximately 20° to 30° where they finally arrive on the surface. In this process the first small sunspots are formed. The deformed and bended helium strings then slowly drift further towards the sun's equator. On their way to the equator the helium strings release more and more helium plasma which drives the growth of the sunspots.

Possible explanation for the sunspot cycle period & intensity

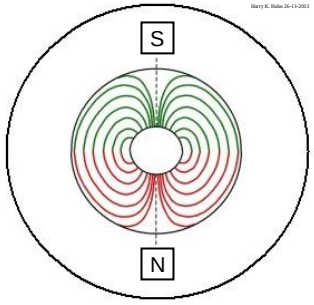
The change of sunspot- and flare activity (Solar-Minimum & -Maximum), the sunspot cycle length and the change of magnetic polarity could be explained by a rotation of sun's core, which is the source of the primordial magnetic field. A change of the magnetic polarity (a half rotation of the core) would take around 11 years, and a complete rotation of the core would take around 22 years. Because of the orientation of the magnetic field during Solar Minimum, much less "helium strings" would ascend in the zone of minimum differential rotation. Changes in the sunspot cycles can be explained by nutation & precession of the core axis.



Solar Maximum



Solar Minimum

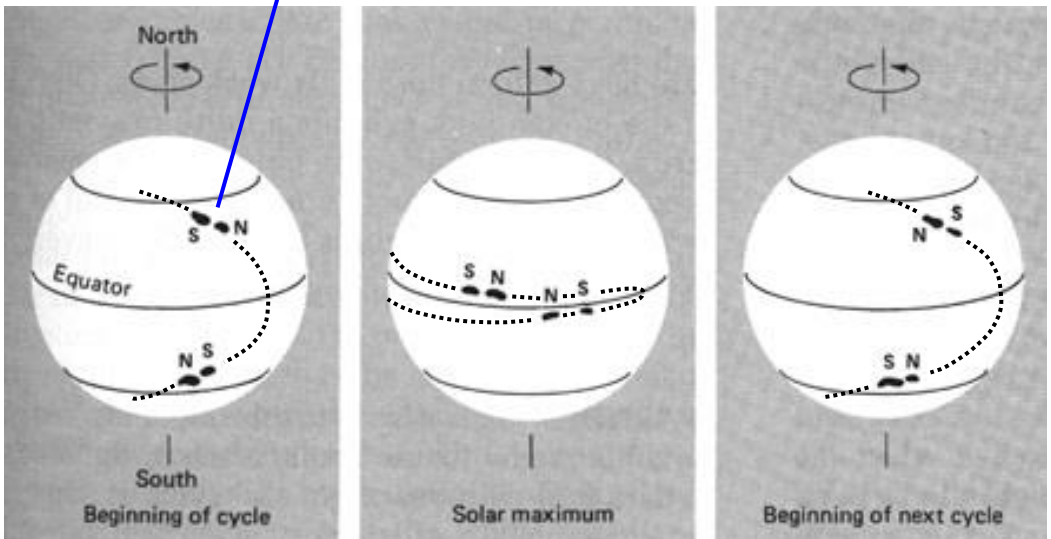


Solar Maximum

Start of cycle

Solar Maximum

Start of next cycle



To the structure of the proposed "helium filaments" and "helium-strings" :

Harry K. Hahn , 26-11-2013

The "helium filaments or –strings" are formed by spiral-shaped plasma vortices probably rich in Helium-4. This Helium-4 in the plasma may contribute "superfluidity-" and "superconductive-" properties to the plasma, which allows to reach extremely strong magnetic fields around the plasma vortices of up to 2000-3000 Gauss. Negatively charged, electron-rich plasma streaming around the "helium strings" constantly induces energy into the "helium strings". The spiral-shaped plasma vortices visible in solar tornados may be the key to understand the physics behind the proposed "helium filaments or –strings" because they seem to be the same plasma vortices which form the "helium filaments or -strings" Therefore an extensive study around "Tornado Movie 2" with original images must be carried out !!! This could be very revealing for the research in fusion reactor technology !!!

FIG. 1 : Shows the assumed structure of the proposed "helium-filaments" or "helium-strings". The outside of the filament or string is a "spiral-shaped plasma vortice" which consists of helium-enriched plasma (with a share of at least 10 - 20% helium (probably helium-4). With a high probability this plasma has a positive charge and this plasma highly amplifies the magnetic field inside the string. The outer plasma vortice may even consist of two different kind of plasma with a double helix structure.

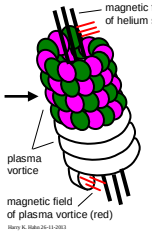
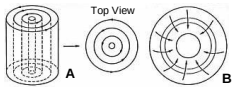


FIG. 2: Superfluid Helium-4



A.) circular flow around central core
B.) (smoke) ring - like flow

See weblinks to superfluid helium :
page1 , page2 , page3 , info to author

FIG. 3 : Shows the assumed three-dimensional shape and orientation of the solar tornados from Movie No. 2 (approximation). The blue funnels represent 4 solar tornados located along the horizon line (marked by the blue arrows in the image from the movie below), the 3 purple funnels represent tornados further in the front.
Along the surface of the blue and purple tornado funnels complex "spiral-shaped plasma vortices" (as shown in **FIG. 4, 5 & 6a/b**) flow up- (& down !!) the funnels ! The plasma of the "spiral vortices" seems to be low energetic. (→ I assume that these "spiral-shaped plasma vortices" are part of the structure of the proposed "helium-strings") The yellow lines represent "high energetic plasma" which streams through the inside of the funnels and through "assumed" plasma vortex tubes below the sun's surface.

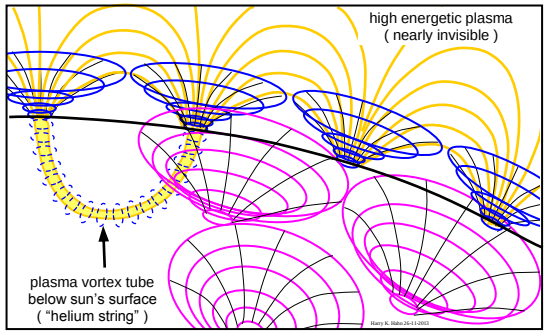


FIG. 4 : This figure shows the assumed complex structure of one of the spiral-shaped plasma vortices visible in FIG 6b

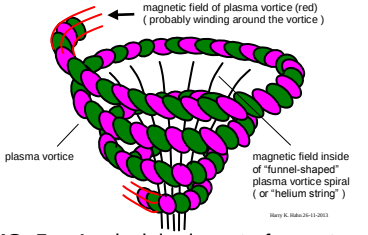
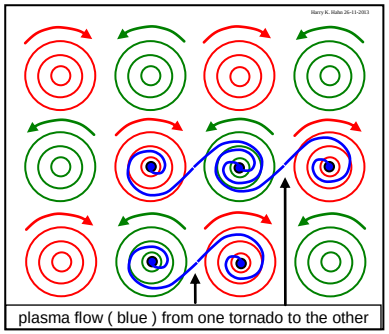
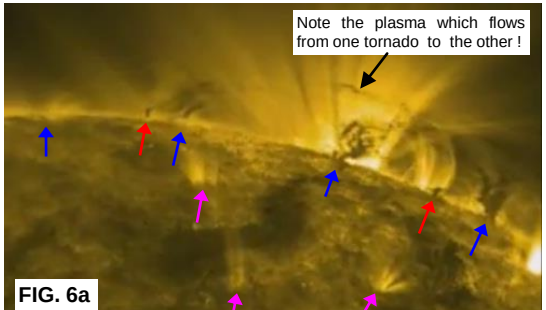
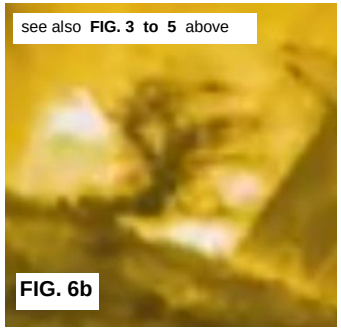


FIG. 5 : A principle layout of counter-rotating tornados which allows plasma flow from one tornado to the other.



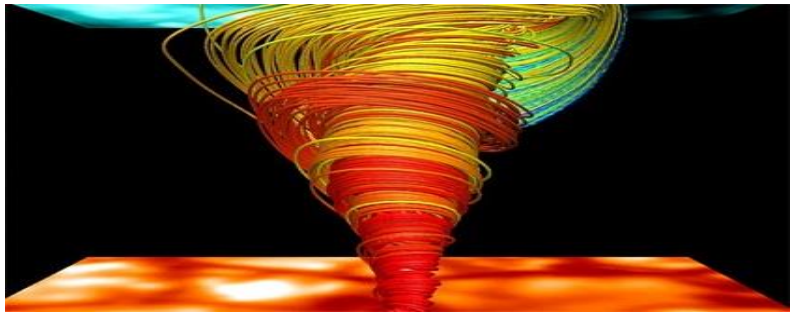


There are 4 tornados visible side by side (blue arrows), and 2 further in the back (red), and probably at least 3 in the front (purple)→ but they are hard to see because of lack of contrast)



At **0:14 to 0:16** seconds a number of "spiral-shaped plasma vortices" which flow along the tornado funnel are visible

To the heating of sun's corona : There are "two plasma systems" which drive the processes on sun's surface and atmosphere. The first system is made of helium-rich plasma vortices (probably positive charged) which form the funnel-shaped plasma spirals of the tornados shown in FIG. 3, 4 and 6b, and the "plasma vortice tubes" (helical helium plasma string bundles below sun's surface (see FIG 3 & 6b) which are identical to the proposed "helium strings" ! The helium-rich plasma of this "system" flows relatively slow and it is low-energetic (see FIG 5). The composition of this plasma must be precisely measured, because this first system is actually the "accelerator" ("Tokamak") of the second plasma system which is the electron-rich high energetic & high temperature plasma of the corona (with temperatures of up to 20,000,000 K) which constantly flows through the "funnels" and trough the "plasma vortice tubes" below sun's surface. Knowing the exact composition of this assumed positively charged helium-rich plasma could help to improve the fusion reactor technology considerably !!! Solar Flares may be the direct result of a partly local collapse (destruction) of the first plasma system !!



It is estimated that there are as many as 11,000 solar tornado events above the Sun's surface at any time. Mathematicians from the Universities of Sheffield, Oslo, Uppsala and the Institute for Solar Physics of Freiburg have reported the discovery of ubiquitous magnetic solar tornadoes and their signature in the hottest areas of the Sun's atmosphere where the temperature is a few millions of degree kelvin. Many scientists are researching how to "heat" the atmosphere above the surface of the Sun to such high temperature. It is understood that the energy originates from below the Sun's surface, but how this massive amount of energy travels up to the solar atmosphere surrounding it is still a mystery. We believe we have found evidence in the form of rotating magnetic structures - solar tornadoes - that channel the necessary energy in the form of magnetic waves to heat the magnetised solar plasma". → Weblink to University Sheffield article

The scientists viewed the solar tornadoes in the outer atmosphere of the Sun by using both satellite and ground-based telescopes. They then created 3D-layered seqence of images of the tornadoes and simulated their evolution with state-of-the-art numerical codes using the magnetic imprints detected by their high-resolution telescopes.

Solar Tornado

The extremely hot gases of up to 2.000.000 degrees travel up at speeds as high as 300,000 km per hour for up to three hours. The tornados occur at the roots of huge coronal mass ejections, which are associated with active regions on the sun's surface such as groups of sunspots.

Movies made by the by Solar Dynamic Observatory (SDO) satellite.
→ see weblink : **tornado movie 1**

The second movie is important because it shows the complex three dimensional structure and interdependence of at least four solar tornados rotating side by side with the same speed !

Watch this movie !!! : → Tornado Movie 2

Dr. Xing Li of Aberystwyth University said these tornadoes often occur at the root of coronal mass ejections. The solar tornadoes drag winding magnetic field and electric currents into the high atmosphere. And that it is possible that the magnetic field and currents play a key role in driving the coronal mass ejections.

Other interesting Solar Tornado Movies !!! :
Movie 3 : shows 4 tornados rotating side by side (similar to Movie 2)
Movie 4 : big and fast "tornado out burst"
Movie 5: large tornado (big helium string ascended in high latitude ?)