Comments on Rock blasting

Flyrock (part 01 of 03)

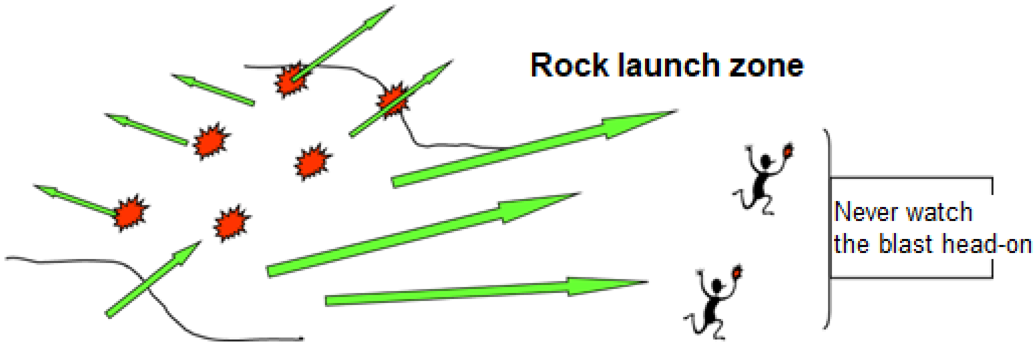
By Bruno Pimentel.

Hello my friends, I hope you are all well, so that we can start another article in our newsletter, where we make a series of comments on important topics related to rock blasting, and if you haven't signed up yet, we invite you to do so on link below, and also be sure to check out the previous articles we've written.

Portuguese: https://www.linkedin.com/newsletters/desmonte-de-rocha-c-explosive-6941709482355748864/

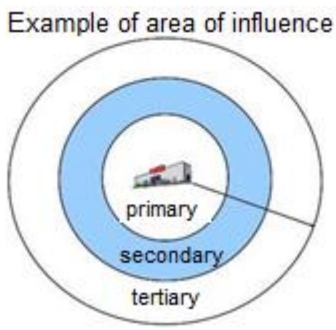
English: https://www.linkedin.com/newsletters/rock-blasting-6959820770344595456/

So, without delay, as we mentioned in our last article, today we will make some comments on a prominent topic, which in a way is linked to the concept of clearance zone, as well as it is directly related to the safety of carrying out our blasts, which is the **Flyrock**.



We commented in the last article that from an analysis carried out on accidents that occurred in the USA, related to rock blasting activity in a period of 12 years, 37% of them were directly linked to issues related to the clearance zone, and in addition, another 30 % were related to events classified as Flyrock, and this makes Flyrocks one of the most worrisome topics in open pit blasting.

That's why at the end of the last article, we talked a little about the concept of what Flyrock is, because first we need to understand that we have two different risk situations, related to the launch of detonated material, and that although both represent risks to the operation, those classified as Flyrock can have a much greater radius of influence.



As we mentioned in the last article, we classified the two main risk situations related to the release of detonated material, in "excessive release" and in "Flyrock".

Excessive launch consists of an event when a detonation throws the material at a much greater distance than expected, that is, when we use the concepts of clearance zone limits, we can say that the excessive launch occurs, when the blast material is launched beyond the limits of influence of the blast, normally reaching the safety area, which is the area where we consider that there is a minimum probability that fragments will be launched, and therefore many operations understand these areas as safe, and it is common practice to leave equipment , thus reducing their travel distance (which is the distance the equipment needs to move away from the blast).

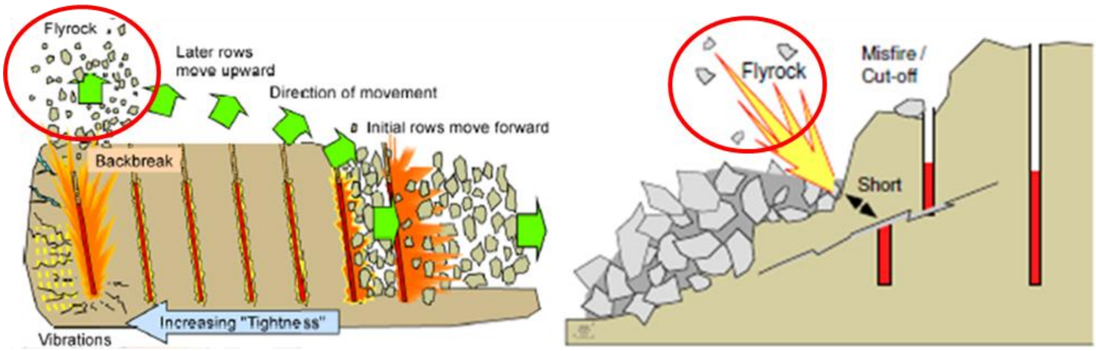

Usually, the concept of excessive launch is related to situations where the complete blast has a launch greater than expected, and this can cause a large amount of material to reach the safe area, or that most of the material is in the intermediate zone, and only a small amount of material reaches the safety area.


In an excessive throw we can have a damage event or not. For example, we may have a situation where the blast was expected to launch material at a distance of 100 meters, and we had a launch greater than 200 meters, and with that, even if nothing is impacted, we will have an excessive launch event, which needs be analyzed, because if the situation can repeat itself, we should reassess the criteria used to define the limits of our clearance zone, as we commented in the previous article. This situation will also impact the material excavation operation, which previously would have to excavate the material in an area of 100 meters, and now will need to excavate an area of 200 meters or more.

We can also have an excessive release, where fragments reach the safe area, and hit equipment or facilities that are in that area, causing material damage. So, we can say that the possible damages related to excessive launch events are related only to operational damages (time and cost) and to material damages, not related to people, since all people should be after the safety area, which is where they must the limits of the clearance zone can be established, as we saw in the last article.

Excessive launch situations are usually generated by failures in the sizing or execution of the blast plan, and represent a situation of general failure of a blast, and when they occur, we usually have the launch of a large amount of material beyond the predicted and the risk of having operational and material damages, but we can say that the entire event will be contained within the limits of the clearance zone.

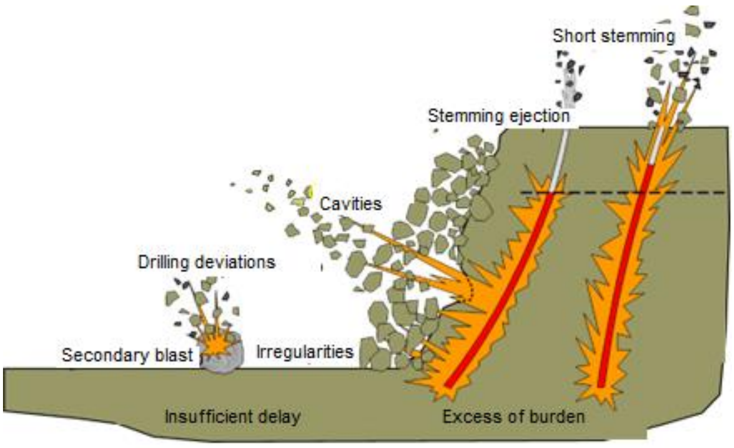
On the other hand, we have Flyrocks, where normally regardless of the release of the blast material, whether excessive or not, we have the event where one or some fragments are thrown beyond the limits of the clearance zone, and that would be the main conceptual difference between the two events, as we normally only consider Flyrock when it passes the limits of the clearance zone.



Here we only open a parenthesis, as some can still differentiate by the type of event, in cases where we have the release of all the material from our blast, well above the expected, it would be classified as an excessive release, whether it exceeds the clearance zone or no, and in situations where we only have a punctual occurrence, which launches one or more fragments at great distances, like a Flyrock event.

Usually, this conceptual difference leaves some situations or nebulous zones, where we have mainly two extremes, where the concepts get confused a little, which is when we have a launch where only a few, or even only 1 fragment, and it hits some equipment in the area that is, inside the clearance zone, and in this case, some may consider it to be a Flyrock, as it was a one-off situation, even though it did not go beyond the clearance zone, or we have the opposite extreme, which is much rarer, and normally this linked not only to failures in the blast, but also to the clearance zone scaling, which is when a large amount of material is launched beyond the clearance zone, and so we would have a joint situation, where the excessive launch would be a Flyrock. But for conceptual effect and for a better understanding, let's leave these extremes aside, because in the end, the terms we use don't make much difference, because the causes are much more important to be analyzed.

So we need to be clear that today our focus is on Flyrock events, and that they can originate from an excessive launch, where all the material is launched at great distances, and thus some fragments can be launched at even greater distances, exceeding the limits of our clearance zone, becoming Flyrock events, but in addition to this situation, which is usually the most common case, and therefore will be our main focus, Flyrocks occur due to specific situations, usually related to the premature escape of the gases, which find fragments in their path and launch them over great distances. So, we can say that Flyrock events do not depend on excessive launch situations, and that we can have blasts with well-controlled material launch, but for a particular condition, often even unknown, we can have a Flyrock event.

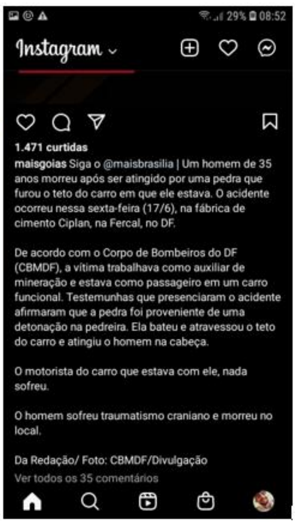


It is also important to understand that we can use various techniques known as "controlled blast" to limit the release of material from our blast, and this will help us to control the risk of excessive release and in the same way we can use it to resize the limits of safety of our clearance zone, but it is important to understand that although the practices employed reduce the risk of Flyrocks, due to the extra controls, these controls do not guarantee 100% effective protection against Flyrocks, as they can occur completely independently of movement of the blast, and that is why we usually say that there are no specific techniques to control Flyrock, and that prevention, through the identification of risk situations, is the best way to establish criteria for each blast.

When we are going to review the literature, we will see that there are several ways used to define Flyrocks...

...sorry, but I stopped writing here, as these coincidences seem incredible, but today is Saturday, it is 9:15 am on June 18, 2022, and as I write I just received the following message in a WhatsApp group :

Unfortunately, another fatality involving professionals in our area, where we have here a report in Portuguese of an incident where a Flyrock hit a car and killed a man,



And that makes us really believe in the criticality of the topic, which unfortunately is most often related to uncontrollable events, but I keep thinking if people had been better trained or more attentive, they could have identified the cause and maybe taken some preventive measure... 🤔 🤔 🤔...

After this reflection, let's go back to the topic, where we were saying that in the literature we will find several definitions for the term “Flyrock”:

• *Throwing rock fragments from blasting at distances greater than the safe area, which can result in human injury, death and structural damage.*

• *It is considered as Flyrock when fragments from the blast are thrown a great distance from the normal launch area of the blasted material pile.*

• *Flyrock happens when part of the blasted material goes out of the area of influence wildly.*

• *Any blast fragment that goes where it shouldn't.*

• *Flyrock is any rock that is thrown outside the clearance zone.*

• *Rock fragment projected in different directions beyond the expected and desired blast distances, due to design error and/or its application and/or the presence of adverse rock conditions that favor the escape of pressurized gases from the blast.*

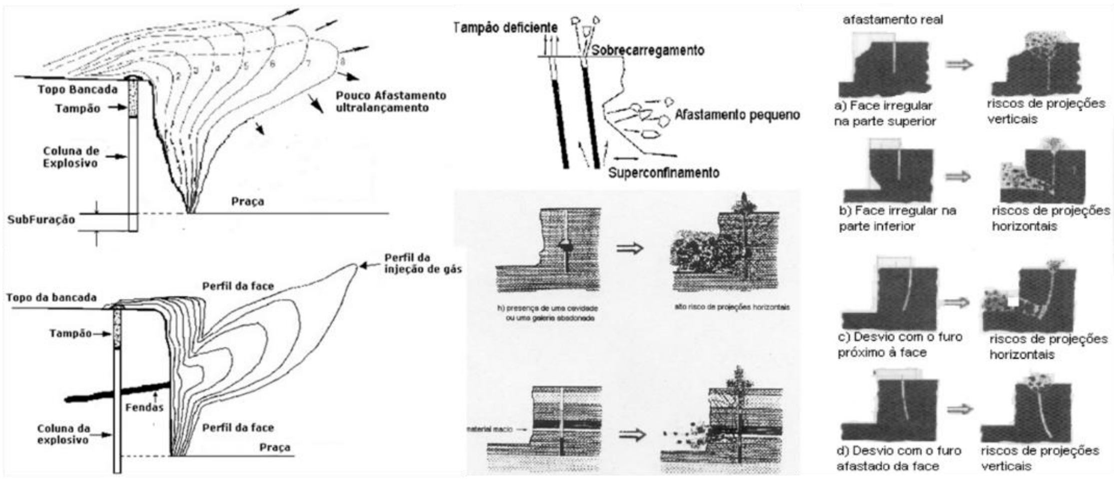
• *Also called homing pigeons, this is nothing more than the launch that usually reaches 5 to 10 times the distance of the normal launch, and occasionally much more.*

We can still add the definition indicated by the Brazilian standard of ABNT NBR 9653, which defines Flyrock as the "throwing of a rock fragment beyond the perimeter of the operational area of the enterprise", and a fundamental point that we find in this same standard is that the limit tolerated for Flyrocks is that “there are no Flyrock events”, that is, there are no limits.

Leaving aside the differences in the definition of the term, we need to understand that in the rock blasting process, the release of the blasted material is an important part of the process, and it occurs because the explosives, when detonating, turn into a high amount of gases, and these, which are subjected to high pressures and temperatures, will contribute to the rock fragmentation process and will later be responsible for the release of the fragmented material.

So in a very summarized and simple way, so as not to get into other topics, we can say that under normal conditions, it is a function of the gases generated by the blast of the explosive, to push the rock towards the free face, forming the pile of blasted material, but in some situations that can occur during the blast process, the gases find escape paths, and this causes them to direct a good portion of their force along these paths, pushing whatever is in front of them, which can cause that in In some situations the gases push fragments and launch them at much greater distances than expected, and when these fragments are launched at distances greater than our clearance zone, we call them Flyrock.

This escape of gases or released fragments, can be from any part of our blast, where we can have, for example, a frontal exhaust, due to a critical condition in the free face, or we can have a large ejection of gases by the stemming area, which can launch fragments in any direction.



Flyrocks are considered one of the main causes of accidents and deaths in rock blasting in open pit operations, mainly because it is an event that impacts beyond the safety limits of our blast, and thus can cause uncontrollable damage.

In underground operations, due to the confinement and limitation of space by the very nature of the operation, we do not have Flyrock events, and the most we can have would be excessive releases inside the galleries, which may at some point cause damage to structures and facilities, such as ventilation ducts, pumping stations, electrical or hydraulic networks, or anything that is at a safe distance, but an unusual launch can launch one or more fragments that cause damage to them.

It is very important to have control of our blast, ensuring the best possible conditions so that this type of event does not occur. Because when they occur, the chances of generating major accidents and impacts are very high, as they escape the control area that is our clearance zone, so the possibilities of damage are uncontrollable.

And we really need to understand, that this is one of the main characteristics of the events of Flyrocks, that its consequences are uncontrollable, and whether it's a matter of luck or probability, the fragment, which can be one or several, and of different sizes, can fall. in an area with nothing, or it can fall into an office, or school, or anywhere else, where the potential for causing casualties and damage is very high.

It is important to recognize that in rock blasting, we do not control the explosive, and therefore much of its energy is wasted, generating unwanted effects, and in fact what we do is try to direct the energy of the explosive so that it acts more intense in our objectives, and thus avoiding as much as possible that its energy generates unwanted effects, which can cause damage, as is the case of Flyrocks, or even vibrations, and other unwanted effects that can be generated.

So even believing that Flyrocks consume less than 1% of the explosive energy used in the blast process, their effects are of a very serious nature, especially when compared to other effects, including vibrations, because in addition to not having safety limits, they can do great direct and immediate damage.

When comparing Flyrocks with other possible impacts, such as vibrations or air waves, which are the most common, the main difference is with the tolerance limits, because small vibrations or air waves, even if they are unwanted effects, will not cause impacts, but even a small fragment thrown beyond the clearance zone already presents a great risk potential.

For example, it is important to highlight that the Brazilian standard indicates an acceptable limit for vibrations, and that they are accepted as risk safety limits, where if we are within these values, it is believed that the risk is controlled, but for Flyrocks, there are no limits, and as we said, the standard states that “we must not have Flyrocks events”, as even a small event cannot be controlled.

Tabela 3 – Limites de velocidade de vibração de partícula de pico por faixas de frequência

Faixa de frequência [a]	Limite de velocidade de vibração de partícula de pico
4 Hz a 15 Hz	Iniciando em 15 mm/s, aumenta linearmente até 20 mm/s
15 Hz a 40 Hz	Acima de 20 mm/s, aumenta linearmente até 50 mm/s
Acima de 40 Hz	50 mm/s

[a] Para valores de frequência abaixo de 4 Hz, deve ser utilizado como limite o critério de deslocamento de partícula de pico de no máximo 0,6 mm (de zero a pico).

NOTA 1 Hz corresponde a uma oscilação por segundo.

Limites de intensidade para Pressão Acústica

ITENS	Pressão acústica
NORMA ABNTNBR 9653	134 dB

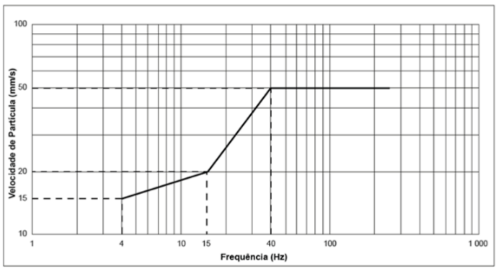
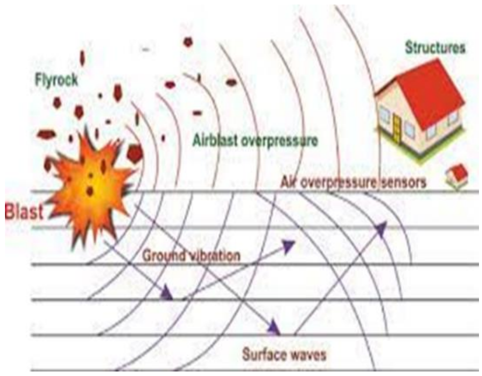


Figura 3 – Representação gráfica dos limites de velocidade de vibração de partícula de pico por faixas de frequência

That's why whenever we are going to evaluate the theme of Flyrocks, we need to reflect that for this type of event there is no acceptable risk, because we have no way to control the level of damage, in the end, we can't guarantee where the fragment will fall.



For example, even compared to the vibrations, if we go a little beyond the established limit, we can break a window, crack a wall or just make people uncomfortable, while if a fragment goes beyond the clearance zone, however small, we can having a situation similar to the one we mentioned before, that a person died, sitting in the passenger seat of a car.

So, to continue the theme, and not delay the subject any longer than necessary, we leave here just a few points that need to be clear, regarding Flyrocks, so we can move on to a more effective point talking about the mechanisms and causes of Flyrocks:

• Flyrocks are one of the most uncontrollable events we have in rock blasting, and can be generated with just a small amount of blast energy;

• We can estimate the normal launch behavior of blasted material, but not Flyrocks;

• Launch control techniques help to minimize the occurrence of Flyrocks, but even so we can have punctual events, which can occur even in controlled blats;

• Flyrocks are not directly related to the amount of blast charge, but to the escape of energy (gases), so even blasts with low power factor can cause Flyrocks;

• Usually Flyrocks are caused by specific situations, which can be pre-existing, and not identified, or can also be caused during any of the stages of blasting preparation, such as sizing the dril pattern, drilling, loading, choice of delays and others;

• There are no magic ways to control Flyrocks, and the best way is prevention, ensuring an effective assessment to identify critical situations, good operational practices, quality controls at all stages (from design to blast performance), and good clearance zone practices.

Leaving theories and reflections aside, we need to understand that Flyrocks events can occur due to several factors, ranging from intrinsic characteristics, such as characteristics of the rock or blast geometry, as well as characteristics of the design and execution of each blast. , such as blast plan parameters or operational errors when executing it.

These factors are often difficult to predict, mainly because of the uncertainty associated with the various variables inherent to the blasting process, as well as the different relationships between them. Therefore, to try to simplify the understanding, we need to remember that these generating mechanisms of Flyrocks can be divided into controllable and uncontrollable factors.

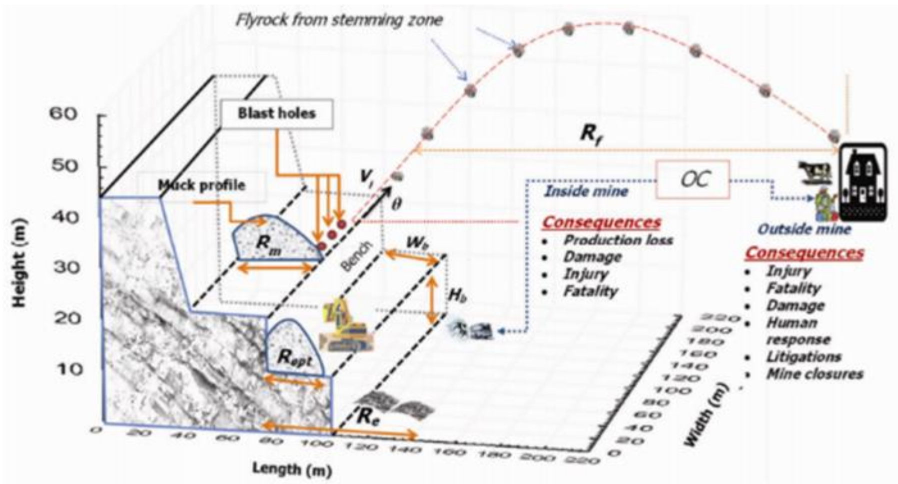


Figure 1. Description of throw, excessive throw and flyrock. H_b, *Bench height;* W_b, Bench width; R_e, Excess throw; R_f, Flyrock distance; R_{opt}, Optimum throw for loading efficiency; V_e, Exit or maximum velocity of flyrock; θ, Launch angle of flyrock and OC, Objects of concern.

The uncontrollable factors are those intrinsic to the process, such as rock geology, natural conditions and geometry of the rock body to be blasted. These factors cannot be modified for blasting, that is, they are fixed characteristics or conditions that cannot be changed in the elaboration of the blast plan, and some of which may even be unknown, such as the existence of an internal cavity or a network. of open and interconnected fractures.

On the other hand, we have the controllable factors, which are those that can suffer some interference due to human decisions, such as loading configurations, drilling design, operational execution, etc. Still in the controllable factors, they can be divided into design/planning factors (eg load settings, sequencing, etc.), which are those that can be dimensioned in advance, and operational factors, which are those determined during the loading and blasting operation. .

It is worth mentioning that we can still consider some parameters of the blast plan as uncontrollable design factors, as is the case, for example, of operations that have only one diameter size available, and so we cannot choose the best diameter for our blast, and the What we need to do is adapt the other variables to this condition, so that we can have a balance in our design, because it is this balance between the variables that will guarantee better conditions and controls over the blast.

Still remembering the analysis of accidents in the USA, where it was identified that 30% were due to Flyrocks, the main factors related to the accidents analyzed were still identified:

• Excessive power factor – incorrect loading or drilling

• Incorrect startup sequence

• Insufficient Burden

• Insufficient stemming

• Anomalies in the geological or geomechanical characteristics of the rock

In this analysis, we can see that the first 4 factors are examples of controllable factors, as we can determine the amount of explosive we use, the blast sequence, as well as the distance and stemming of our blast plan, and similarly, what we have control over the execution of these parameters, and only the last factor is related to an uncontrollable factor, which perhaps could be controlled, if we could identify the situation before the blast was performed.

There are numerous factors that can be sources of Flyrock events, but we can say that in addition to those identified in the analysis of the aforementioned accidents, we have a series of others, which are very important to be evaluated in each blast:

• Natural conditions

• Rock geology

• Inadequate clearance

• Overbreak

• Inadequate drilling

• Free face conditions

• Blocked holes

• Lining material

• Inappropriate stemming

• Load sizing

• Drill pattern

• Excessive load concentration

• Inadequate sequencing

• Lack of energy confinement

• Exhaust of gases

• Secondary blast

• Others.

Continued in the next article... **Flyrock (part 02 of 03)**

The themes seem to extend the average we are writing, so we think it's better to end here, otherwise the content is too long, and the goal is that it's a good read to be reflected throughout the week, as soon as too much content can end up getting in the way.

We will continue with this topic in the next article, where we will try to focus on the most practical part, taking the opportunity to detail most of these factors a little, as a way of drawing everyone's attention to this topic, which often seems to be very punctual, but as we have seen, it is one of the main causes of accidents and deaths in blasting.

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Suggest topics that they believe need to be better addressed, remembering that our objective is to disseminate knowledge.

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