December 31st, 2022
(min. corr. April 7th, 2023)

Bush took a photograph out of his pocket - a family group,
people of various generations on some cliffs by the sea.
He said: "Here's the guarantee that
we will never use nuclear weapons first.
This is my family, my wife, children and grandchildren.
I don't want them to die.
No one on Earth wants that."
If, said Sakharov to Bush, "you insist that you will
not strike first, you must make an official announcement
of that, put into law."
Bush remained silent. **Andrei Sakharov** [1]

Nordstream – Anatomy of Dante's Explosion [2] [3] [4]

Abstract: *Even months after the demolition of the Nordstream Pipelines it is a widely held opinion that the pipelines were destroyed with a moderate explosive of a few hundred kilograms TNT corresponding to a seismic event of (Richter-) Magnitude 2.3 and that the destruction of the pipeline was the only goal of that act. An overview over publicly available seismic data all over Northern Europe shows that this could not be farther from the truth: Seismic traces were detected as far as the North Cape (1800km) and Greenland, thus characterizing the Nordstream explosion as a teleseismic event. An analysis of the waveforms detected at seismic stations around the Baltic and Bothnian Sea characterizes this event to have ('body-wave') magnitude* $m_b = 3.9 \pm 0.15$*, corresponding to a detonation energy of 200 tons TNT-equivalent or more rather than the 500kg claimed in the press. The actual explosive power involved in the detonation is thus at least by a factor of 400 larger than what has been claimed in the press. The resulting waveforms reveal little resemblance with conventional underwater explosions, but they share characteristics with known underground nuclear explosions. The explosive was positioned along the pipeline at a deliberately chosen location such that the generated shock wave was channeled and amplified by a natural oceanic canyon of approx. 20km width which runs from the detonation site towards Kaliningrad (RF). Indeed, in neighbouring Polish Suwałki seismic amplitudes were registered that were 1000-fold of what is expected from a magnitude 3.9 event at that distance from the epicentre. Infrared satellite images of aerosols taken a few hours after the explosion show a cloud extending over more than a hundred kilometers into the Swedish mainland in wind direction while the adjacent coastal town of Karlskrona exhibited brief spell of mild rainfall in the following hours. Hydrodynamic satellite data show the emergence of a strong underwater current near the ocean floor (at 60m depth) away from the explosion site accompanied by significant backflow in the following hours. The topography of the ocean floor exhibits a natural, elliptically shaped depression of about 50km size and the explosive was placed close to the focal point. Such an arrangement is well known to be responsible for strong focussing effects of shockwaves towards the underwater channel directed towards Kaliningrad. This explains the extraordinary seismic amplitudes detected along that direction as registered in Suwałki. These facts point towards a controlled and carefully prepared attack not only on Nordstream but also on the Russian exclave of Kaliningrad.*

Contents

[1] cited in Elaine Scarry, "Thermonuclear Monarchy", Norton (2014). (https://wwnorton.com/books/thermonuclear-monarchy/)

[2] Entire article (except designated figures/panels): ©Hans-Benjamin Braun

[3] **Disclaimer:** The content of this document exclusively originates from publicly accessible sources (OSINT), is independent, and has not been funded by any public or private funds. The author also refers to the UN NPT Art.3 [2] [Original version: https://www.un.org/disarmament/wmd/nuclear/npt/text] which states that any non nuclear weapon state which is a signatory of this treaty (in this case Switzerland) is obliged to invoke security measures that have the goal to prevent nuclear materials from being diverted from their peaceful use for the use in nuclear weapons and other nuclear devices. The NPT also states that "each of the Parties to the Treaties undertakes to pursue negotiations in good faith on effective measures relating to cessation of the nuclear arms race at an early date and to nuclear disarmament, and **on a treaty on general and complete disarmament under strict and effective international control.**"

[4] Dante's Inferno and the nine circles of hell, cf. https://www.thoughtco.com/dantes-9-circles-of-hell-741539

I. Prologue

Details behind the Nordstream explosion have been raised to the Status of a National Security Issue in Germany as well as in Scandinavic countries. Any further statements and inquiries were declined even in German Bundestag.
Upon closer inspection it becomes evident that the public discourse was narrowed down to a streamlined version of events that originated in the immediate aftermath of the detonations on Sept 26th and which was rigidly and blindly adhered to ever since: Namely that the explosive consisted of a few hundred kg TNT and that the only goal of the attack was the destruction of the Nordstream Pipeline repeated as recently as Nov 17th [3] **[Link]**. However, these claims were not based on actual facts. In particular the widely reported "facts" were false regarding

(1) the detonation energy of the used explosive and thus the inferred seismic strength

(2) with respect to the stated exclusive goal, namely the mere destruction of the Nordstream pipelines

(3) with respect to the nature of the used explosive.

It appeared that from the very beginning any piece of information which could have revealed doubts about this official information was deliberately hidden. In particular it was soon agreed upon that it was an event of small seismic strength (corresponding to a fairly small amount of explosive) even though the (even publicly known) facts at that time didn't stand up to this claim.

As discussed in detail below, this narrative was placed in the very first hours after the second of the two explosions (Sept 26th 2022, at 17:03(UTC)) in Danish, Swedish, and Norwegian Media, directly referring to graphs (without units!) of the Norwegian-US organization NORSAR.[5] The latter was founded in 1968 as a cooperation between Norway and the US Los Alamos National Lab (in short 'LANL' - which was in charge of the Manhattan project) and maintains highly sensitive seismic arrays such as NORSAR, whose purpose is the worldwide detection and identification of nuclear tests. [6] [7]

Before turning to an analysis of the seismic facts it is therefore instructive to look more closely at the initial spread of these rumours. In this context it is useful to reiterate the fact that even though being perceived as being related to scientific research, seismic surveillance serves as the primary tool for the supervision of nuclear nonproliferation compliance, and thus rests in the hands of organizations such as NORSAR, that are operating in the gray-zone between military alliances (such as NATO) and Science. In fact, the above rumour of a 'small scale' event responsible for the pipeline destruction can be traced back to their Press Release on Sept 27 [4] **[Link]**. However, remarkably, the graphics presented there show no units on the seismograms, but nonetheless put forward the claim of a magnitude 2.3 event in conjunction with the statement that the largest explosion was produced by "600-900 kg TNT".

The most detailed account of the situation is found on the website of the Swedish National Seismic Network (SNSN) [5] (**[Link]**), which however abruptly ceased to be updated after Sept. 29, 2022 and remained in this state ever since. The information that is there (as per Dec 28th), however, is sufficient to reveal that it is not even internally consistent: At face value the authors follow entirely the NORSAR assessment, even though this claim is at variance with their own data: Data are shown from the (not publicly accessible) station LUNU in Lund, where the magnitude derived from the shown maximal amplitude leads to $m_b^* = 3.0$ in contrast to the simultaneously expressed claim of $M_L = 2.3$ (corresponding to $m_b^* = 2$). Also it is remarkable that both the SNSN and the Danish seismic service base their statements solely on stations situated to the West of the detonation site. However, by the very nature of their location these stations are shielded from the Baltic Sea Basin where owing to hydrodynamic effects the explosion gave rise to substantially larger seismic amplitudes as is detailed below. Also, the SNSN webpage displays a waveform overview displaying the propagation of the seismic perturbation

[5] It should be noted here that seismic investigations constitute an essential tool for the identification of nuclear tests. For this reason, the US established a series of seismic networks, in particular also in Scandinavia due to proximity to the Soviet Test Sites. In particular the seismic array 'NORSAR' (**[Link]**) was established in 1968 with a view of establishing a 'Comprehensive Nuclear Test Ban Treaty' (CNTBT) that would include the still allowed underground tests . The widely employed numerical-mathematical method of 'Fast-Fourier' transform had its origin in establishing seismic surveillance tools for nuclear weapon testing, cf. [9] (**[Link]**)

[6] It is interesting to note that the Finnish seismic service (whose publicly available data would have cast some doubts on the official version), in contrast to the Danish, Norwegian and Swedish counterparts abstained from the discussion around Nordstream in Europe.

[7] Also, it is not inconceivable, that both opening of the Norwegian-Baltic Pipeline and the Nordstream explosions were coordinated in such a way as to have an argument to be able to blame the Russians for the Nordstream attack.

beyond the Polar Circle (station MASU) which is hardly reconcilable with the NORSAR claim of a magnitude 2.3 event caused by a ~700 kg (TNT-) explosive.

It is thus even more remarkable that a representative of that same group of Swedish seismologists reiterated this claim on camera while presenting those very same data playing it even further down as being caused by a "100kg or a bit more" of TNT equivalent [6] (**[Link]**). Exactly the same interpretation was blindly adopted by the Danish colleagues [7] **[Link]** as well as taken up by a German website [8] **[Link]**, copying the NORSAR value of magnitude 2.2.

It should be noted here that such an event, if it in fact had corresponded to the described conventional minor explosion of the size of a few hundred kg TNT would most likely have escaped the automatic "event triggers" of NORSAR: The reason being that this array and its IT infrastructure is specifically designed to filter out nuclear explosions from the vast amount of irrelevant 'background' seismic events that are detected during the continuous surveillance of the ground motion on the site. This may indicate that both significance and time of the event were known to the authorities at NORSAR/LANL. It is therefore remarkable that the misleading claims about the event magnitude originated at the very same institution and notably were never revised as is normally the case with seismic events.

To the contrary, the corresponding narrative of "an explosive of a couple of hundred kg TNT" stuck ever since without ever having been seriously checked or questioned, most recently in the *'Guardian'* of Nov 18th 2022, i.e. roughly 2 months after the event, [3] **[Link]**. This gave directly rise to the narrative of that of an explosive most likely placed by a small and possibly "rogue" troup of individuals.

The first crack in this superficially coherent picture starts to emerge when checking on the 'Geofon' Website (which is the official earthquake event catalogue site maintained by the Helmholtz Society in Potsdam) where the explosion is registered as a magnitude M_L=3.1 event ($m_b^* = 3.0$) [10] (**[Link]**). This value now corresponds to an explosive charge of approx. a 23t TNT equivalent. This is suddenly in a completely new league of explosive as it is nearly two orders of magnitude more than what is needed for a mere destruction of the pipeline which can be achieved via a so called 'cutting charge'. [8] [9] Even in this case of a still considerably underestimated magnitude the use of a conventional explosive would be highly unrealistic, in the case of our revised estimates virtually impossible, and in the face of a waveform analysis and additional atmospheric and hydrodynamic evidence literally excluded.

Indeed the more detailed investigation of the seismic data not only reinforces the upward revision of the Geofon estimate compared to the general agreed upon NORSAR/LANL narrative, but actually shows that even that value considerably underestimates the actual explosion energy. At the same time this poses the urgent question: Why the need for such a powerful explosion in order to accomplish the fairly straightforward task of destroying Nordstream for which a couple of hundred kilograms TNT would be sufficient? Indeed it is remarkable to note that Geofon's official scientifically approved estimate of $M_L = 3.1$ never reached the headlines.

We shall now present experimental evidence that four distinct observations, namely the seismic magnitude, the characteristic waveform, the underwater currents and the vast amounts of generated aerosols are incompatible with the use of a conventional explosive.

II. Seismic considerations

II.1 Introductory remarks

The answer to this question forces us to consider in detail the seismic data that underly these estimates. Use shall also be made of other geophysical data in order to clarify the nature of the explosive. In doing so I shall be able to unveil the intricate design of the explosion and demonstrate that there was a much more far reaching goal than simply the destruction of Nordstream 1/2.

To reiterate, the low-magnitude estimates put forward in the NORSAR/LANL referred exclusively to stations situated to the West of the explosion site, even though the numerical claim was not even backed up by quantitative data. But even more important is the systematic omission of all data to the East of the detonation site (as is evident from the Danish Seismic Service Website **[Link]**). In fact it turns out that most of the energy was emitted into the Baltic Sea Basin which requires an analysis of the corresponding seismic stations.

The knowledge of the seismic magnitude is of utmost importance since it is directly linked to the explosion energy W which is here measured in TNT mass equivalents:

$$m_b = 4.45 + 0.75 \cdot \log_{10} W, \tag{1}$$

[8]For a discussion of this issue by a former German Bundeswehr Expert on Explosives see [11] (**[Link]**).

[9]Blasting Demolition of steel structures is, e.g., discussed in the following scientific article [12] *"Blasting demolition of steel structures" (2017)* **[Link]**.

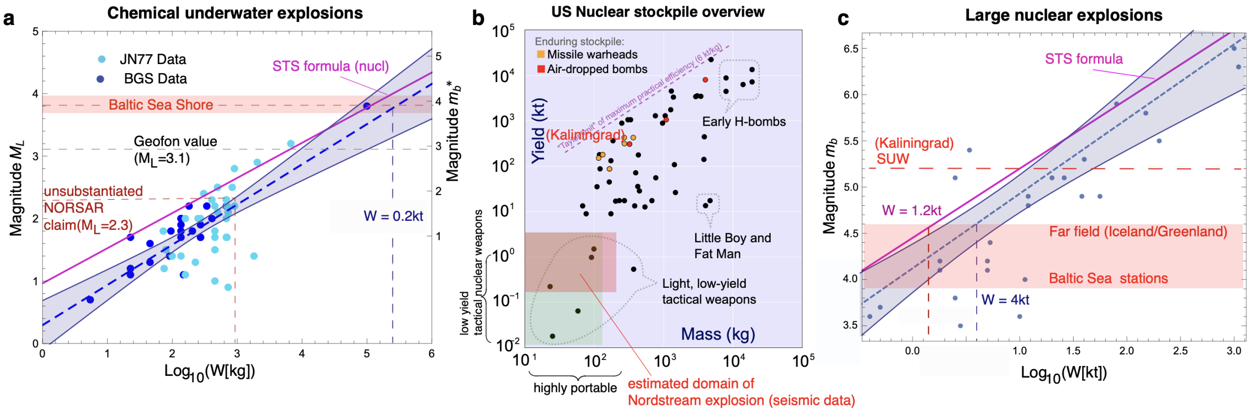

Figure 1 — Relation between magnitude $\mathbf{m_b}$ and the TNT mass equivalent for chemical underwater and nuclear detonations: a, Chemical underwater detonations according to data by the British Geological Survey (BGS) [18], [**Link**], also including data by Jacobs und Neilson (JN77) with the 'depth optimized' events omitted as they are irrelevant in the current context. [a] Here the Richter magnitude M_L and regional magnitude m_b^* are plotted against $\log_{10}(W)$ with W the detonation energy measured in kg TNT equivalents. The broken line is the linear regression through the data points with the shaded area indicating the 95% confidence interval. The violet straight line is the STS expression of Eqn (1), $m_b = 4.45 + 0.75 \log W$ (cf. C. Ammon et al. *Found. of Mod. Global Seismology*, Ass. Press, 2nd ed. 2021). The red-shaded area results from the magnitude derived from the waveform amplitudes in the Baltic Sea area resulting in an estimate for the explosive charge energy of 0.2 kt ($1\text{kt} = 10^6\text{kg}$). Note that the **STS** relationship provides essentially a **lower bound** on the explosive charge at a given magnitude (M_L or m_b^*) for all collected data presented here, **b**, Overview over the US nuclear stockpile (Wiki). The green shaded area marks the range of (thermonuclear) tactical nuclear weapons with W in the range of 10 tons (t) up to several kilotons (kt) with an actual physical weight in the range of less than 100kg that can be transported even with underwater unmanned vehicles (UUV) (cf. NATO Repmus"22 exercise, Sept 12-22, 2022 [14] ([**Link**])). **c**, Magnitude explosive-charge relationship for nuclear explosions listed in the BGS report [18]. The broken line is the linear regression with the shaded area denoting the 95% confidence interval. Notice that here the charge is measured in kilotons. The red shaded areas denote estimates that result from seismic considerations, lower band extending from Baltic Sea to magnitudes derived from waveforms detected in Greenland/Iceland (m_b=M_S ≈ 4.6) . The upper value results from the vicinity of Kaliningrad ($m_b^* \approx 5.2$). Based on the STS relationship, the resulting values for the explosive charge are between $W = 0.2\text{kt}$ und 4kt (the considerable uncertainty is due to the logarithmic dependence). It should be noted that the enormous values of the seismic magnitude near Kaliningrad are owed to the particular amplification due to the shock waves via the underwater canyon as shown in Fig. 7. [Fig1a,c: ©Hans-Benjamin Braun]

[a] The optimum depth relation is given by $W = [d \cdot (d + 10)^{5/6}/8030]^3$ with d the optimal depth in meters and W the explosive charge in tons, or for $d \gg 10$, $d \approx 135W^{2/11}$. Thus for the size of the charges W that are relevant in the current context, the optimum depth d would be much larger than the Baltic Sea floor depth of approx. 75m at the detonation site.

Here m_b denotes the so-called body wave magnitude, which in general slightly exceeds M_L. [10] (cf. Ref. [17]) Here W denotes the "explosion yield" in kilotons (1 kt= 1 Mio kg) TNT-equivalent.[11] This empirical, so called Semipalatinsk Test-Site (STS) relationship between seismic magnitude and explosion yield not only holds for nuclear explosions for which it was originally derived, but also characterizes conventional, non-nuclear explosions as is evident from detailed data by the British Geological Service (BGS). (cf. Fig. 1 and Original Report [18].

[**Link**]). From these data it can be inferred that in the case of underwater explosions the STS formula actually serves as a reliable lower bound onto the explosive yield for a given seismic magnitude.

As extensive use shall be made of this relationship in the following and in view of the somewhat counterintuitive logarithmic dependence, it is discussed with a few characteristic examples that shall be used in the following:

[10] Jacob & Neilson (1977) [15], present the following empirical relationship between the Richter magnitude M_L and the "regional body wave" magnitude m_b^*, generalizing m_b to the scale of 'regional events', $M_L = 0.72m_b^* + 1.0$. Here the 'regional body wave magnitude' is defined via $m_b^* = \log_{10} V_{\max} + 2.3 \log_{10} R - 2$, where now R denotes the distance to the epicentre in km, and $V_{\max}$ is he maximally detected seismometer velocity measured in μm/s

[11] We use the notation $\log_{10}$ to designate the logarithm to base 10.

m_b^* or m_b	W [tons TNT]
2.0$^{(a)}$	0.6
3.1$^{(b)}$	23
3.9$^{(c)}$	**185**
4.5$^{(d)}$	1200 (1.2kt)
5.2$^{(e)}$	25'000 **(25kt)**

$^{(a)}$: value put forward by NORSAR ($M_L = 2.3$ corresponds to $m_b^* = 2.0$)
$^{(b)}$: according to the Geofon-Website (Helmholtz, Potsdam) ($M_L = 3.1$ corresponds to $m_b^* = 3.0$)
$^{(c)}$: $m_b^* = 3.9 \pm 0.15$ is derived from the seismic stations PBUR, SLIT, SJUU, RAF, VADS (distance: 400-1750km)
$^{(d)}$: derived from ANGG station in Greenland
$^{(e)}$: local peak value measured in Suwałki, due to focussing effect by the Bornholm/Åhus/ Karlskrona basin and the resulting channeling into the underwater Canyon towards Kaliningrad.

It should be noted here that the NORSAR value of $m_b^* = 2$ (corresponding to $M_L = 2.3$) would indeed imply a load of 600kg TNT, demonstrating that our considerations here are based on the same ('textbook') magnitude-explosion yield conversion as that of the Scandinavian researchers (but reminding that actual statements on m_b^* about the magnitude were presented without quantitative reasoning thus resulting in an entirely unsubstantiated claim).

Motivated by this apparent discrepancy between the NORSAR/LANL narrative, the Geofon entry, and the apparent contradiction to the SNSN obervation of seismic fingerprints into the teleseismic regime of over more than 3000 km (Iceland, Greenland) it appears necessary to examine the original seismic data in detail. As data source served the FDSN global network of seismographic stations. [12] In the case of Sweden unfortunately only a small fraction of stations are accessible, while some of those which would have been important in the current context such as BLEU near Karlskrona or BYXU on Öland were missing (even though data manifestly exist as evidenced by the SNSN website, cf. also Fig. 2)).

II.2 Seismic Data of the Nordstream explosion

Generally the first challenge is the identification of the epicentre of a seismic event, as this determines the subsequent characterisation of its magnitude via the analysis of the seismic waveforms. Here the location shall be used that has prior been determined by seismic means, e.g. SNSN or via Geofon, which has within accuracy also been shown to agree with the reported location of the Nordstream leaks which in turn can be checked via geophysical satellite data on aerosols and underwater hydrodynamic phenomena. We thus adopt here the Geofon event coordinates: (lat.: 55.553°N ; long.: 15.833°E on Sept 26th 2022 at 19:03:49 (local=UTC+2)).

Before turning to a discussion of the seismic data it should be noted that in the current context of the Nordstream explosion, and in contrast to a proper underground explosion (incl nuclear), a sizeable fraction of the released energy is not directly transferred into ground (thermal or seismic) but emitted into the water in the form of underwater shock waves which are multiply reflected on shorelines or on islands. As a consequence a considerable fraction of the energy is dissipated in water without being converted into seismic energy. Due to the fairly large area of the Baltic/Bothnian Sea compared to Fjords or sweetwater lakes, this energy contribution is expected to be larger than usual. For the conversion of magnitude into a lower bound on the explosive yield use shall be made of the solid-soil relation (1) which in turn constitutes a reliable lower bound to the released energy as is inferred from Fig. 1.

We start by reconsidering the data presented on website of the Swedish National Seismic Network (SNSN) [5] [**Link**] which is reproduced here for ease of access in Fig. 2. Note that this website has not been updated since Sept 30th 2022, but also to a large extent contains information in graphics whose underlying data cannot be accessed via the official data services. For this reason I shall independently focus on those stations whose data are available with results that are summarized below in Table I. The magnitude was determined in standard fashion from the velocity response $V_{\max}$ of a broadband signal (<100Hz; HH channel) measured along all 3-axes. According to the IASPEI Standard (Ammon op. cit., p. 204 and Jacob/Neilson op.cit) the magnitude is determined as follows:

$$M_S = \log_{10}(V_{\max}/2\pi) + 1.66 \log_{10} \Delta + 3.3 \qquad (2)$$

where the maximal ground velocity $V_{\max}$ is measured in μm/s and Δ denotes the distance to the epicentre measured in degrees (1 deg. $\approx$ 111.1 km). This relation holds for distances $2^\circ \le \Delta \le 160^\circ$, but is considered reliable[13] only for $\Delta \ge 20^\circ$ or distances larger than 2000km. For this reason the "regional body wave magnitude" m_b^* has been introduced to which shall be returned to shortly. But first M_S is determined via Eqn (2) with the results summarized in Table I.

The last two stations listed in Table I are situated in Greenland, the locations of all other stations is shown in Fig 2. As the raw data of the waveforms of LUNU (Lund, SE) shown in Fig. 2 are not publicly available, the

[12] For the data analysis use has been made of the designated seismic open source software 'Obspy' (TU Munich)
[13] Jacob & Neilson in 'Magnitude estimation on LOWNET', GSU Report (1977)

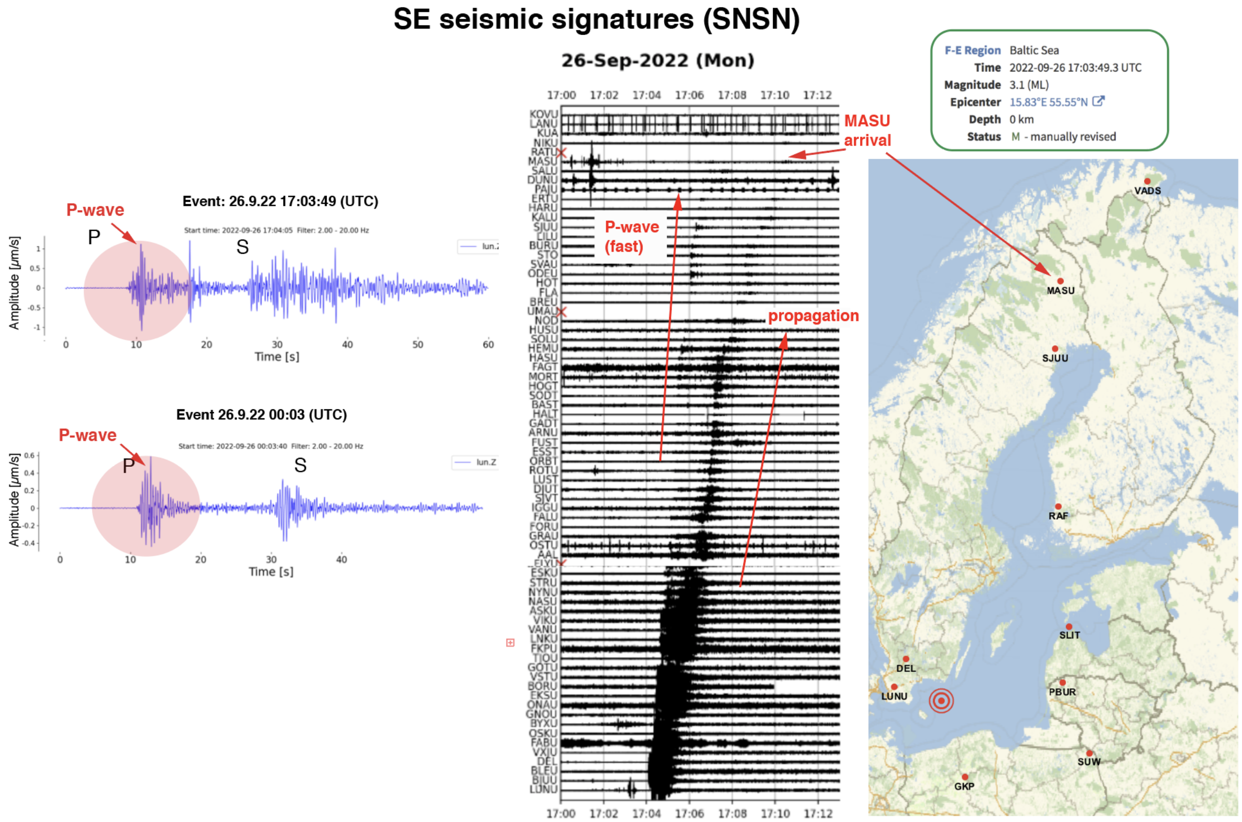

Figure 2 — **NordStream explosion and seismic signatures at Swedish stations according to the website of the Swedish Seismological Service SNSN** [5] [Most of the data displayed in Ref. [5] are not available as waveforms and thus can not be analysed]. **Left:** Seismic waveforms measured in Lund (LUNU: 55.63200°,13.44680°) the first (weaker) event around midnight on Sept 26, and a stronger event at 17:03 (UTC). Note the sharp rise of the P-Wave signal whose amplitude exceeds that of the subsequent shear waves. **Middle:** Propagation of the seismic waves towards North, where station MASU is the most northern Swedish station displaying seismic signatures which is at a distance of 1365km from the explosion site (the Norwegian station VADS at 1754km also displays seismic signatures of the 17:03 event, and in fact also stations in Iceland and Greenland). Inset top right: Entry in the Geofon database describing the localisation of the explosion up to 8km. This "Geofon Global Seismic Monitor" indicates magnitude $M_L = 3.1$ for the event at 17:03:49.32 (UTC). Source: [10] (**[Link]**).

corresponding magnitude has been derived here from the data shown there. In fact a value is obtained that is larger than the $M_L = 2.3$ listed on the SNSN website which in turn just followed the undocumented NORSAR claim. But in any case one should note that DEL and LUNU are too close to the epicentre for Eqn (2) to be reliable. Since it is known according to Jacobs/Neilson that reliable results from this Equation are only obtained beyond 2000km (op. cit. in footnote above), the corresponding values for m_b^* are presented here. This is of importance as it is this quantity which has been introduced by these authors and used in their compilation of data shown in Fig. 1.

Comparing the magnitudes listed in Table I one cannot help but notice that the early narrative was constructed around those stations which detected by far the lowest seismic signals. Even more, as is evident from the report of the Danish Geological Service 'GEUS' , [7] (**[Link]**) the stations were exclusively restricted to those situated in the West of the detonation site which are all characterized by low seismic response due to the resonant effect of the Baltic Sea to which I shall return to below.

From the values of Table 2 it is inferred that the magnitude of stations in the Baltic/Bothnian Sea evaluates to $m_b^* = 3.9 \pm 0.15$ if stations are excluded with $d < 200$km but also the stations SUW with its enhanced m_b^* value due to shock wave focussing. Note also that the value of is one magnitude higher than the one listed by Geofon, $M_L = 3.1$ ($m_b^* = 2.9$). The value of $m_b^* = 3.9$ indeed corresponds to a explosive yield of 185 tons TNT (sic!) [14] [15]

Even including statistical uncertainties it can thus be excluded that a conventional explosive was being used. This conclusion is further corroborated by considering the seismic waveforms of the seismograms as shall be shown

[14] The statistical uncertainty in the value of m_b^* implies an uncertainty between 120 t and 300 t.

[15] In this context it is also instructive to watch the video in which the sheer mass of a 25 ton conventional explosive (corresponding to roughly 1/10 of the above estimate) is illustrated **[Link]**.

station code	LUNU	DEL	PBUR	SLIT	RAF	SJUU	VADS	**SUW**	NOR	ANGG
M_S	2.7	2.9	3.3	3.6	3.2	3	2.9	4.6	3.7	4.5
d(km)	150	160	380	460	701	1150	1754	500	3100	3000

Table 1 – Seismographic stations (for their geographic location cf. Fig. 1), and derived values for M_S based on the observed $V_{\max}$ and the distance from the explosion site (epicentre). **Notice the enormous value at SUW which is representative for the not publicly available data of Kaliningrad (RF).**

Infobox: Common definitions of seismic amplitudes

This is a list of the most common definitions for seismic magnitudes:

- M_L: local Richter magnitude
- M_S: magnitude determined from surface wave data
- m_b: 'body wave' magnitude determined from teleseismic P-waves
- m_b^*: scale that attempts to measure m_b at short range

M_L is the original definition introduced by Richter and is based on a standard Anderson-Woods seismometer. M_L is commonly the largest of all these values and is widely quoted in the media. The IASPEI standard (Ammon et al. (2021) op. cit.) is given by,

$$M_S = \log_{10}(V_{\max}/2\pi) + 1.66\log_{10}\Delta + 3.3,$$

which goes back to the so-called "Prague-Moscow ('62)" Standard. Here $V_{\max}$ is the maximal seismometer velocity measured in micrometers/second and Δ the distance from the epicentre in degrees (1 degree = 111.1 km). At teleseismic distances (>2000 km) M_S serves as an accurate measure for the body wave magnitude m_b. At shorter distances a more accurate measure for m_b is given by

$$m_b^* = \log_{10}(V_{\max}) + 2.33\log_{10} R - 2,$$

which has been introduced by Navarro/Brockmann ('70) and Jacob/Willmore ('72). $V_{\max}$ is defined as above while R denotes the distance between seismometer and epicentre in km. Finally, a conversion formula between M_L and m_b^* has been introduced by Jacob/Neilson ('77) and is given by

$$M_L = 0.72\, m_b^* + 1.0.$$

below, and confirmed via the atmospheric and hydrodynamic data. Actually the observed data of Greenland (as well as Iceland) where Eqn (2) yields adequate values suggest an even higher value of $M_S = 4.5$ implying a yield of more than 1kt TNT. As can be inferred from Fig 1b, all values reported here are in the characteristic range of tactical nuclear weapons. And of course the pertinent question that has to be asked is why one would use this excessive amount of conventional explosive if at most a couple of hundred kg would do the job.

What is equally striking are the seismic amplitudes which were measured in Suwałki (SUW) at the Polish/Russian border to Kaliningrad and to a lesser degree in the station GKP. The corresponding waveforms exhibit a very sharp intense peak. This is indeed unusual in the seismological context, but less surprising in the context of signal processing and shock waves: Signals that are being reflected may show such behaviour as discussed in the Appendix. Taken at face value, one would infer from these amplitudes explosive yields of the order [16] of 20 kt (cf. Nagasaki-bomb had a yield of 25kt)

Finally one should add here that the public debate in the US and Europe has been dangerously and semi-consciously been sliding towards the use of tactical nuclear weapons [17] One recalls the remarkable answer of Liz Truss shortly before her election to UK PM to an interviewer's question: "Whether you Liz Truss, as Prime Minister are ready to unleash our nuclear weapons which means global annihilation. Would you push the button?" Under the audience's applause she replied: "I am ready to do that" [19] (**[Link]**).

After these considerations on the yield of the Nordstream explosion I shall focus more closely on the characteristic features of the measured seismic waveforms and their relations to known conventional underwater explosions,

[16] In a first version of the manuscript the even larger values of the station BEL have been taken into account as maximal values. However, in contrast to the SUW data with their apparent echo nature (cf. Method document [23]), the origin of these data cannot be unambiguously verified.

[17] This tendency can also be inferred from a detail such as the 4th (2019) edition of the standard work "The evolution of nuclear strategy" by Freedman & Michaels. One hardly escapes noticing the dates of the previous editions: 1981 (Cold War); 1989 (Collapse of SU); 2003 (NATO East extension and Irak)

station code	LUNU	DEL	PBUR	SLIT	RAF	SJUU	VADS	**SUW**
m_b^*	3	3.2	3.9	4.2	3.9	3.8	3.8	5.2
d(km)	150	160	380	460	701	1150	1754	500

Table 2 – Seismographic stations, derived seismic regional 'body wave' magnitude m_b^* of the Nordstream detonation, as well as the distance from the detonation site. **Notice also here the extremely large values for SUW in the vicinity of Kaliningrad corresponding to a sizeable earthquake.** (Suwałki lies in the border region of Kaliningrad exclave, Poland, Lithuania and Belarus).

earthquakes and known underground nuclear tests. To this end the waveforms are considered in two of the stations which exhibit the clearest signals, DEL and RAF at a distance of 160km or 700km respectively (cf. Fig. 3). Notice the close similarity of these waveforms to the known nuclear event on Feb. 12th 2013 in North Korea, the characteristic being the initial sharp rise of the initial P-wave whose amplitude exceeds the magnitude of the consecutive shear-wave trains. Also notice the nearly isotropic nature [i.e. (almost) equal in all (Z,N,E) directions] which is due to near-ground explosion associated with the Nordstream event.

Above waveforms are in clear contrast to those originating in conventional underwater explosions as studied by a group of AWE-Blacknest Scientists (AWE: British Atomic Weapons Establishment). These latter results are summarized in Fig. 4. A characteristic feature is the much smaller amplitude of the P-wave compared to surface waves, in clear contrast to the observations of the Nordstream Explosion. Figure 4 thus shows that a conventional explosive generates a much less pronounced shock wave and a waveform clearly distinct from the Nordstream observations.

Finally the difference between an earthquake and a nuclear explosion is addressed. Fig. 5 is taken from the textbook by Ammon et al [17]. Also here the nuclear events are characterised by the abrupt onset of the P-waves whos amplitude exceeds that of the subsequent surface waves, whereas waveforms associated with earthquakes exhibit the reverse ratio. Also here the Nordstream seismograms share distinct features with the nuclear detonation while being distinct from the earthquake waveforms which in turn share characteristics with the conventional underwater explosions as shown in Fig. 4.

A conventional explosion of the observed magnitude would undoubtedly have generated detectable amounts of NO2. Extensive satellite data (access via GEE or Copernicus) however show *no* signatures of such emissions that could be associated with the explosion. What is noteworthy, however, are the aerosol concentrations in the infrared and the underwater currents near the ocean floor which shall be discussed next.

III. Hydrodynamic signatures

With a detonation yield of the order of 0.2-1kt TNT equivalent (or possibly larger) one expects a significant influence onto the underwater currents. Indeed the current distribution on the day after the explosion shows a massive increase of a jet-like current (white arrow) directed away from the detonation site. Also the topography of the ocean floor reveals that the explosive was positioned very judiciously: It was placed such that the subsequent shock wave was focussed into a approx. 20km wide natural underwater canyon which is directly pointing into the direction of the Russian Exclave Kalininingrad. This is evident from the Figure which shows currents both on the day before (Sept 26th) as well as two days afterwards (Sept 27/28th). On the day before the explosion one may also infer from the East-West velocity (u_x) data (which are not shown here) that a small current towards East exists, whereas there are virtually no currents in the basin of the subsequent explosion. In contrast, on Sept 27 a strong southwards directed current emerged which is directed away from the explosion site. Simultaneously the canyon starts to support a backflow compensating the initial emission of the shockwave. This is particularly evident in the data at a depth of 50m which are shown on the r.h.s. Also shown is a sketch of the flows together with the vortex that was generated after the detonation in the basin enclosing the explosion site.

IV. Atmospheric signature – aerosol coverage in the infrared

Infrared images collected during the night demonstrate an enhanced concentration of aerosols detected at the (infrared- IR-A) wavelength of 685 nm and 1240 nm respectively. Clearly visible from Figure 6 is the emergence of an aerosol layer emanating from the detonation site directly extending into the direction of the measured wind (N to NNW) over distances of more than 100km. Equally discernible is a significant increase of the aerosol concentration around Kaliningrad extending towards Poland, Latvia, Belarus, even extending towards north up to Stockholm. It is remarkable that the regions with increased aerosol load coincide with precisely those regions that are directly and openly exposed to the oncoming shock-wave as evidenced by the clear seismic signals as observed in RAF. This is indeed expected following the evidence of a focussed shock-wave aimed at Kaliningrad. The aerosol coverage to the North of the detonation site and its position is paralleled by the weather data (**[Link]**.)

in Karlskrona where it has been raining after 20:00 until 01:20 (UTC) which constituted an exceptional event given the general global weather conditions. [18]

V. Conclusion

In conclusion it is found that each of our four main observations, the seismic magnitude, the characteristic seismic waveform, the underwater currents and the vast amount of generated aerosols cannot be reconciled with the use of a conventional explosive. Conversely, the promoted NORSAR/LANL narrative of an explosive with "detonation energy of a few hundred kilograms TNT" is at variance with every single of the above observations. We may thus summarize:

(1) From the detonation energy and the well-planned positioning of the explosive which follows from both seismic data as well as from the hydrodynamic details it is apparent that the goal of the attack was not only the destruction of Nordstream but a "Tsunami-like" attack [19] onto the Russian exclave Kaliningrad. This is not only evident from the existence of a direct free path between the chosen explosion site and the Kaliningrad coast, but also from satellite based observations of the generated underwater currents but also from the seismic amplitudes near Kaliningrad (Suwałki) which corresponded to a seismic event of magnitude $m_b^* = 5.2$. This in turn manifestly excludes the possibility that Russia was responsible for the attack[20] In this context the reason behind the NATO exercise BALTOPS '22 from June 5-17, 2022 [20] (**[Link]**) becomes highly plausible as its primary goal was the navigation of unmanned underwater vehicles (UUV) and the collection of more than 200 hours of detailed underwater mapping data in the vicinity of Bornholm, which also happened to be the close vicinity of the eventual detonation site. Our considerations demonstrate how crucially important such detailed bathymetric knowledge of this region turned out to be for carrying out the attack.

(2) The explosion energy was played down in media reports by a highly selective and misleading choice of the seismic stations on top of actually not being backed up by quantitative data. The actual detonation energy exceeded these 'reports' by several orders of magnitude. An evaluation of the data collected by seismic stations around the Baltic/Bothnian Sea yields a (body wave) magnitude of $m_b^* = 3.9 \pm 0.15$. Even with most conservative estimates one arrives at an explosive charge of 185t TNT equivalence (with statistical uncertainty of 60 tons). Given the seismic data from Greenland even a charge of 4 Kilotons lies within the realm. The effect of a nuclear underwater explosion of this size can be inferred from the following footage which was taken as part of the US Wahoo/Hardtack test series (**[Link]**). Apart from the considerable creation of aerosols one should also take notice of the rapidly emanating surface shock wave at the very beginning of this (time lapsed) video.

Given these facts it can be safely excluded that the explosion was caused by "an equivalent to several hundred kilograms of TNT" which appeared in the Guardian on November 18th quoting experts even after completion of the (secret) investigations **[Link]**. The use of a conventional explosive of the order of 0.2kt can also be excluded given the fact that the destruction itself could have been achieved with a fraction of this explosive yield. Further testament to this fact are the enormous hydrodynamic effects with induced currents at the scale of dozens of kilometers that are evident from satellite imagery, together with the vast amounts of aerosol detected around the coastlines in the hours after the explosion.

Finally and importantly, the seismic waveforms show no resemblance with conventional underwater explosions but rather with nuclear underground explosions as is evident from a comparison with the seismic data of a North Korean Nuclear Test. In fact it is precisely these seismic fingerprints that are regularly used to reliably identify nuclear tests. And finally, the estimated size of the detonation energy lies in the reported range of tactical thermonuclear weapons. Despite their enormous energy release these are fairly small devices and may weigh less than 100kg. Thus they can safely be navigated via UUV's to a designated position, a procedure that was precisely practiced in the very Bornholm area by NATO during their BALTOPS'22 exercise in June 2022.

(3) It is far from obvious why a conventional explosive charge of this magnitude would be used if a fraction of that would be sufficient to destroy the pipeline even at multiple locations. The only motive is thus a deeply

[18] The effects of a nuclear underwater explosion of a charge with 5kt TNT equivalent can be seen from the following video **[Link]**. Notice the considerable generation of aerosols in contrast to the conventional explosion shown in Fig. 4a.

[19] due to the steep coastline which follows from bathymetric date (cf. Ref. [22]) the shock waves resulted in intense crashing waves with subsequent gist that led to the large aerosol concentrations

[20] In the meantime this fact that has even been met with doubt in media such as the Washington Post [21] which appeared shortly before this current document has been completed.

> disturbing geopolitical one: "Hey - we are able to navigate into your backyard and initiate a thermonuclear explosion of deliberate strength". The very cynical aspect of thermonuclear weapons is that one and the same weapon can be literally "dialled" to the required explosive strength which thus can be tuned in the very last moment at a whim. The global coercive potential ist thus considerable - one is thinking of Iran, China/Taiwan, North-Korea but it may also include Turkey.

The Nordstream explosion was therefore not only a well planned attack onto the European energy supply. It was primarily a reckless geopolitical demonstration of power with unimaginable consequences. From the 1968 UN-Treaty on Non-Proliferation of Nuclear Weapons[21] (NPT) it is also clear that the only responsibles for both the preparation and the actual carrying out of the attack are to be found among the UK and US.

We can only frightingly speculate about the reaction if - mutatis mutandis - Russia or China would have launched a similar attack onto a vital US infrastructure. And finally, it should be noted that by definition it cannot be regarded as a "nuclear test" which is forbidden according to the LTBT, but then the only option left is that it was by definition the infamous "first strike" every US president since G.H.W. Bush refused to refrain from, and we are left in shock only remotely contemplating about the consequences a heated and prompted reaction on the side of the affected could have had.

VI. Epilogue

As a Physicist I personally encountered some of the colleagues who were among the principal architects of the thermonuclear weapon on either side of the Iron Curtain, a weapon that - for the first time in the history of mankind - bears the potential of wiping it out at the impulsive reaction of a single individual. In setting out the prerequisites for this to happen and allowing the weapons to come into existence, mankind has moved as far from the concept of democracy as it possibly can. [22]

As a father and grandfather I was shocked to my bones while I was uncovering the facts which are detailed above and which reveal the true nature and scale behind the attack on the Nordstream pipelines.

It appears that we are tacitly led to accept that the use of tactical nuclear weapons is becoming the 'new normal', even though all efforts since WWII including the UN-Treaty on Non-Proliferation of Nuclear Weapons (NPT) were designed to aim exactly at the opposite, namely the complete abolition from nuclear weapons.[23]

Having soon recognized the disastrous consequences of their engagement in the Manhattan Project during WWII, the majority of my colleagues immediately engaged in activities aimed at putting an end to the nuclear arms race. Some of them faced drastic consequences for their efforts: Some refused to witness against their own colleagues, as for example David Bohm did, and as a consequence they were forced to give up most prestigious academic positions and emigrate, or J.R. Oppenheimer who lost the security clearance, was ousted and was never fully rehabilitated. Similarly on the other side of the Iron Curtain, Andrei Sakharov, despite having been the principal architect of the Soviet H-Bomb (at 50 Megatons the most powerful weapon ever constructed), he engaged actively in the dialogue between East and West under much threat and oppression by that regime.

And despite these efforts we now find ourselves in a situation that the public (including Scientists not working for the defense industry even in a wider sense) has not even remotely realized that they are on the battlefield of an ongoing nuclear conflict which has recklessly been unleashed by the West.

The danger of this nuclear conflict is the unbounded slippery slope of escalation. Every retaliatory strike will consecutively increase the energy scale of the weapons involved, taking us step by step closer to the precipice of total annihilation, and nobody is not even remotely realising into what dangerous territory we have been maneouvred into!

Now that Nuclear War has raised its ugly head above the surface of the Baltic Sea, it is up to us to either permanently dispose of it or we risk the end of humanity. [24]

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[21] In fact the NPT starts with the following statement: "Considering the devastation that would be visited upon all mankind by a nuclear war and the consequent need to make every effort to avert the danger of such a war and to take measures to safeguard the security of peoples"

[22] In the World's first democracy under Cleisthenes 10 districts were created, from each of which 50 representatives were selected by lot to be sent to the Pan-Atheneian council of the 500 boulae which put forward ten military formations, which were headed by democratically elected strategists. Thus the rise of democracy was intimately intertwined with defence. [cf. St Bajohr, "Kleine Weltgeschichte des demokratischen Zeitalters", Springer, 2014]

[23] In fact Art. VI of the NPT states: *"Each of the Parties of the Treaty undertakes to pursue negotiations in good faith on effective measure relating to cessation of the nuclear arms race at an early date and to nuclear disarmament, and on a treaty on general and complete disarmament under strict and effective international control."*

[24] At this stage it is illuminating what the sceptics within the US Scientific Advisory Committee to the SAC prophetically stated in 1949 shortly

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before President Truman's decision to embark on the development of the Super-Bomb (i.e. thermonuclear bomb):
"We have been asked by the commission whether or not they should immediately initiate an "all-out" effort to develop a weapon whose ***energy release is 100 to 1000 times greater [..] than those of the present atomic [i.e fission] bomb.***
We base our recommendation on our belief that ***the extreme dangers to mankind inherent in the proposal wholly outweigh any military advantage*** *that could come from this development. Let it be clearly realized that this is a super-weapon;* ***it is in a totally different category from an atomic bomb****. The reason for developing such super bombs would be to have the capacity to devastate a vast area with a single bomb. Its use would involve a decision to slaughter a vast number of civilians. We are alarmed as to the possible global effects of the radioactivity generated by the explosion of a few super bombs of conceivable magnitude. If super bombs work at all [..this has been shown to be the case by US, Russia and China], there is no inherent limit in the destructive power that may be attained with them.* ***Therefore, a super bomb might become a weapon of genocide****.*
The existence of such a weapon in our armory would have far-reaching effects on world opinion: reasonable people the world over would realize that ***the existence of a weapon of this type whose power of destruction is essentially unlimited represents a threat to the future of the human race which is intolerable."***
signed J.B. Conan, H. Rowe, C.S. Smith, L.A. DuBridge, O.E. Buckley, and J.R Oppenheimer on Oct 30th, 1949
(US. Atomic Energy Commission, Hist Doc. No. 349)

Appendix — Focusing effects of shock waves

The focusing effect of the approximately elliptically shaped ocean floor which was indicated in Fig. 7 has been described in specifically designed experiments which are shown in Fig. 8. Firstly it is known that the dispersion of an existing signal that arose from a sharp blast can be 'undone' via reflection processes and refocussed to a narrow pulse whose magnitude may exceed that of the original excitation, in the example shown in the Figure by a factor of 6. Image **d** shows a comparison between experiment and simulation of the amplification of a shock wave via an elliptical reflector into a focal point that is more distant from the elliptical reflector than the original site of explosion. Indeed the arrangement closely resembles the underground topography in the vicinity of the Nordstream explosion site. Correspondingly the focal point must have been close to the entrance to the underwater canyon directed towards Kaliningrad. This setup had the effect of significantly amplifying and focusing the shockwave generated in the explosion into a highly energetic beam-like shock wave directed at Kaliningrad. In this relation it is also important to note the generation of an enormous aerosol cloud within a few hours after the detonation. This also explains the enormous seismic amplitudes generated in Suwałki (cf. Table 1) representative of Kaliningrad and the adjacent border territory of Lithuania, Belarus and Poland. Finally it should be noted that NATO carried out the exercise BALTOPS'22 in the Baltic Sea specifically around Bornholm during which more than 200 hours of detailled underwater footage were collected which is a prerequisite for the scenario described here.

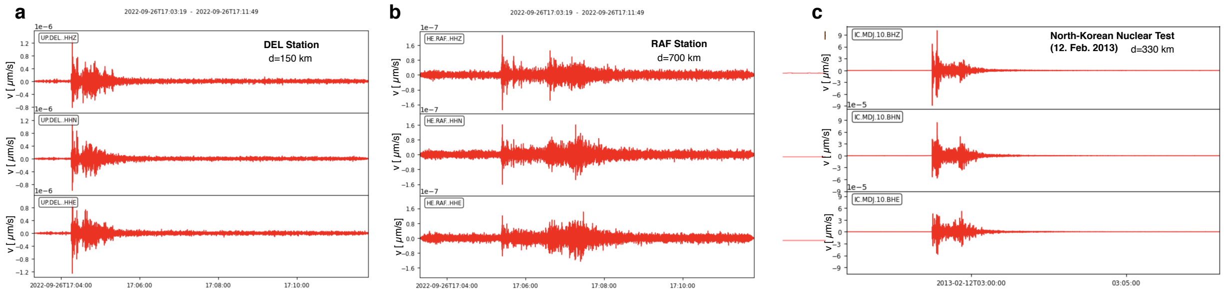

Figure 3 — Measured 3D seismograms of DEL and RAF compared to a North-Korean underground nuclear test of magnitude $M_L = 5.1$. **a**, Measured seismic response at DEL on the Swedish mainland at a distance of 150km towards West (cf. Fig. 2). From top to bottom: Response in vertical (Z), north (N) and East (E) direction. Notice the abrupt beginning of the response which is characteristic of a shock wave which is particularly pronounced for a nuclear explosion. Also characteristic for an underground event is the nearly isotropic response indicating the existence of a hybrid water/solid shock primary wave. **b**, Measured response at the station RAF situated at the Finnish coast close to Turku at a distance of 700km. Also here the onset of P-waves is still well pronounced. Note that the station RAF is virtually freely accessible across water from the detonation site. For this resaon the shock wave arrives virtually unscattered and is moving with a velocity of approx. 6 km/s far exceeding the sound velocity (1.5km/s). Note both panels a and b reveal a periodic substructure which is related to resonance-like reflection of shock waves in coastal regions. **c**, Measured response of a underground nuclear test (UNE) in North Korea of strength $M_L = 5.1$ corresponding approx. to a 7 kt TNT yield. Clearly visible are the clear onset of the P-wave which also exceeds the intensity of the surface waves. [Note, based on the independent method employed here, the same estimate $M_L = 5.1$ was obtained determined in the following press release of the Earth Institute of Columbia University [**Link**]]. [Fig3a,b: ©H.B. Braun]

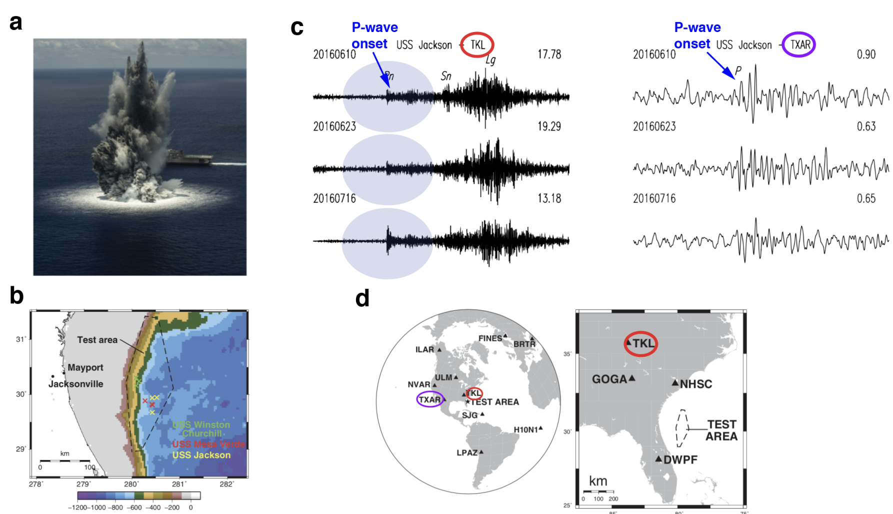

Figure 4 — Comparison to conventional (chemical) underwater explosions ('shock tests' with 10'000 lbs TNT) off the Florida coast: **a** Conventional explosion triggered by USS Jackson on June 10th 2016, **b** Location of the explosions **c** Corresponding waveforms of various tests as registered at TKL (the world's most sensitive seismographic instrument in Tennessee under DoD management) and TXAR (Texas). Note the similarity to the earthquake in Fig 5 and the striking difference to the nuclear event shown in the same Figure. Source: R. Heyburn, S.E. J. Nippress, and D. Bowers, *Seismic and Hydroacoustic Observations from Underwater Explosions off the East Coast of Florida*, Bull. Seism. Soc. Am. **108**, pp. 3612–3624, (2018). [**Link**]

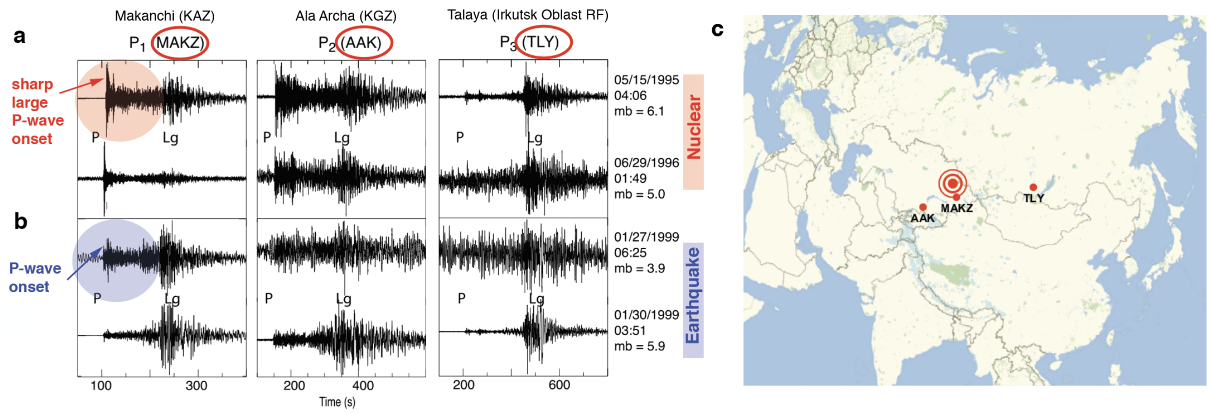

Figure 5 – Comparison between earthquake and nuclear explosions at the Semipalatinsk test site with nearly identical epicentre (red circles): a Seismograms of a nuclear explosion on the Semipalatinsk test site registered at seismic stations MAKZ, AAK, TLY at distances of 440km, 892km, and 1754km respectively. Top row: a magnitude $m_b = 6.1$ event, second row a $m_b = 5.0$ nuclear explosion. Note the abrupt and intense onset of P-waves exceeding that of the following Lg-waves at distances less than 1000km from the seismic stations. This is in contrast to a conventional earthquakes (bottom two rows) where the Lg wave amplitude always exceeds that of the P-waves at all distances. **c** Geograpic location of epicentre (red concentric circles) and seismic stations. Source: panels **a**,**b**, from C.J. Ammon et al. *Foundations of Modern Global Seismology*, 4th ed. (2021).

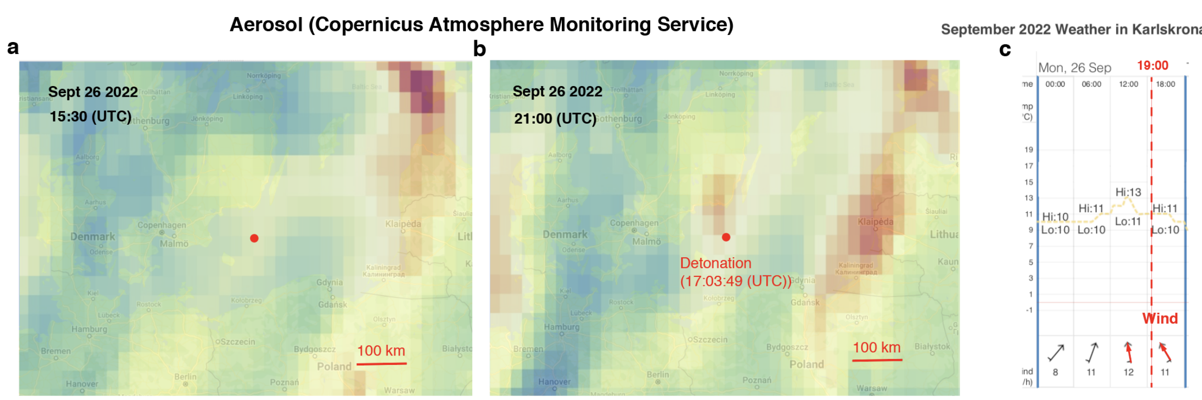

Figure 6 – Aerosols both before and after the detonation: a, Aerosol distribution 1.5 hours before the detonation detected in the infrared at 785nm wavelength. **b**, Aerosol distribution 4 hours after the detonation (note that local time = UTC +2) . Clearly visible are both the extended cloud emanating from the detonation site (red dot) into the direction of the prevailing winds (cf. **c**) and extending over 100km. Also clearly visible is the enhancement of the aerosol concentration along the Kaliningrad coastline as is expected from the focussing of shock waves along the underwater canyon directed at Kaliningrad (cf. Fig. 7) and the entailing enormous seismic magnitudes observed at Suwałki in the border region of Belarus, Lithuania, Poland and Kaliningrad. **c** Wind direction in Karlskrona on the Swedish coast facing the explosion site against the wind direction. [Source: GEE: Copernicus Atmosphere Monitor (CAMS) @ 785 nm wavelength]. [Fig5a,b: ©H.B. Braun]

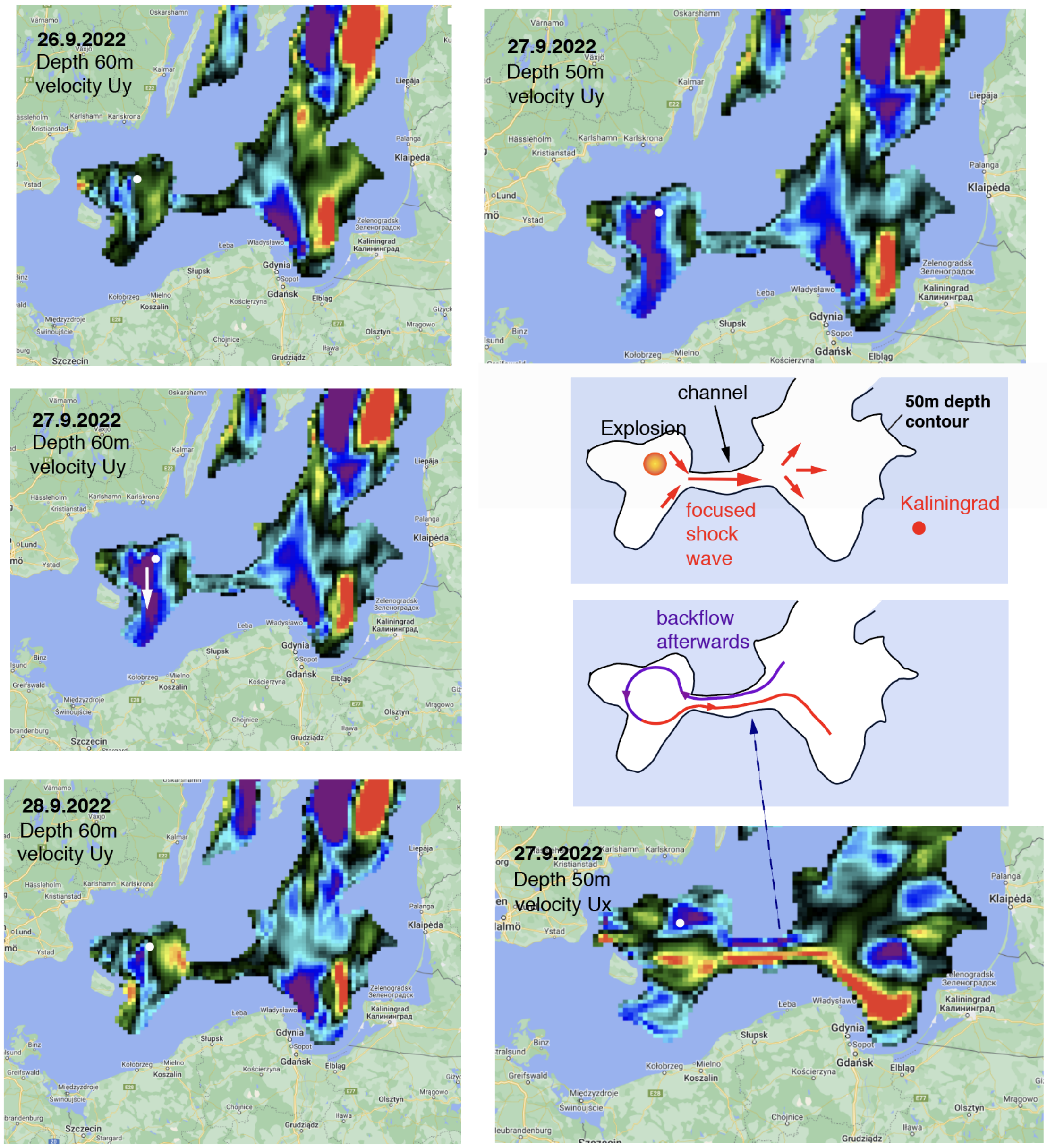

Figure 7 – Underwater canyon and explosion induced underwater vortex formation after the explosion: Left: Satellite images on Sept 26th to 28th (Explosion on Sept 26 at 17:04 UTC) at a depth of 60m. Shown are the North/South components of the currents (yellow/red is directed towards North, blue/black towards South). The white arrow indicates the emergence of a strong underwater current after the explosion away from the detonation site (white dot) which did not exist before (Sept 26th) and considerably after (Sept 28th) the explosion. One should also notice the existence of a pronounced underwater canyon of a width of less than 20km running East West which directly points towards Kaliningrad. On the right hand side both North/South (top) and East/West currents (bottom) are shown at a depth of 50m. Also here red indicates a flow in positive (x or y = East or North) direction, while blue black indicates a flow in the opposite direction. Notice the existence of a significant backflow through the canyon in the aftermath of the explosion compensating the outflow caused by the outgoing shockwave triggered by the explosion. As indicated in the top inset, the shape of the ocean floor near the explosion site (reflecting the Karlskrona bay) had the effect of focussing the shock wave into the underwater canyon giving rise to a highly intense focused shock-wave aimed directly at Kaliningrad and thus explaining the enormous seismic magnitudes in Suwałki. Data Source: GEE: HYCOM satellite images. [Fig7: ©H.B. Braun] .

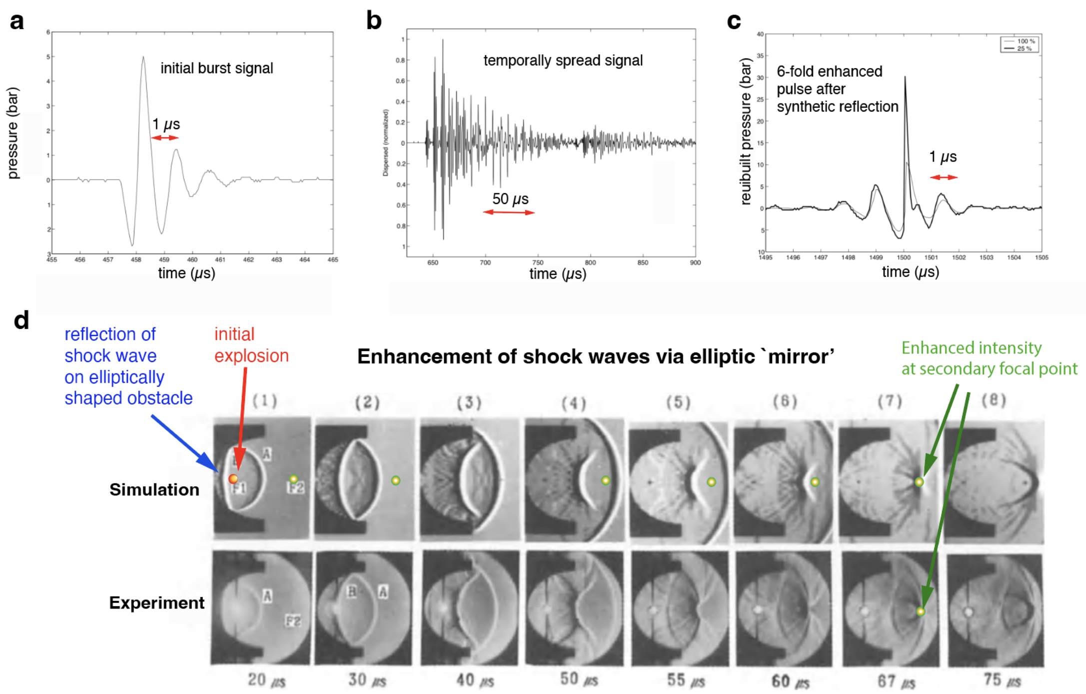

Figure 8 – Focusing effect of shockwaves a - c The dispersion of a sharp detonation signal can be reversed through reflection. In this example an initial burst signal of 1 μs duration is spread to 50 μs in a waveguide. In this example of a piezo-dispersive generator the electronically simulated reflection ('time reversal mirror') recreates a shock wave **c** whose pressure amplitude exceeds that of the orginal pulse by a factor 6. [Reference: S. Dion, C. Herbert. M. Brouillette, *Comparison of method for generating shock waves in liquids*, in Shock Waves, eds Hannemann Seiler, 26th Symposium on Shock waves, 2007, Springer (2009)]. **d** Focusing of shock waves in water via an elliptically shaped boundary: A shock-wave that is created at the detonation point (orange/red) bouncing off the elliptically shaped reflector (black, left) and upon reflection becomes focussed close to the green/yellow focal point with maximal focussing at the instant of image (7) (2nd last column). Notice the similarity to the shape of the ocean floor close to the detonation point (cf. Fig. 7, top inset). Thus after reflection at the underwater basin a secondary shock wave is generated and directly focussed into the entrance of the underwater Canyon directed at Kaliningrad. [Reference: K. Isuzugawa, M. Horiuchi, *Experimental and numerical studies of blast wave focusing in water*, in "Shock Waves", Proceedings Sendai 1991, Vol1, Springer (1991).]