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Tim B. Spahr PhD, CEO

The -------- Impact Scale
--or alternatively—
NO NUKES

Tim Spahr, NEO Sciences, LLC & University of Maryland Small Bodies Node

IAWN Steering Committee Meeting, Vienna, 5 February 2020

**The author list includes just about everyone in the field! I've discussed this idea directly with many Steering Committee members, NEO colleagues, IAU personnel, UN folks such as Romana Koffler, etc!

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Background & Motivation

Asteroid scientists need better means of communicating impact energies and likelihood with the public

Image Credit ESA

2019 LA—Bardend Swanopoel

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But why change?

Current units are confusing

--megatons TNT (who's seen a pile of TNT lately?)

--'Hiroshima' units based on nuclear yield measured from a real wartime event 80 years ago

--Nuclear units confuse the public—no radiation is released during asteroid impacts (!!!)

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Old units

1 megaton TNT = 4.2 X 10^15 joules

Wartime nuclear blasts ~ 2 X 10^13 joules

25–100	29–116 TWh	During the Cold War, the United States developed hydrogen bombs with maximum theoretical yields of 25 megatons of TNT (100 PJ). The Soviet Union developed a prototype weapon, nicknamed the Tsar Bomba, which was tested at 50 Mt (210 PJ), but had a maximum theoretical yield of 100 Mt (420 PJ).[19] The effective destructive potential of such a weapon varies greatly, depending on such conditions as the altitude at which it is detonated, the characteristics of the target, the terrain, and the physical landscape upon which it is detonated.
26.3	30.6 TWh	Megathrust earthquakes 2004 Indian Ocean earthquake released record M_E surface rupture energy, or potential for damage at 26.3 megatons of TNT (110 PJ).
200	232 TWh	The total energy released by the eruption of Mt. Krakatoa in Indonesia in 1883.
540	628 TWh	The total energy produced worldwide by all nuclear testing and combat combined, from the 1940s until the present is about 540 megatons.[*citation needed*]
1,460	1.69 PWh	The total global nuclear arsenal is about 15,000 nuclear warheads[20][21][22] with a destructive capacity of around 1460 megatons[23][24][25][26] or 1.460 gigatons (1,460 million tons) of TNT.
104,400	121 PWh	The total solar irradience energy received by Earth in the upper atmosphere per hour.
875,000	1,000 PWh	Approximate yield of the last eruption of the Yellowstone supervolcano.
6×10^6	6,973 PWh	The estimated energy at impact when the largest fragment of Comet Shoemaker–Levy 9 struck Jupiter is equivalent to 6 million megatons (6 trillion tons of TNT.
9.32×10^6	10,831 PWh	The energy released in the 2011 Tōhoku earthquake and tsunami was over 200,000 times the surface energy and was calculated by the USGS at 3.9×10^{22} joules,[27] slightly less than the 2004 Indian Ocean quake. This is equivalent to 9,320 gigatons of TNT, or approximately 600 million times the energy of the Hiroshima bomb.
9.56×10^6	11,110 PWh	Megathrust earthquakes record huge M_W values, or total energy released. The 2004 Indian Ocean earthquake released 9,560 gigatons TNT equivalent.
1×10^8	116,222 PWh	The approximate energy released when the Chicxulub impact caused the mass extinction 65–66 million years ago was estimated to be equal to 100 teratons (i.e. 100 exagrams or approximately 220.462 quadrillion pounds) of TNT (a teraton equals 1 million megatons). That is roughly 8 billion times stronger than each of the bombs that hit Hiroshima and Nagasaki and the most energetic event on the history of Earth for hundreds of millions of years, far more powerful than any volcanic eruption, earthquake or firestorm. Such an explosion annihilated everything within a thousand miles of the impact in a split second. Such energy is equivalent to that needed to power the whole Earth for several centuries.

		10 m (17 by 34 ft)) awaiting detonation at Operation Sa Hat.
$(1–2) \times 10^{-3}$	1.16–2.32 GWh	Estimated yield of the Oppau explosion that killed more than 500 at a German fertilizer factory in 1921.
2.3×10^{-3}	2.67 GWh	Amount of solar energy falling on 4,000 m^2 (1 acre) of land in a year is 9.5 TJ (2,650 MWh) (an average over the Earth's surface).
3×10^{-3}	3.49 GWh	The Halifax Explosion in 1917 was the accidental detonation of 200 tons of TNT and 2,300 tons of Picric acid
4×10^{-3}	9.3 GWh	Minor Scale, a 1985 United States conventional explosion, using 4,744 tons of ANFO explosive to provide a scaled equivalent airblast of an eight kilot (33.44 TJ) nuclear device,[14] is believed to be the largest planned detonation of conventional explosives in history.
$(1.5–2) \times 10^{-2}$	17.4–23.2 GWh	The Little Boy atomic bomb dropped on Hiroshima on August 6, 1945, exploded with an energy of about 15 kilotons of TNT (63 TJ), and the Fat Man atomic bomb dropped on Nagasaki on August 9, 1945, exploded with an energy of about 20 kilotons of TNT (84 TJ). The modern nuclear weapons in t United States arsenal range in yield from 0.3 kt (1.3 TJ) to 1.2 Mt (5.0 PJ) equivalent, for the B83 strategic bomb.
1	1.16 TWh	The energy contained in one megaton of TNT (4.2 PJ) is enough to power the average American household for 103,000 years.[15] The 30 Mt (130 PJ) estimated upper limit blast power of the Tunguska event could power the same average home for more than 3,100,000 years. The energy of that blast could power the entire United States for 3.27 days.[16]
3	3.5 TWh	The total energy of all explosives used in World War II, including the Hiroshima and Nagasaki atom bombs, is estimated to have been three megatons TNT.
8.6	10 TWh	The energy released by a typical tropical cyclone in one minute, primarily from water condensation. Winds constitute 0.25% of that energy.[17]
21.5	25 TWh	The complete conversion of 1 kg of matter into pure energy would yield the theoretical maximum ($E = mc^2$) of 89.8 petajoules, which is equivalent to 21.5 megatons of TNT. No such method of total conversion as combining 500 grams of matter with 500 grams of antimatter has yet been achieved. In event of proton–antiproton annihilation, approximately 50% of the released energy will escape in the form of neutrinos, which are almost undetectable. Electron–positron annihilation events emit their energy entirely as gamma rays.
24	28 TWh	Approximate total yield of the 1980 eruption of Mount St. Helens.

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But why change?

Also—and importantly—measuring these events based on acts of war (that had profound influence on Japanese society) is as good a reason as any to change

(PDC in Japan here)

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LPL NEO Meeting/Tucson

--At a recent NEO meeting in Tucson there was a *very* energetic discussion

--Crowd suggested ‘Shoemaker’ for the name of the scale

--Many participants (including Bill Gray, Eric Christensen, Davide Farnocchia) made suggestions

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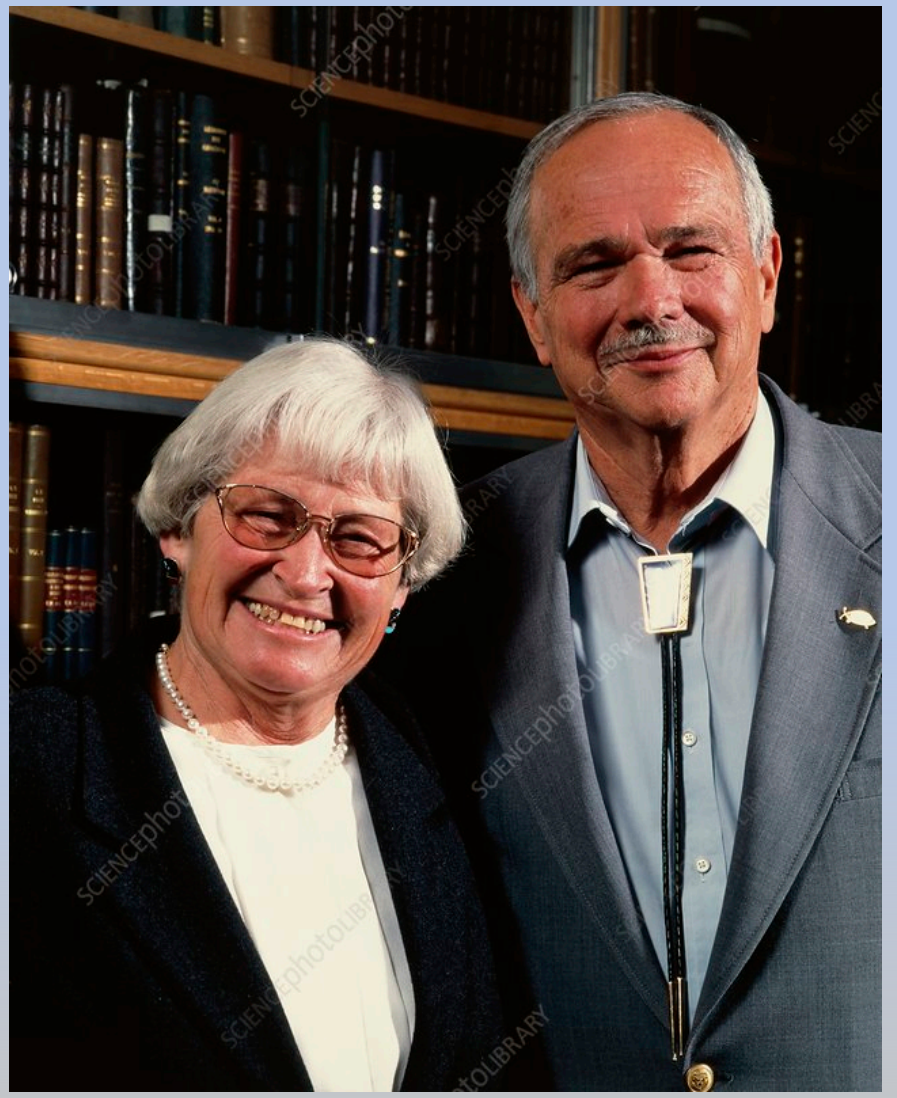
Introducing The Shoemaker Scale

--After much discussion, Shoemaker Scale was suggested

--Tribute to Eugene Shoemaker (and Carolyn!), some of the founders of regular NEO surveying and the study of NEOs and impacts

--Range 0 to 10, similar to Richter Scale, with 10 being catastrophic and 1 being entirely routine and not something public would notice

--Impact energy scales nicely with impact probability! (rarer events produce more damage)



David Parker/Science Photo Library

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Score/Unit	Frequency	Damage
0---***Meteor***	Many Daily	None
1---***Fireball***	Daily	None
2—***Dashcam Fireball***	Monthly	None
3--***Peekskill***	Annual	Extremely rare
4--***Airburst***	Decadal	
5--***Chelyabinsk***	100-year event	Local and limited
6	1,000 year event	
7	10,000 year event	
8	1,000,000 year event	
9	100,000,000 year event	
10	Billion year event	Planetwide Catastrophe

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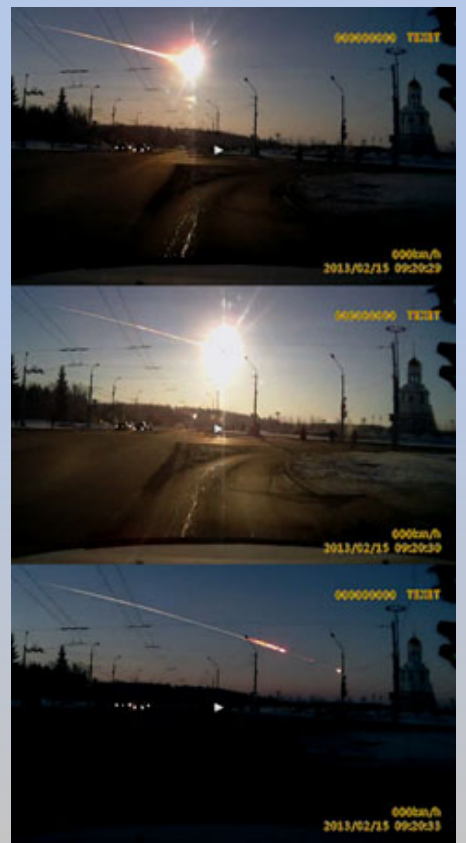
Example

--1 ***CHELYABINSK*** (to be used for airbursts) = 2 X 10^15 joules (1/2 megaton)



Константин Кудинов

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Example Units

--1 ***BARRINGER*** (to be used for actual terrestrial impacts)
= 4 X 10^16 joules

(Presumably no humans
In this part of the world
50,000 years ago? Any
anthropologists in
The room?)

Wallchan image

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Usage of new unit system

Gently encourage the use of these units in the future (keep in mind I have no power here whatsoever)

Most airbursts are a small fraction of a single *Chelyabinsk* and less than 4 on the Scale

This was intentional—most of the small airbursts are not worth getting excited about!

Nudge folks away from using nuclear units that confuse issue

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Still under construction. Comments!?