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10. Discussion on the possible extension of the available range of SI prefixes

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SI prefixes

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- pm (picometre), mmol (millimole), GΩ (gigaohm), THz (terahertz), etc
- Part of the SI, use is optional
- Clear communication across disciplines

Factor	Name	Symbol	Factor	Name	Symbol
10^{1}	deca	da	10^{-1}	deci	d
10^{2}	hecto	h	10^{-2}	centi	c
10^{3}	kilo	k	10^{-3}	milli	m
10^{6}	mega	M	10^{-6}	micro	µ
10^{9}	giga	G	10^{-9}	nano	n
10^{12}	tera	T	10^{-12}	pico	p
10^{15}	peta	P	10^{-15}	femto	f
10^{18}	exa	E	10^{-18}	atto	a
10^{21}	zetta	Z	10^{-21}	zepto	z
10^{24}	yotta	Y	10^{-24}	yocto	y

- Guards against creation of local units
- Sit alongside scientific notation, but arguably more useful

Possible extension of the available range of SI prefixes

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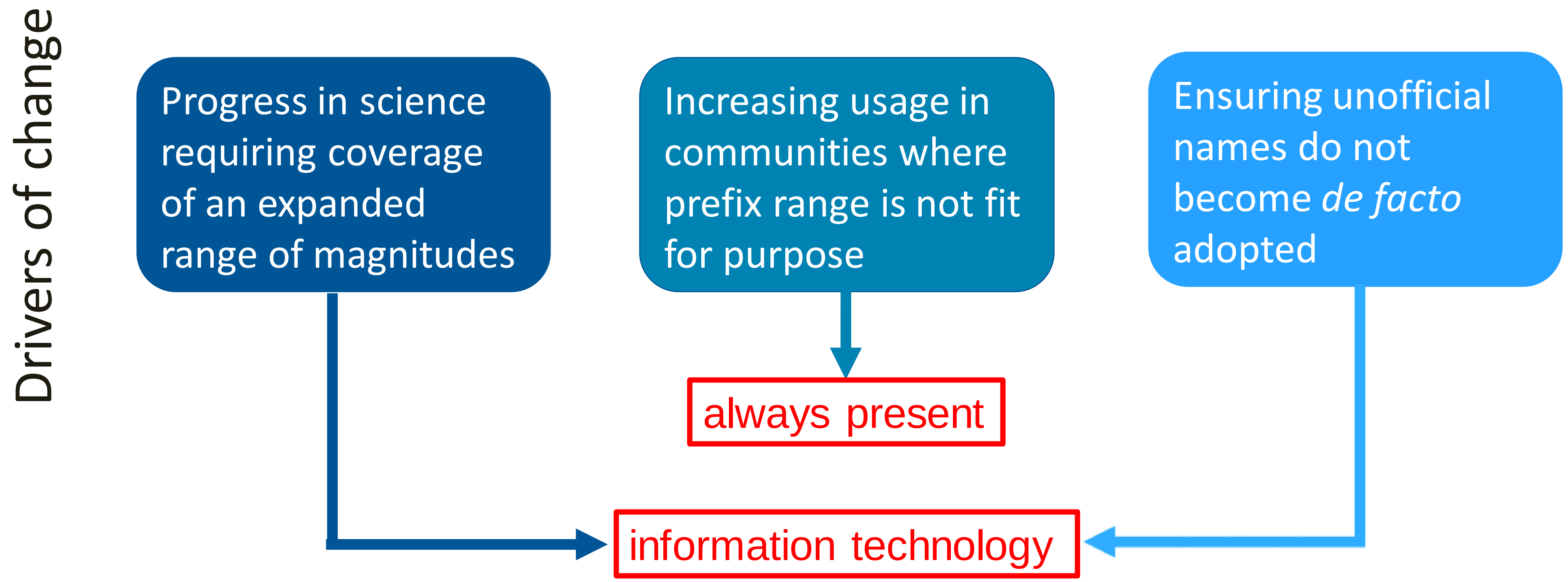
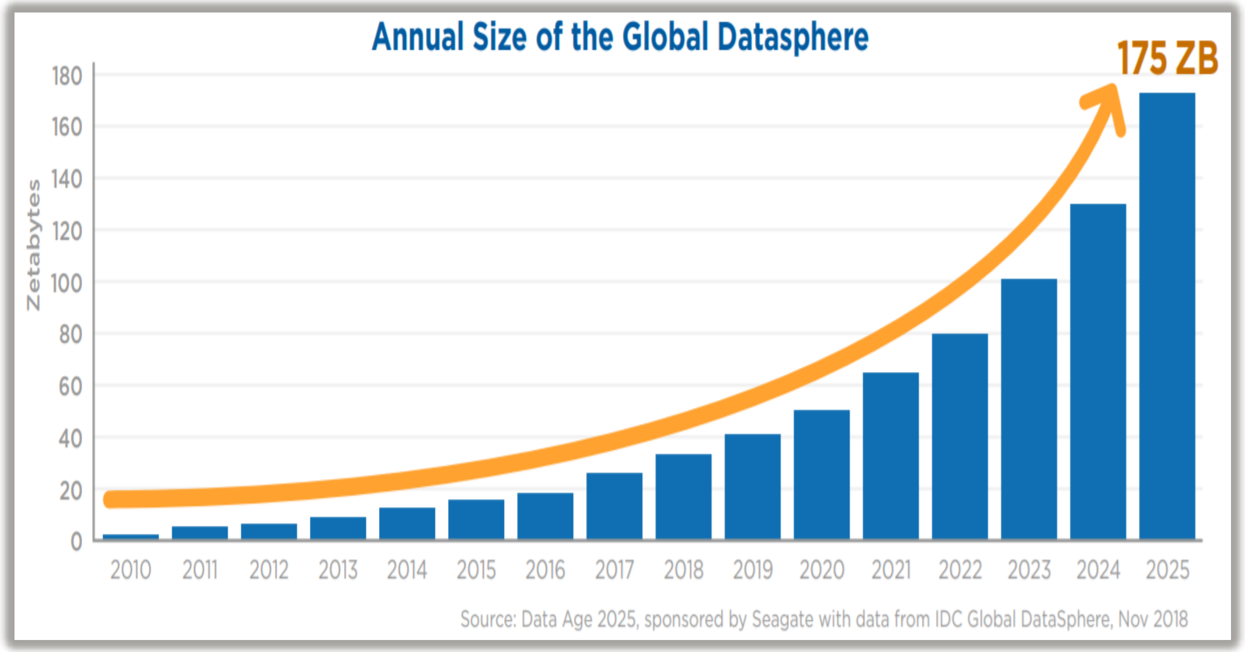


Information technology

- Data storage – and the non-SI unit ‘byte’ – needs prefixes in excess of 10^{24}, especially with advent of quantum computing



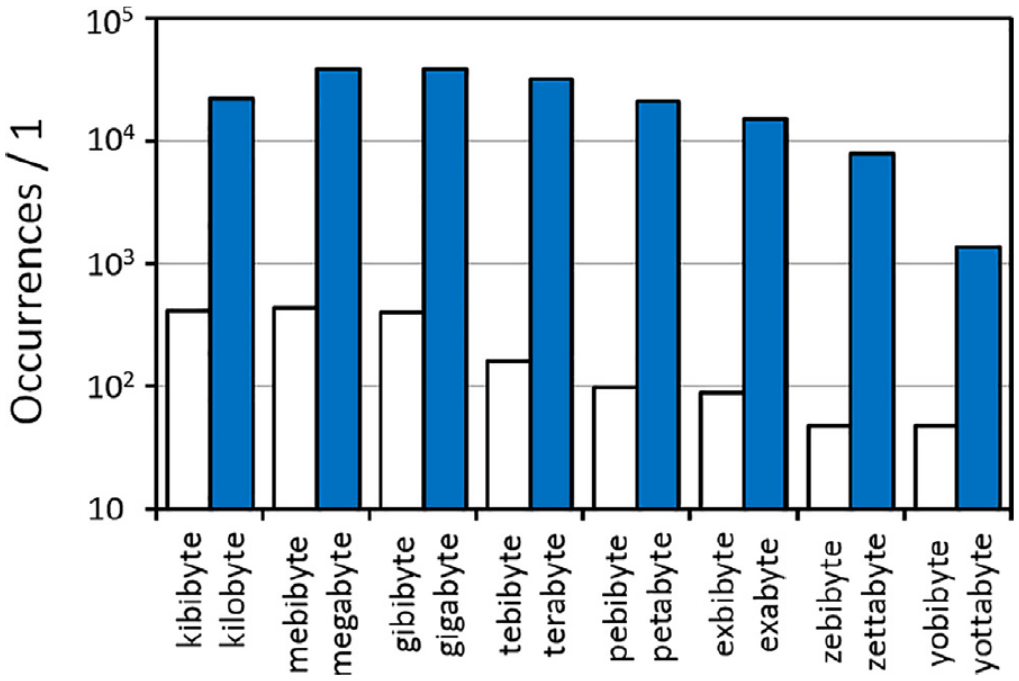
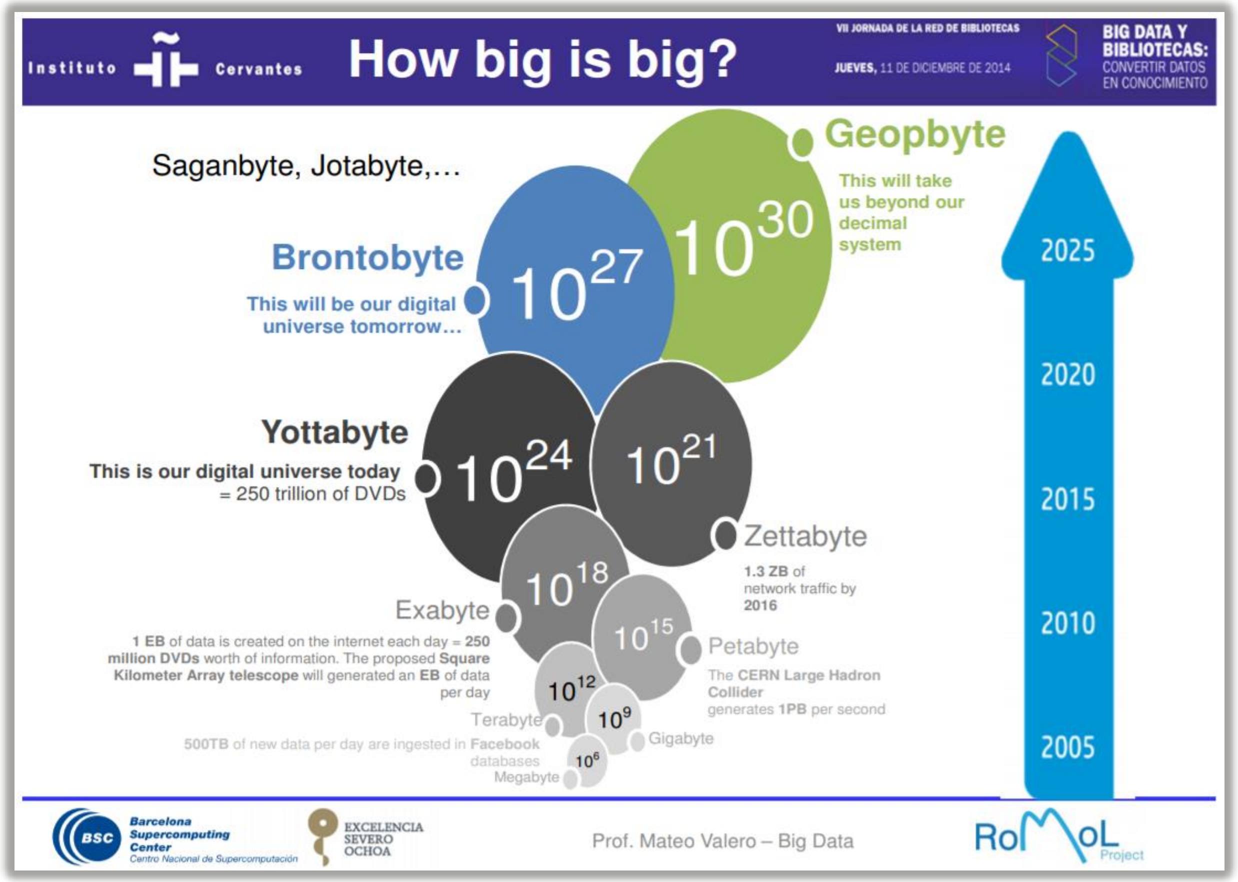
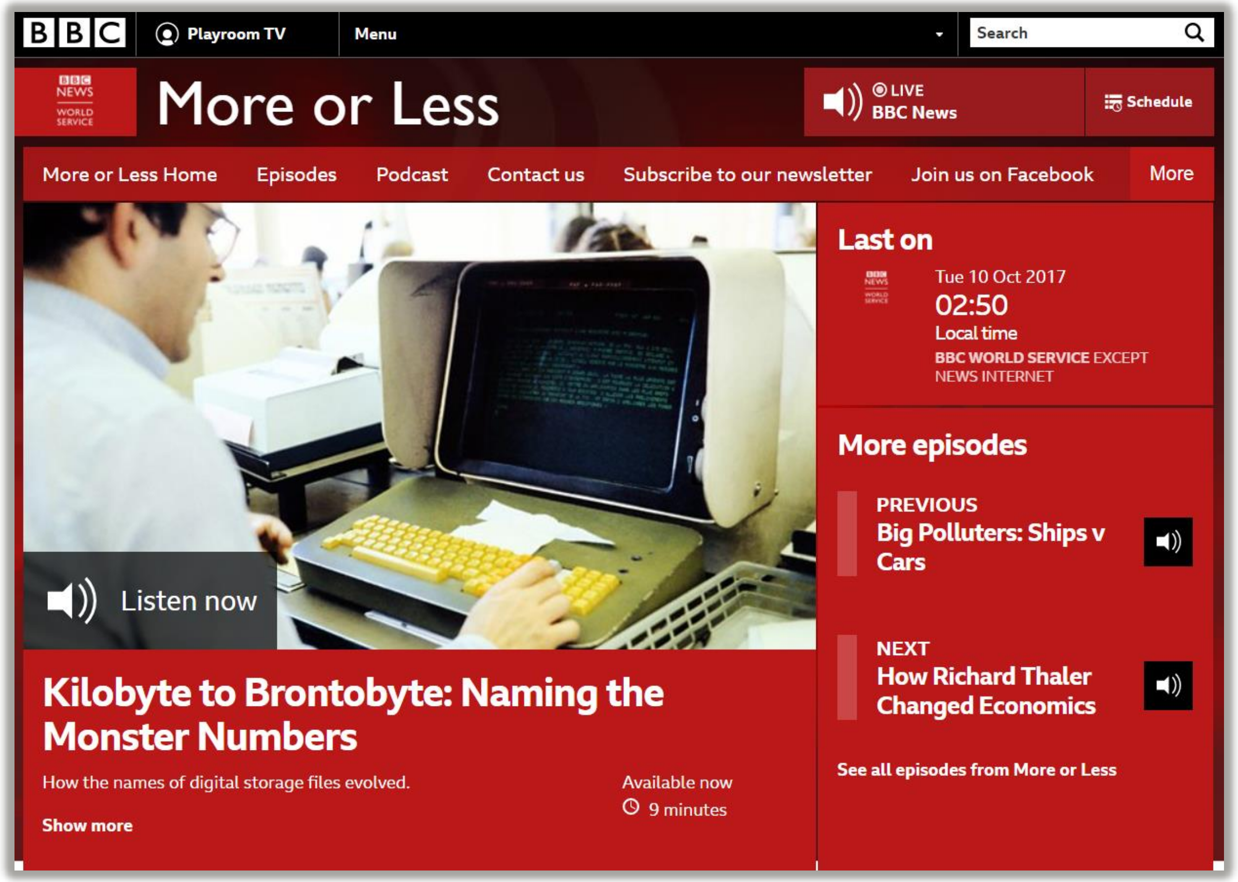


Fig. 1. Approximate number of times prefixes combined with ‘bytes’ or ‘byte’ appear on Google Scholar between 1992 and 2017 (inclusive, not including patents or citations); IEC prefixes (empty bars) and SI prefixes (shaded bars).

- An area where the popular science media is active
- Yottabyte(s) (412k Google hits), Brontobyte(s) (114k), Geopbyte(s) (60k), Hellabyte(s) (76k)
- IEC prefixes are used significantly less

This discussion is real, evolving and happening now!





Expanding the range: current usage of symbols

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English alphabet	Use in SI prefixes or SI units		Other non-SI units or symbols
	Lower case	Upper case	
a, A	**atto**	ampere	year (a)
b, B			barn (b), bel (B), byte (B)
c, C	**centi**	coulomb	
d, D	**deci, deca**		day (d), Dalton (Da)
e, E		**exa**	electronvolt (eV)
f, F	**femto**	farad	
g, G	gram	**giga**	
h, H	**hecto**	henry	hour (h), hectare (ha)
i, I			square root of −1 (*i*), number one (1)
j, J		joule	
k, K	**kilo**	kelvin	
l, L			litre (l & L), number one (1)
m, M	**milli**, metre	**mega**	
n, N	**nano**	newton	
o, O			octet (o), number zero (0)
p, P	**pico**	**peta**	
q, Q			
r, R			röntgen (R)
s, S	second	siemens	
t, T		**tera**, tesla	tonne (t)
u, U			atomic mass unit (u), **micro** (μ), uncertainty (*u* & *U*)
v, V		volt	
w, W		watt	
x, X			multiplication symbol (x)
y, Y	**yocto**	**yotta**	
z, Z	**zepto**	**zetta**	

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Expanding the range: etymologies of current prefixes

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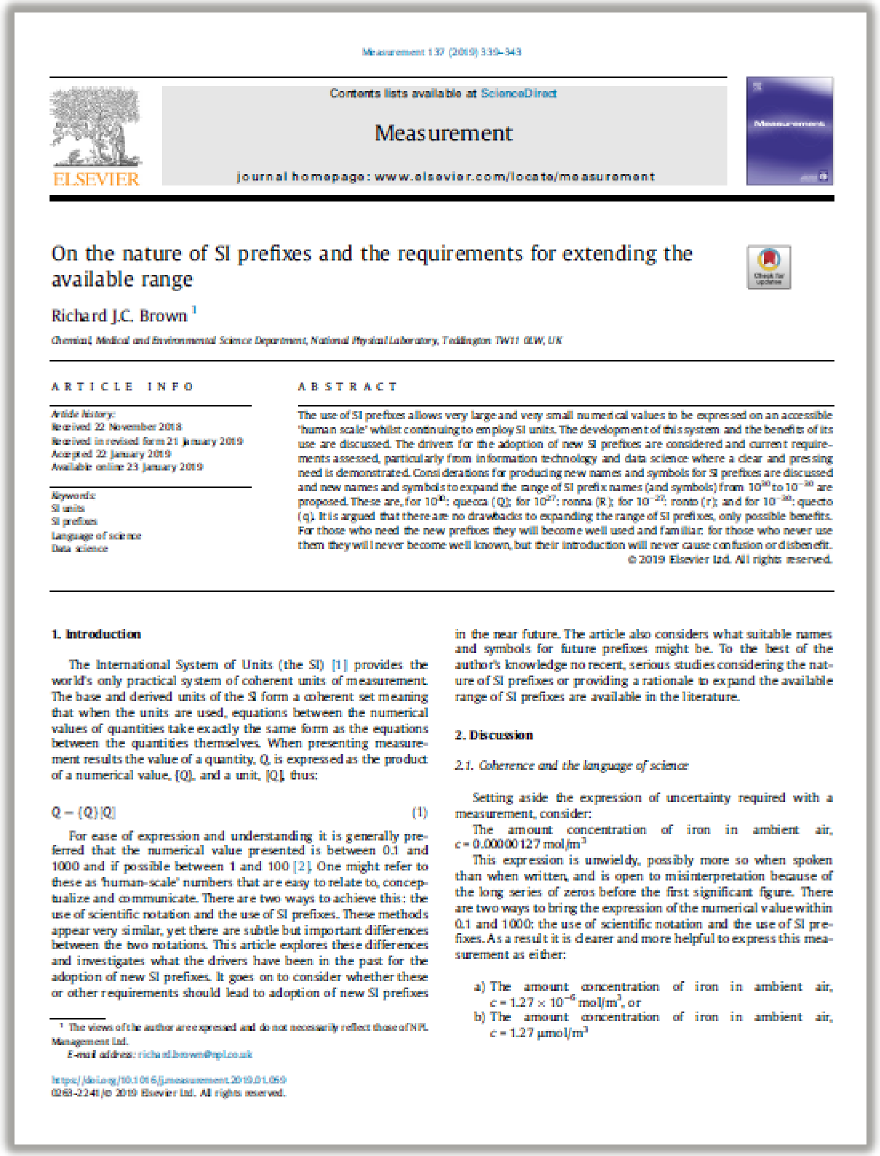
Etymology	Sub-multiple	Magnitude	Multiple	Etymology
Latin, decem = 10	deci	1	deca	Greek, deka = 10
Latin, centum = 100	centi	2	hecto	Greek, hekaton = 100
Latin, mille = 1000	milli	3	kilo	Greek, chilioi = 1000
Greek, micros = small	micro	6	mega	Greek, megas = large
Latin, nanus; Greek, nanos = dwarf	nano	9	giga	Greek, giga = giant
Italian, piccolissimo = very small	pico	12	tera	Greek, tera = monstrous
Danish, femten = 15	femto	15	peta	Greek, pente = 5
Danish, atten = 18	atto	18	exa	Greek, hex = 6
Latin, septem = 7	zepto	21	zetta	Latin, septem = 7
Latin, octo = 8	yocto	24	yotta	Latin, octo = 8

- Last expansion to the range was in 1991

RJC Brown, *Measurement*, 137 (2019) 339–343

Expanding the range: symbols and names

- r, q & b are the only letters not generally in use for other units or symbols
- Previous conventions suggest loosely basing names on Latin and Greek for 9 and 10
- The choice of names is not actually critical, although it seems so before it is made
- The important decision is whether an expansion to the system is required
- There are no negative implications of an optional usage addition to the SI, only benefits



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On the nature of SI prefixes and the requirements for extending the available range

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ABSTRACT

The use of SI prefixes allows very large and very small numerical values to be expressed on an accessible 'human scale' whilst continuing to employ SI units. The development of this system and the benefits of its use are discussed. The drivers for the adoption of new SI prefixes are considered and current requirements assessed, particularly from information technology and data science where a clear and pressing need is demonstrated. Considerations for producing new names and symbols for SI prefixes are discussed and new names and symbols to expand the range of SI prefix names (and symbols) from 10^{30} to 10^{-30} are proposed. These are, for 10^{30}: quecca (Q); for 10^{27}: ronna (R); for 10^{-27}: ronto (r); and for 10^{-30}: quecto (q). It is argued that there are no drawbacks to expanding the range of SI prefixes, only possible benefits. For those who need the new prefixes they will become well used and familiar: for those who never use them they will never become well known, but their introduction will never cause confusion or disbenefit.

1. Introduction

The International System of Units (the SI) [1] provides the world's only practical system of coherent units of measurement. The base and derived units of the SI form a coherent set meaning that when the units are used, equations between the numerical values of quantities take exactly the same form as the equations between the quantities themselves. When presenting measurement results the value of a quantity, Q, is expressed as the product of a numerical value, {Q}, and a unit, [Q], thus:

$$Q = \{Q\}[Q] \quad (1)$$

For ease of expression and understanding it is generally preferred that the numerical value presented is between 0.1 and 1000 and if possible between 1 and 100 [2]. One might refer to these as 'human-scale' numbers that are easy to relate to, conceptualize and communicate. There are two ways to achieve this: the use of scientific notation and the use of SI prefixes. These methods appear very similar, yet there are subtle but important differences between the two notations. This article explores these differences and investigates what the drivers have been in the past for the adoption of new SI prefixes. It goes on to consider whether these or other requirements should lead to adoption of new SI prefixes in the near future. The article also considers what suitable names and symbols for future prefixes might be. To the best of the author's knowledge no recent, serious studies considering the nature of SI prefixes or providing a rationale to expand the available range of SI prefixes are available in the literature.

2. Discussion

2.1. *Coherence and the language of science*

Setting aside the expression of uncertainty required with a measurement, consider:

The amount concentration of iron in ambient air, $c = 0.00000127$ mol/m^3

This expression is unwieldy, possibly more so when spoken than when written, and is open to misinterpretation because of the long series of zeros before the first significant figure. There are two ways to bring the expression of the numerical value within 0.1 and 1000: the use of scientific notation and the use of SI prefixes. As a result it is clearer and more helpful to express this measurement as either:

a) The amount concentration of iron in ambient air, $c = 1.27 \times 10^{-6}$ mol/m^3, or
b) The amount concentration of iron in ambient air, $c = 1.27$ μmol/m^3

[1] The views of the author are expressed and do not necessarily reflect those of NPL Management Ltd.
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Proposals for expanding the range

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Submultiple	Name	Symbol	Etymology
10^{-27}	ronto	r	Greek & Latin, derived from 'ennea' and 'novem', suggesting 9 (ninth power of 10^3)
10^{-30}	quecto	q	Latin, derived from 'decem', suggesting 10 (tenth power of 10^3)

Multiple	Name	Symbol	Etymology
10^{27}	ronna	R	Greek & Latin, derived from 'ennea' and 'novem', suggesting 9 (ninth power of 10^3)
10^{30}	quecca	Q	Latin, derived from 'decem', suggesting 10 (tenth power of 10^3)

- Further still? Bundecca (B) and bundecto (b) for 10^{33} and 10^{-33}

An alternative way forward?

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Suggestions for compound, or double, SI prefixes to extend the available range from 10^{48} to 10^{-48}.

Multiple	Prefix name	Prefix symbol
10^{48}	yottayotta	YY
10^{45}	zettayotta	ZY
10^{42}	exayotta	EY
10^{39}	petayotta	PY
10^{36}	terayotta	TY
10^{33}	gigayotta	GY
10^{30}	megayotta	MY
10^{27}	kiloyotta	kY
Submultiple	**Prefix name**	**Prefix symbol**
10^{-27}	milliyocto	my
10^{-30}	microyocto	µy
10^{-33}	nanoyocto	ny
10^{-36}	picoyocto	py
10^{-39}	femtoyocto	fy
10^{-42}	attoyocto	ay
10^{-45}	zeptoyocto	zy
10^{-48}	yoctoyocto	yy

- A time may come where even greater range is required
- Ruling out other character sets (machine readability)
- Only option is compound, or double, prefixes

RJC Brown, *Measurement*, 140 (2019) 237–239

Evolution of the SI – challenges of adoption

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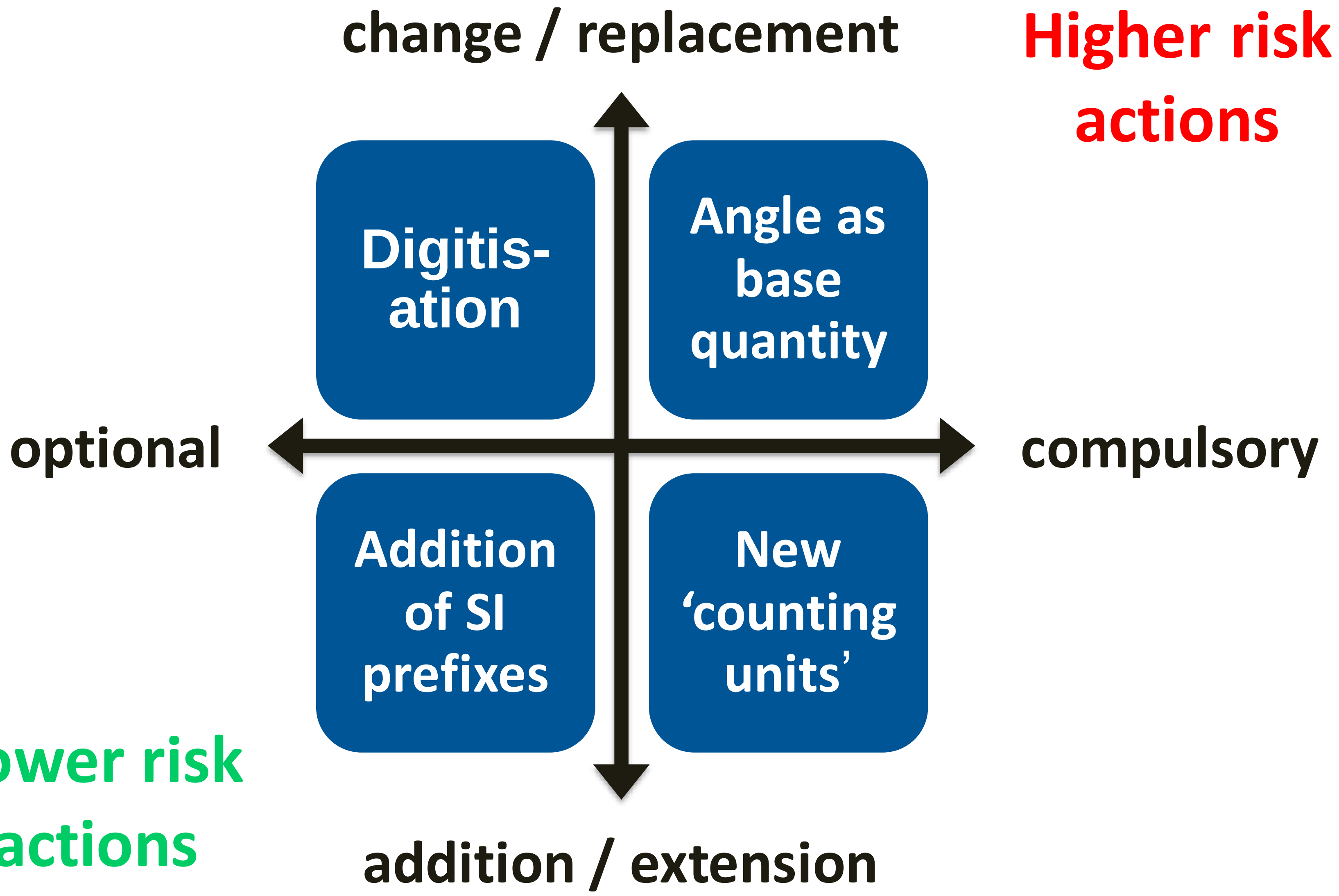

In conclusion – the questions posed