

MODULARITY

as One Principle in Sustainable Technology Design -
A Design Case Study on ICT



Ines Junge, PhD candidate, Dep. of Informatics, University of Oslo



OUTLINE

Responsibility for the futures that design materializes

A design case study on (modular) ICT

Nowadays insufficiencies and desirable, meaningful futures

Vision: Sustainable Technology and Interaction Design (STaID), Critical Design Practice

POLITICS BY OTHER MEANS

- Have to engage more with the politics of technology

“Design is politics by other means”

Randi Markussen, 1996

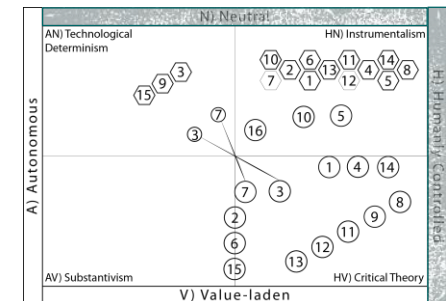
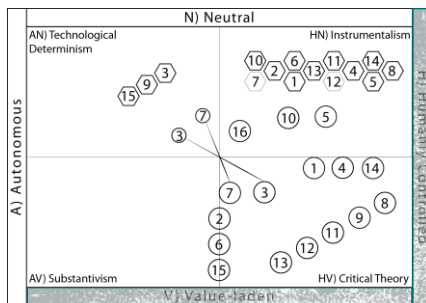
- As long as understanding of “technology as neutral” ...

- values invisible! -

- critical stances in the Norwegian media: continuation of the liberal idea of control over technology for more acceptable ends



lack of deeper engagement





OUTLINE

Responsibility for the futures that design materializes

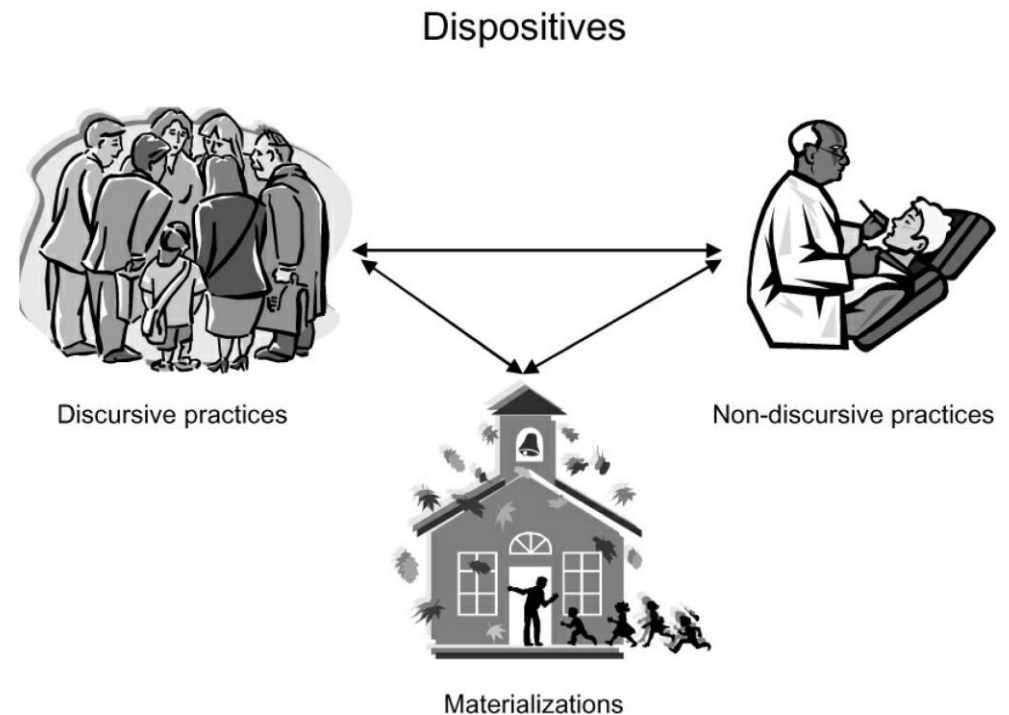
A design case study on (modular) ICT

Nowadays insufficiencies and desirable, meaningful futures

Vision: Sustainable Technology and Interaction Design (STaID), Critical Design Practice

DISPOSITIVES (JÄGER)

- Research into the **non-discursive practices** and underlying **established or emerging manifestations** = designed technology and its lifecycle
- Forthcoming publication(s) on modularity as a particular and 5 other sustainable design principles identified through a comprehensive design case review





OUTLINE

Responsibility for the futures that design materializes

A design case study on (modular) ICT

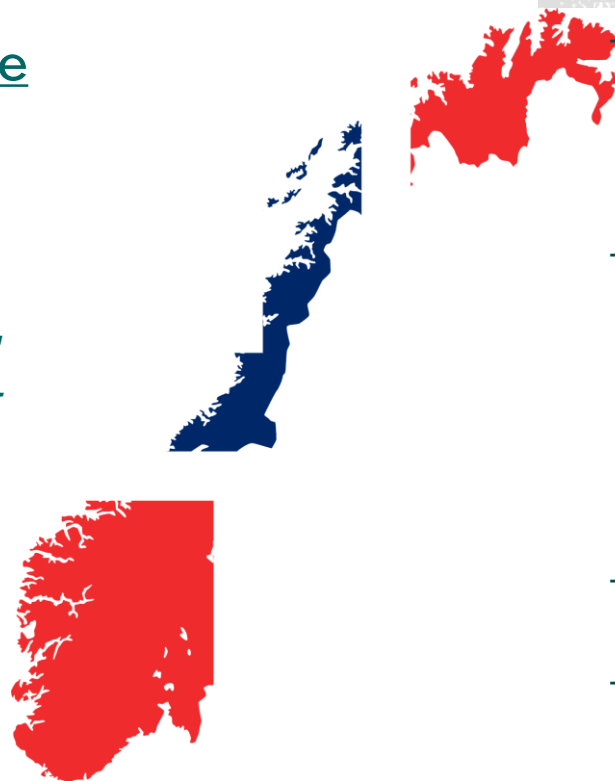
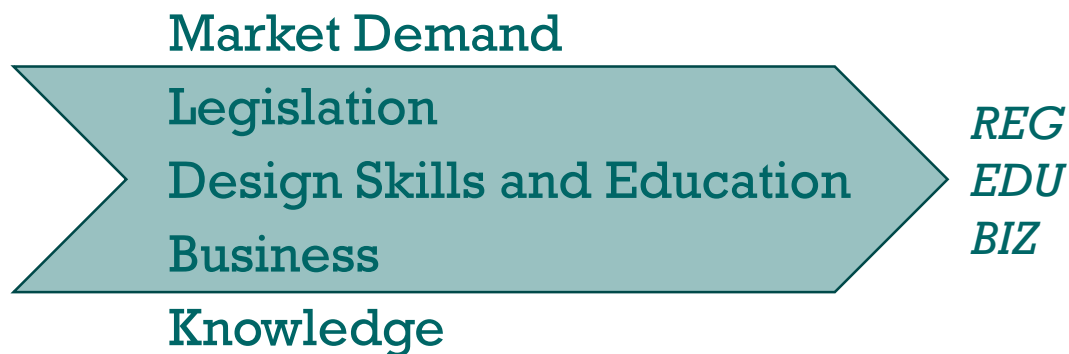
Nowadays inefficiencies and undesirable, meaningless futures

Vision: Sustainable Technology and Interactions Design (STaID): Critical Design Practice

▪ Vision: STaID

Sustainable **T**echnology and **I**nteraction **D**esign

Challenges to Increased Design for X (like Remanufacture, Recycling):



RESEARCH CONTEXT

Research cluster *Digital Sustainability* at Department of Informatics, UiO, Digitalization & Entrepreneurship section
<https://digent.blog/>

- *SMART* (Sustainable Market Actors for Responsible Trade) project led by Faculty of Law at UiO, : Dep. of Informatics with Ass. Prof. Maja van der Velden contributing with the case of the Life Cycle of the Mobile Phone;
<https://www.smart.uio.no/project>
- *Futuring Sustainable Nordic Business Models*
- PhD project “From Designed Obsolescence to Sustainable Technology Design”



RESPONSIBILITY

FOR FUTURES THAT DESIGN MATERIALIZES

- Transitional state
- Find new ways of designing, take responsibility

TRANSITION DESIGN FRAMEWORK

Four mutually reinforcing and co-evolving areas of knowledge, action and self-reflection

New ways of designing will help realize the vision but will also change/evolve it. As the vision evolves, new ways of designing will continue to be developed.

The transition to a sustainable society will require **new ways of designing** that are characterized by:

- Design for 'initial conditions',
- Placed-based, context-based design,
- Design for next level up or down in the system,
- Network & alliance building
- Transdisciplinary and co-design processes,
- Design that amplifies grassroots efforts,
- Beta, error-friendly approach to

New Ways of Designing

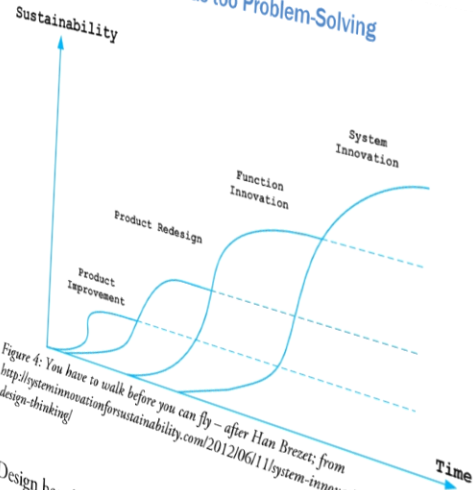
Visions for transition needed, based on life-styles that a globally connect information and upon community to the ecosystem

Design for Transitions - from and to what?

Cameron Tonkinwise
School of Design, CMU

As part of its attempt to resituate the practice of designing within a commitment to facilitating social change toward more sustainable futures, the School of Design at Carnegie Mellon University has started talking about 'Transition Design.' It is risky to invent yet another term which too easily looks like an appropriative branding exercise. But

4) Sustainable Design was too Problem-Solving



Design has always sought resource efficiency: the minimalist functionalism of modernism aimed to do more with less. Designers have been explicitly concerned about the ecological



Is the potential design space of (modular) built ICT and design concepts well populated?

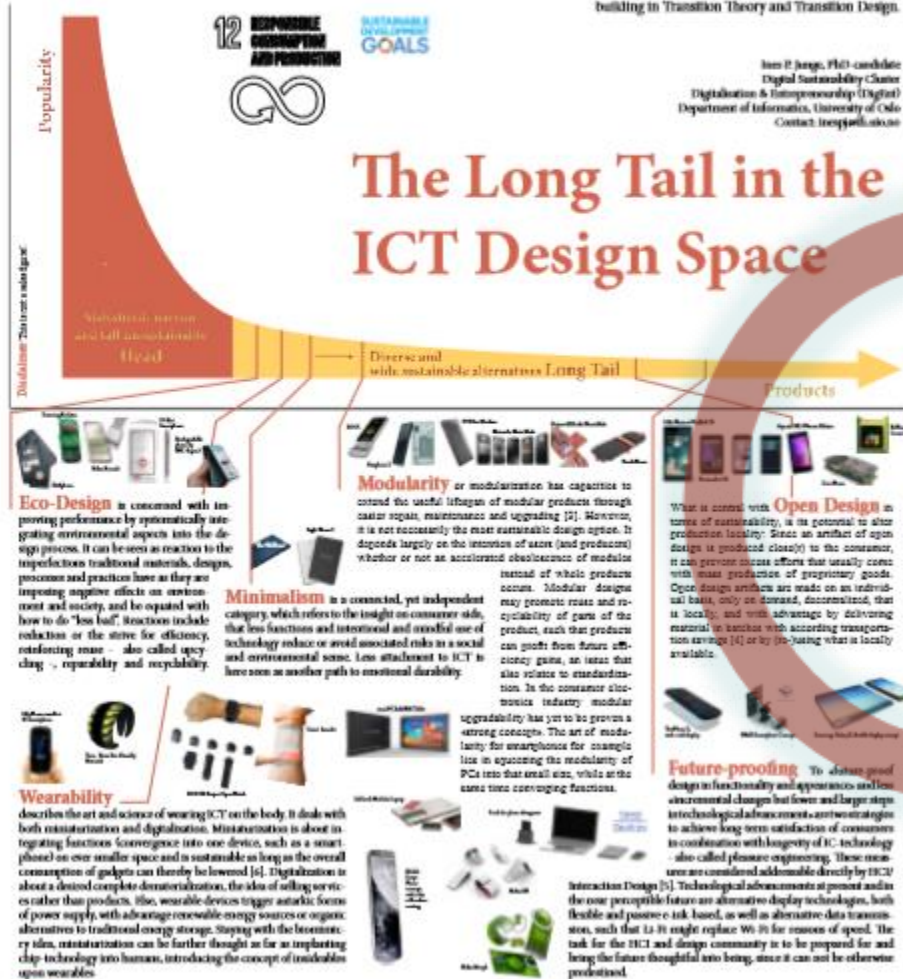
Paint a rich(!) picture

As a society pursuing United Nations' Sustainable Development Goals, such as *Responsible production and consumption*, we need to engage more with the politics of technology: how to limit its excesses and destructions. Our current lifestyles, value systems and the existing production and consumption patterns are manifestations of inherent unsustainability [1], the wicked problems we face when addressing excesses and destructions. Designing for a *Circular Economy* is one of the strategies in this politics of technology.

The focus of my research project is on how the performance of sociotechnical systems as a whole can become sustainable. Until now, rather sustainable user behaviour alone or eco-friendly technology have been contemplated. I am in particular interested in linking the one phase of information and communication technology (ICT) with its design. Since object-based designing is not an optimal way of addressing the wicked problem of sustainability, the narrow view of the term *product* is broadened to encompass product-service systems. The expanded idea of product then includes any form of designed outcome, physical or non-physical [1].

Below, the state of the art in (un)sustainable designed ICT is visualized through the *Long Tail* model [2], resulting from a review of a wide variety of design cases as well as academic literature. I identified *six sustainable design principles*. The analysis aims to contribute to theory building in *Transition Theory* and *Transition Design*.

Jan P. Jørgen, PhD candidate
Digital Sustainability Cluster
Digitization & Entrepreneurship (DigitE)
Department of Informatics, University of Oslo
Contact: hoep@iuh.uio.no



DESIGN CASE REVIEW

[1] P. M. Jørgen, "Product of the open design context" in *Handbook of Sustainable Product Design*, J. Chiarenza, Ed. London and New York, Routledge, 2017, pp. 544-558. [2] C. Anderson, "The Long Tail: Why the Future of Business is Selling Less of More," HarperCollins, 2006. [3] M. Jørgen, M. E. S. Børdum, and E. Christensen, "The role of modularity in sustainable design: A systems' view," *Journal of Cleaner Production*, vol. 132, pp. 189-199, Mar. 2017. [4] Børdum, "Tactics of obsolescence for the case of open product development," *International Journal of Sustainable Engineering*, vol. 10, no. 4, pp. 308-320, Dec. 2017. [5] J. P. Jørgen, "The Design of Information for the Transition of ICT: How Design Approaches from the Field of Sustainable ICT can Contribute to Sustainability of ICT," in *ICT Innovation for Sustainability*, ed. M. A. S. Khan and R. Adelman, 10th. Cham, Springer International Publishing, 2017, pp. 357-368. [6] J. P. Jørgen and M. Jørgen, "Sustainable design product design in Smart Electrical and Electronic Equipment (SEEE) Handbook," *Medford Publishing*, 2017, pp. 40-44.



FINDING DESIGN CASES



What types of (modular) built ICT and design concepts exist?

ANALYSIS

- Snowball multimedia search
- Smartphone disassembly as course project work
- Literature review



modular smartphone

YouTube

Startside
På vei opp
Abonnementer
Bibliotek
Logg
Se senere
The Story Behind...
Likte videoer

ABONNEMENTER

Modular Smartphones: Explained!
Marques Brownlee • Sett 1,9 mill. ganger • for 3 år siden
The modular phone dream has evolved... Project Ara Update: <https://youtu.be/aWW5mQadZAY> Video Gear I use: ...
4K

Google cancels Project Ara Modular Smartphone. Nexpaq is trying to keep alive the Modular Tech.
Rajamanickam Antonimuthu • Sett 10k ganger • for 3 år siden
Google is cancelling its Modular smartphone project named as Project Ara. Project Ara was announced by Motorola around 3 ...
Teksting

The Customizable Android Phone You've Never Heard Of...
Unbox Therapy • Sett 1,4 mill. ganger • for 2 år siden
This tiny laptop raised \$3.5 Million Dollars... https://youtu.be/KFgbF-oR18c?list=PL7u4lWXQ3wfl_7PgX0C-VTiwLeu0S4v34 NuAns ...
4K

Google's Project Ara: Reinventing the smartphone with building blocks
The Verge • Sett 2,6 mill. ganger • for 5 år siden

MODULAR MANIA

Your No. 1 site for Project Ara news. The definitive guide to Modular Tech.

HOME MODULAR WORLD PROJECT ARA OTHER DEVICES

Air Quality Module
Extra Battery Module
Adventure Module
The Core
Heart Rate Module
Haptic Module





What's hot what's not: the social construction of product obsolescence and its relevance for strategies to increase functionality

Jaeger-Erben M. (a) and Proske M. (b)

a) Center for Technology and Society, TU Berlin, Germany
b) Environmental and Reliability Engineering, TU Berlin, Germany

Keywords

Obsolescence
Material culture
Public discourse
Design scenarios

Abstract

"Is it ethical to deny our products what we wish ourselves: A long life?" is one of the major questions the German documentary "Do mixers go to heaven?"¹ from 2016 asks. The star of this documentary is the RG28, a mixer once produced by a former GDR electronic factory, which became famous for its robustness and longevity. The factory didn't survive the Wende in 1989 but the mixers are still available on internet platforms and un junk-shops, some spare parts for the easy-to-repair mixer are still produced. Although it appears as a somewhat pathetic humanization of objects at a first glimpse, it makes an important point: Product lifetimes are more than a property of things made, used and disposed by humans can also be in a product's design. The lifetimes of objects, a rationally calculated number that is inscribed as an important characteristic of a given material culture and is rooted in current human-object relationships. This paper discusses both aspects – material culture and human-object relationship – with relation to the highly-contested term obsolescence². Starting with the observation that obsolescence received most public attention in times of crisis, we report results of an analysis of current media discourses. Subsequently we present an alternative praxeological approach to obsolescence than the usual rational choice related explanations. The closing section discusses opportunities to increase a product's "affordance" to be kept alive longer.

Obsolescence as a contested issue

Latest since the term "throw-away society" has been taken up in the second half of the 20th century (Packard 1960) the question of how long consumer goods last and how much waste is produced has been the issue of much debate, particularly driven by an increasing number of consumption- and growth-critics (O'Brien, Barnett 2013). According to Weber (2014) the public interest in long-lived products started even earlier and has risen in three waves since the industrial revolution, indicating critical turning points in the history of mass consumption society. First occurring in the interwar period in the USA, obsolescence became an issue again around the first environmental crisis in the 1970s and is coming up another time around 2000 when issues such as toxicity, resource scarcity and digitalisation gained more and more public interest. Particularly since 2011 obsolescence enjoys constant media attention, at least in Germany.

Results of a media analysis

Any sensible analysis of social phenomena particularly socially contested ones like obsolescence need to pay attention to how it is perceived as well as constructed in public discourses. As indicated above obsolescence is not a neutral description for a specific "natural" state of an object. It refers to a process where something is actively discarded, or seen as antiquated and outmoded. Even if an object like an electric device seems to be terminally broken it persists, and might still be useful, and be it only repaired, upcycled or re-used or not is socially negotiated. One approach to the communicative construction of obsolescence it to investigate media discourses.

A comprehensive search of online archives of German national and regional newspapers revealed over 300 newspaper and online articles that included the "obsolescence" or "product lifetimes" from the 1990s years. The analysis was guided by the following

RELATED RESEARCH

- Social construction of product obsolescence study from PLATE2017, Young researcher group "Obsolescence as a challenge for sustainability"



¹ German: "Kommen Rührgeräte in den Himmel", see also www.rg28.de
² The paper presents some initial results and concepts of a 5-year transdisciplinary sustainable consumption. It is financed by the German Ministry for Education and Research (BMBWF) (Baudrillard, Turner 2007)
³ See also Baudrillard's notion of the aesthetic transfiguration of matter



A BIT OF THE BACKGROUND...

Questioning the pace of ICT consumption

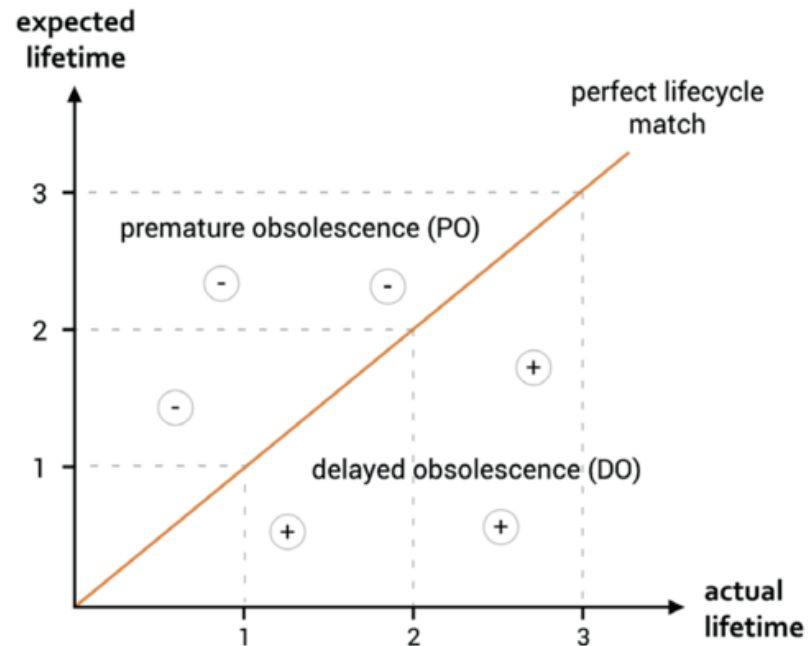
FAST TECH <> SLOW TECH

- The smartphone – replaced on average every 18-24 months



https://en.wikipedia.org/wiki/IPhone_X

- Fast consumption
- Fast pace of technological development
- Premature
obsolescence



[13] J. Longmuss and E. Poppe, 'Planned obsolescence: who are those planners?', in *Product Lifetimes And The Environment 2017 - Conference Proceedings*, Delft, 2017, pp. 217-221.



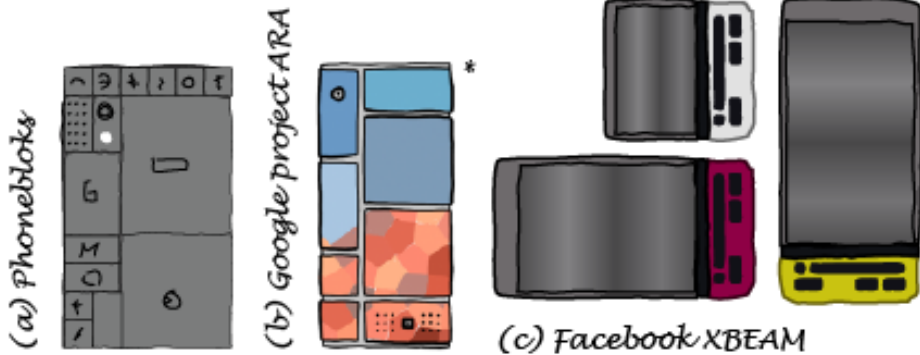


FINDINGS

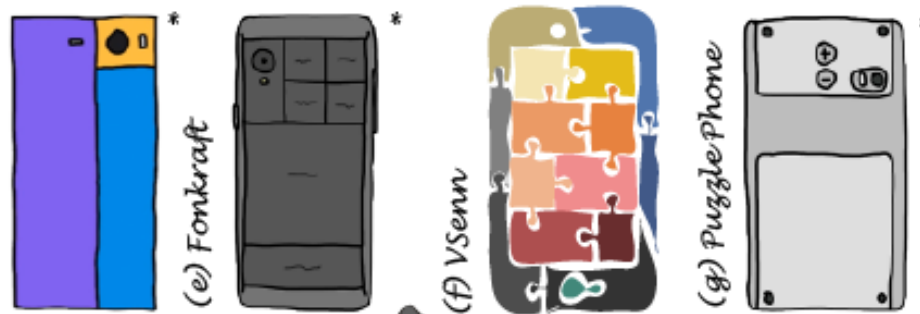
Features of Modularity

15+ CONCEPTS IN RENDERINGS

i) Definite modular phone concepts:



(d) Xiaomi Magic Cube



ii) Marketed (semi-)modular phones or components:



iii) Related modular ICT in R&D or early market.



FEATURES OF MODULARITY

- Define modular

Main units of ICT

A base unit

upgrade in terms of

a new screen,

CPU,

GPU,

camera,

battery and

RAM

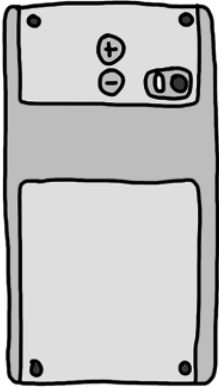


FEATURES OF MODULARITY **MODULE**

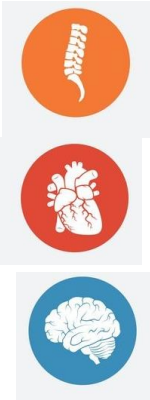
Sub assembly
Part
Component



(o) Fairphone 2



(g) Puzzle Phone



Spine (display, speakers, microphones)

Heart (battery) and

Brain (main electronics)



Transceiver (or core) unit

Display unit & the receiver module and

Rear camera module & speaker unit



FEATURES OF MODULARITY **EXTEND LIFESPAN**

- Easier repair, maintenance and upgrading



(o) Fairphone 2

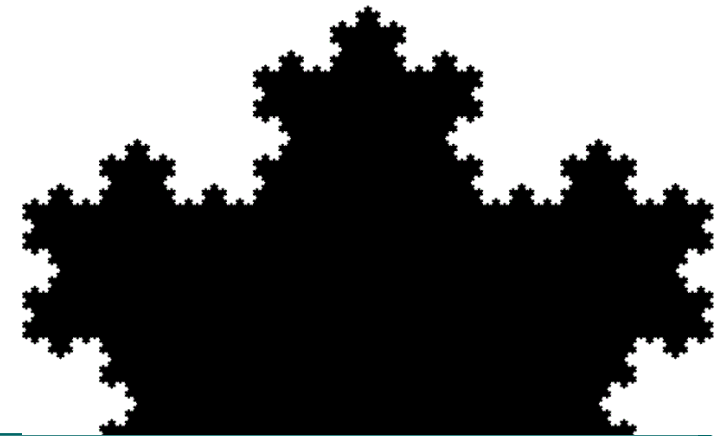


(i) Microsoft Surface Phone Andromeda



Independence of components and/or their lifecycle processes

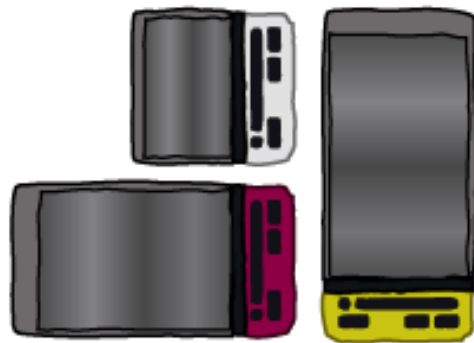
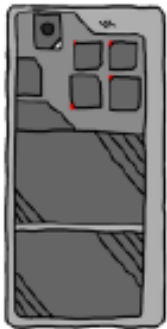
Self-similarity



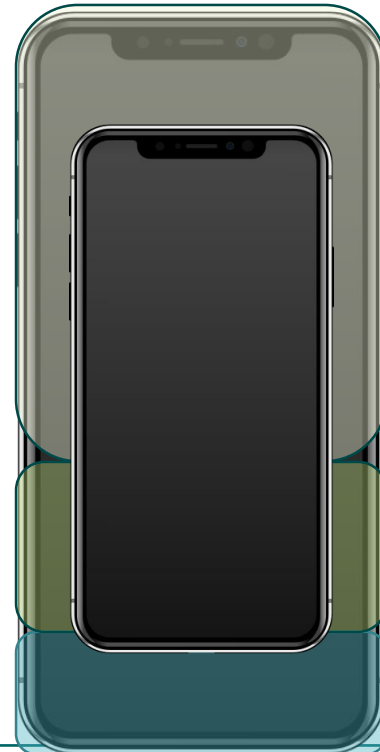
FEATURES OF MODULARITY **MODULARLY UPGRADEABLE**

- Easy(?) (hardware) upgrading

(h) ZTE Eco Moebius



(c) Facebook XBEAM



Independence of components and/or their lifecycle processes

Self-similarity

Display «growth»

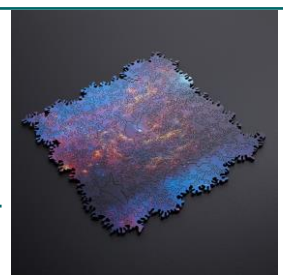
CPU «growth»

Battery «growth»



<https://twistedgifter.com/2018/11/infinity-earth-puzzle-by-nervous-system/>

https://www.touchofmodern.com/sales/nervous-system-45a0b5e2-7f47-44dc-ad9b-424f27d55b01/infinite-galaxy-puzzle?share_invite_token=RY07OOEE&open=1

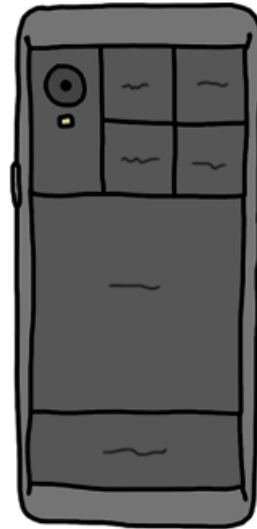


FEATURES OF MODULARITY MOUNTING

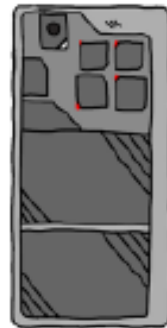
- Mounting mechanism

Special push button and hidden slider- mechanism

(e) Fonkraft



(h) ZTE Eco Moebius



(k) LG G5

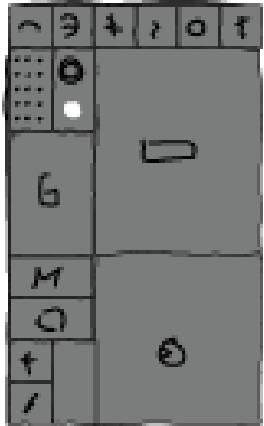
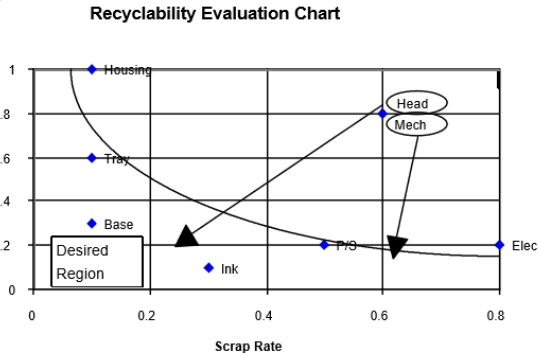
Five-Year Phone (Designer James Barber), 2009/10

It uses just one screw to open the device for recycling...



FEATURES OF MODULARITY MODULARIZATION

- modularly upgradable architectures: from industrial markets to consumer electronics



(a) Phonebloks

Figure 19.6 Recyclability Evaluation Chart

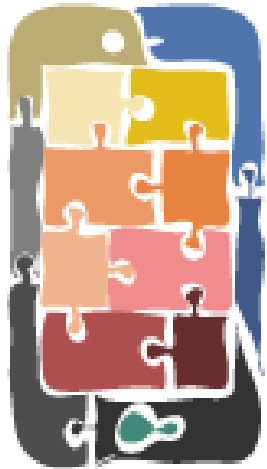
(Ishii, 1998)

<https://gadgetsextremes.wordpress.com/2012/09/20/future-technologyfuture-designindustrial-designgadgetsand-technology-news/>



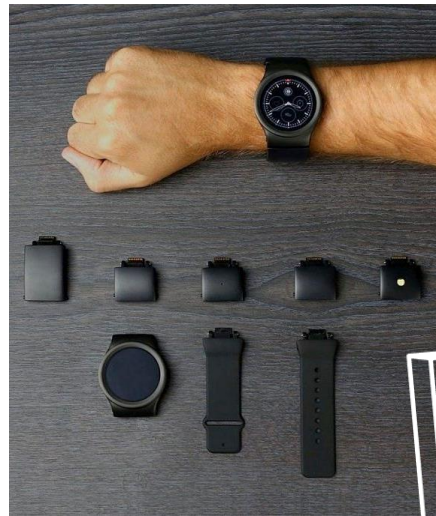
FEATURES OF MODULARITY **SOFT MATTER**

- OS a module? Modular OS?



Swap OSs,
4 years warranty

(f) VSenn



BLOCKS Project OpenWatch

the idea of a modular Android-software open to system developers of wearables

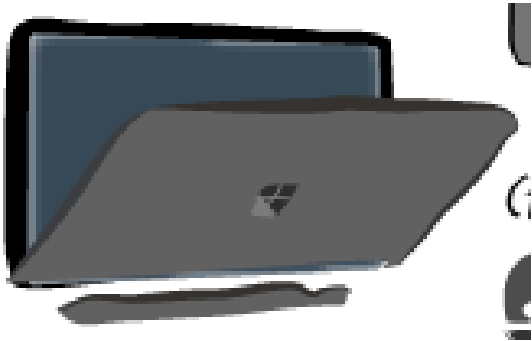
AsteroidOS 1.0 released: Open source smartwatch operating system (for Wear OS devices)

05/16/2018 at 11:41 AM by [Brad Linder](#) [Leave a Comment](#)
The smartwatch space has changed a lot in recent years. Pebble is dead. Fitbit makes smartwatches now (after acquiring Pebble's assets). Google's Android Wear is now called Wear OS since it supports iPhones as well as Android. And Apple and Samsung continue to dominate.
I guess not everything has changed.
But through it all, a group of developers have been [working on an open source alternative called AsteroidOS](#). Now the team has released the first stable version: meet [AsteroidOS 1.0](#).



FEATURES OF MODULARITY DEMANDINGNESS

- more material in the first place (demandingness)

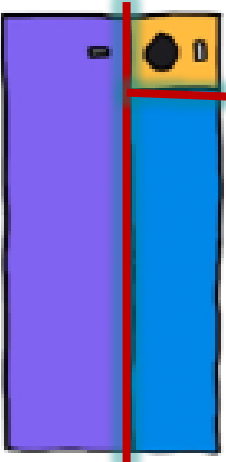


(i) Microsoft Surface Phone Andromeda



(b) Google project ARA

(d) Xiaomi Magic Cube



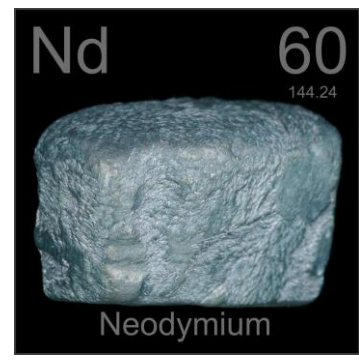
FEATURES OF MODULARITY **REBOUND**

- increased consumption of critical or scarce raw materials

One iPhone requires 46 elements



Strong magnetic surfaces, much more neodymium necessary



FEATURES OF MODULARITY **DISADVANTAGES**

- Rebound – greatest environmental impact

Originally: easier repair, maintenance and upgrading ???

Disadvantages

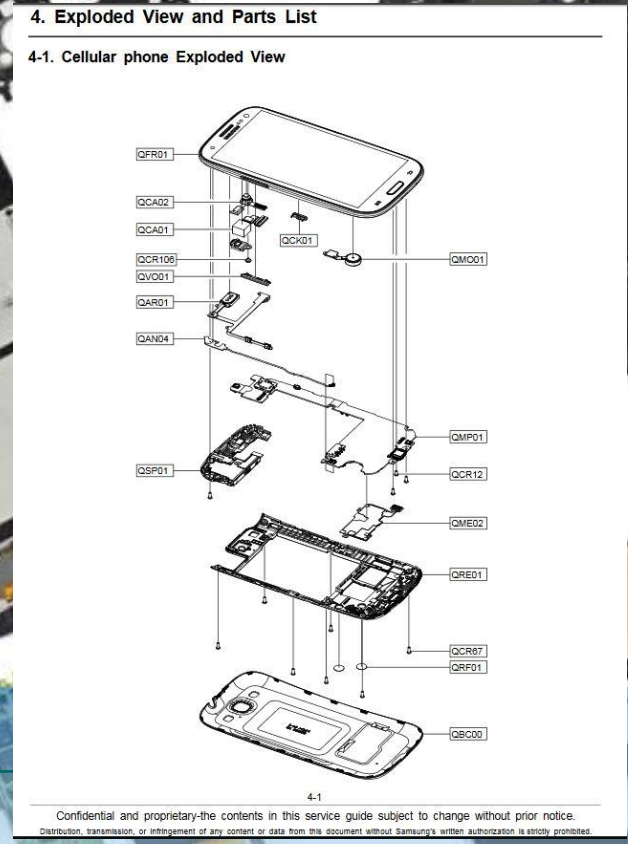
- Rebound effects
- Redundant structures, overdesigned products with sacrificed performance
- Perceived less durable
- Difficult to use and onerous to maintain
- Less reliable and safe



FEATURES OF MODULARITY **EVERYTHING MODULAR**

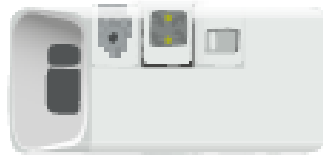
©MobilePhone-Spares.com

How I Made My Own iPhone - in China
<https://www.youtube.com/watch?v=leFuF-zoVzA>



FEATURES OF MODULARITY MODULARITY LEVELS

(l) Moto Z Moto-Mods



(m) Moduware modular smartphone cases



(j) Modu/Modu T

HISTORY

The Modu Mobile is the world's first modular phone ! It was created in 2009 by an Israeli company founded by Dov Moran.



FEATURES OF MODULARITY PLATFORM MODULARITY

upcycling.io

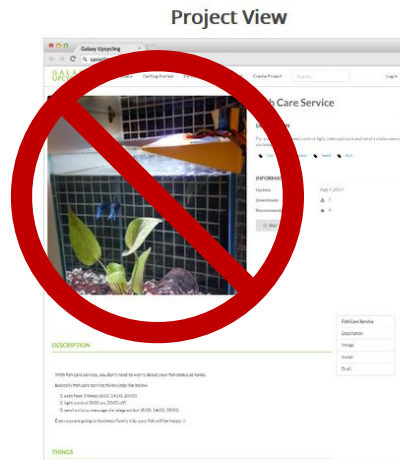
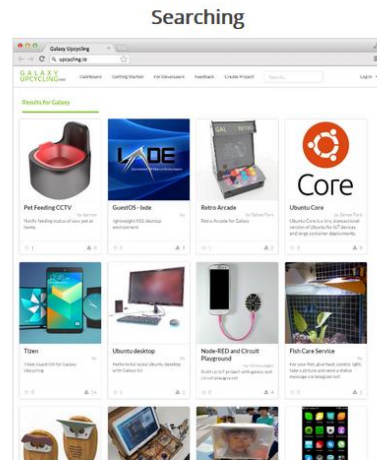
WEB community

where sharing and connecting with the creative reuse of Galaxy mobile devices.

Advanced Removable Modules technology

(re)configurability important for to build a “shared product platform”

not whole devices reused (“downcycled”)

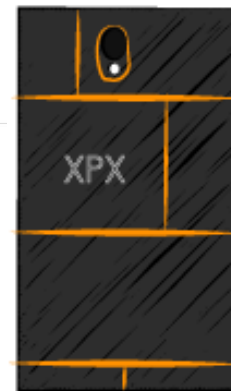


Upcycling your Galaxy

Experience Galaxy Upcycling first at SDC 2017!

We will soon open beta service to users.

(a) ML Blocks
 (æ) Samsung
 (o) B-Squares
 (aa) cellBot.



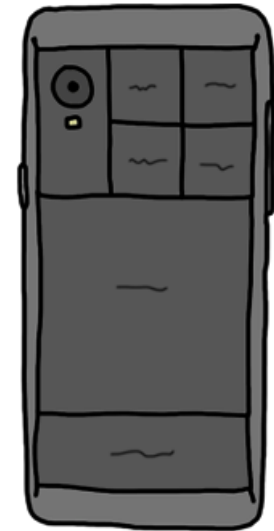
(t) XPX Life 7 tablet (y) RePhone open source and modular phone kit,



FEATURES OF MODULARITY VALUE PRESERVATION



online shop
for new and
used modules,
third party
manufactured



(e) Fonkraft





CONCLUSION

Important principle – fight rebound – link reg-edu-biz ecologies -
fundamental creativity-based research in academic context



FUTURE RESEARCH

Critical (speculative) Design, RtD, Transition Design, Proto-practices, Slow Tech

CRITICAL (SPECULATIVE) DESIGN, R&D, TRANSITION DESIGN, PROTO-PRACTICES, SLOW TECH

Proposal of proto-practical, speculative design scenarios

Forthcoming publication(s) on Speculative design scenario/proto-practice of “borrowed for use” mobile phone/ICT

Journal/Special issue publication about the complete ICT design space study (wide, not in-depth as about modularity)

Workshop on Futuring STaID

U10 : Department of Informatics
University of Oulu

Research approach & theoretical background

As a society pursuing United Nations' Sustainable Development Goals, such as Responsible production and consumption, we need to engage more with the politics of technology: how to limit its excesses and destructions. Our current lifestyles, value systems and the existing production and consumption patterns are manifestations of inherent unsustainability [1], the wicked problems we face when addressing excesses and destructions. Designing for a Circular Economy is one of the strategies in this politics of technology.

The focus of my research project is on how the performance of sociotechnical systems as a whole can become sustainable. Until now, rather sustainable user behaviour alone or eco-friendly technology have been contemplated. I am in particular interested in linking the use-phase of information and communication technology (ICT) with its design. Since object-based designing is not an optimal way of addressing the wicked problem of sustainability, the narrow view of the term product is broadened to encompass product-service systems. The expanded idea of product then includes any form of designed outcome, physical or non-physical [1].

Below, the state-of-the-art in (un)sustainable designed ICT is visualized through the Long Tail model [2], resulting from a review of a wide variety of design cases as well as academic literature. I identified six sustainable design principles. The analysis aims to contribute to theory building in Transition Theory and Transition Design.

Ilona P. Junge, PhD-candidate
Digital Sustainability Cluster
Digitalisation & Interoperability (Digital)
Department of Informatics, University of Oulu
Contact: ilonaj@oulu.fi

The Long Tail in the ICT Design Space

Eco-Design is concerned with improving performance by systematically integrating environmental aspects into the design process. It can be seen as a reaction to the respective traditional materials, design processes and practices here as they are imposing negative effects on environment and security, and be equated with how to do “low low”. Decisions include reduction or the strive for efficiency, redefining mass – also called up-cycling – reparability and recyclability.

Modularity or modularisation has capacities to extend the useful lifespan of modular products through easier repair, maintenance and it is not necessarily the most effective strategy on the second whether or not as acceleration.

Minimalism is a contextual, yet independent category, which refers to the insight on consumer side, that few functions and intentional and careful use of technology reduce or avoid associated risks as a social and environmental sense. Low attachment to ICT is here seen as another path to emotional durability.

Wearability describes the art and science of wearing ICT on the body. It deals with both materialisation and digitalisation. Materialisation is about integrating functions/ functionalities into one device, such as a smart phone, on one smaller space and sustainable as long as the overall consumption of gadgets can thereby be lowered [4]. Digitalisation is about a desired complete dematerialisation, the idea of selling services rather than products. Also, wearable devices trigger markets: Science of power supply, with alternative renewable energy sources or organic alternatives to traditional energy storage. Staying with the biometric, try idea, materialisation can be further thought as for an implanting chip-technology into humans, introducing the concept of (invisible) organic wearables.

Future-proofing To obtain good design in flexibility and openness and less conventional changes but lower and longer steps into technological advances present awareness design to combine long-term satisfaction of consumers to combine long-term longevity of technology also called lifespan engineering. These measures are considered addressable directly by ICT/Interaction Design [5]. Technological advancements at present and in the near perspective future are alternative display technologies, both flexible and pressure-ink based, as well as alternative data transmission, such as Li-Fi might replace Wi-Fi for reasons of speed. The task for the ICT and design community is to be prepared for and bring the future thoughtful into being, since it can not be otherwise predicted.

References
[1] M. J. Heulemans, “Product of the technology center”, in *Handbook of Sustainable Product Design*, C. Chapman, Ed., London and New York, Routledge, 2013, pp. 244–250.
[2] C. Anderson, “The Long Tail: Why the Future of Business Is Distributed”, New York, Simon & Schuster, 2006.
[3] M. J. Heulemans, “The Long Tail: Why the Future of Business Is Distributed”, in *Handbook of Sustainable Product Design*, C. Chapman, Ed., London and New York, Routledge, 2013, pp. 244–250.
[4] M. J. Heulemans, “The Long Tail: Why the Future of Business Is Distributed”, in *Handbook of Sustainable Product Design*, C. Chapman, Ed., London and New York, Routledge, 2013, pp. 244–250.
[5] M. J. Heulemans, “The Long Tail: Why the Future of Business Is Distributed”, in *Handbook of Sustainable Product Design*, C. Chapman, Ed., London and New York, Routledge, 2013, pp. 244–250.

DESIGN CASE REVIEW

REFERENCES

- Agrawal, V. V., Atasu, A., & Ülkü, S. (2016). Modular Upgradability in Consumer Electronics: Economic and Environmental Implications. *Journal of Industrial Ecology*, 20(5), 1018–1024. <https://doi.org/10.1111/jiec.12360>
- Dieter Rams 10 Principles of “Good Design” | ArchDaily. (n.d.). Retrieved November 7, 2018, from <https://www.archdaily.com/198583/dieter-rams-10-principles-of-%25e2%2580%259cgood-design%25e2%2580%259d/>
- Farman, J. (2017). Repair and Software: Updates, Obsolescence, and Mobile Culture’s Operating Systems. *Continent*, (6.1), 20–24.
- Gershenson, J. K., Prasad, G. J., & Allamneni, S. (1999). Modular Product Design : A Life-Cycle View. *J. Integr. Des. Process Sci.*, 3(4), 13–26.
- Good Design / Inkahoots. (n.d.). Retrieved November 7, 2018, from https://inkahoots.com.au/ideas/i_66-good-design
- Hankammer, S., Jiang, R., Kleer, R., & Schymanietz, M. (2016). From Phonebloks to Google Project Ara. A Case Study of the Application of Sustainable Mass Customization. *Procedia CIRP*, 51, 72–78. <https://doi.org/10.1016/j.procir.2016.04.157>
- Ishii, K. (1998). Modularity: a key concept in product life-cycle engineering. In A. Molina & A. Kusiak (Eds.), *Handbook of life cycle enterprise*. Dordrecht: Kluwer Academic.
- Jäger, S. (2001). Discourse and knowledge: theoretical and methodological aspects of a critical discourse and dispositive analysis. In R. Wodak & M. Meyer (Eds.), *Methods of critical discourse analysis. Introducing Qualitative Methods* (1st ed., pp. 32–62). <https://doi.org/10.4135/9780857028020>
- Junge, I., & van der Velden, M. (2018). Obsolescence in Information and Communication Technology: A Critical Discourse Analysis. In D. Kreps, C. Ess, L. Leenen, & K. Kimppa (Eds.), *This Changes Everything – ICT and Climate Change: What Can We Do?* (pp. 188–201). Springer International Publishing.
- Malpass, M. (2017). *Critical design in context: history, theory, and practices*. London: Bloomsbury Academic.
- Möller, M., Diesner, M., Manhart, A., Küppers, P., Spieth-Achnich, A., & Pistner, C. (2014). Investigation of the impacts of selected nanotechnology products with view to their demand for raw materials and energy. *IOP Conference Series: Materials Science and Engineering*, 64, 012028. <https://doi.org/10.1088/1757-899X/64/1/012028>
- Rowland, C., Goodman, E., Charlier, M., Light, A., & Lui, A. (2015). *Designing Connected Products: UX for the Consumer Internet of Things*. O’Reilly Media, Inc.
- Schischke, K., Proske, M., Nissen, N. F., & Lang, K. D. (2016). Modular products: Smartphone design from a circular economy perspective. 2016 *Electronics Goes Green 2016+ (EGG)*, 1–8. <https://doi.org/10.1109/EGG.2016.7829810>
- Sonego, M., Echeveste, M. E. S., & Galvan Debarba, H. (2018). The role of modularity in sustainable design: A systematic review. *Journal of Cleaner Production*, 176, 196–209. <https://doi.org/10.1016/j.jclepro.2017.12.106>
- Tonkinwise, C. (2015). Design for Transitions – from and to what? *Design Philosophy Papers*, 13(1), 85–92. <https://doi.org/10.1080/14487136.2015.1085686>
- Upcycling: Teaching Old Smartphones New Tricks. (n.d.). Retrieved December 21, 2018, from <https://news.samsung.com/global/upcycling-teaching-old-smartphones-new-tricks>

