ELISA
Enabling Linux in
Safety Applications

WORKSHOP

NASA Goddard

Building an OSS Ecosystem for Space

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Who am I?

- Principal Software Engineer at Sony Electronics
  - At Sony for over 20 years, including time as Sony's Linux kernel maintainer
- Member of Linux Foundation Board of Directors
- Creator and organizer of Embedded Linux Conference (started in 2005)
- Former CTO of Lineo, an early embedded Linux company
- Working with Linux and OSS for over 30 years
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Photo by Jake Edge, LWN.ne

Lessons from OSS in space

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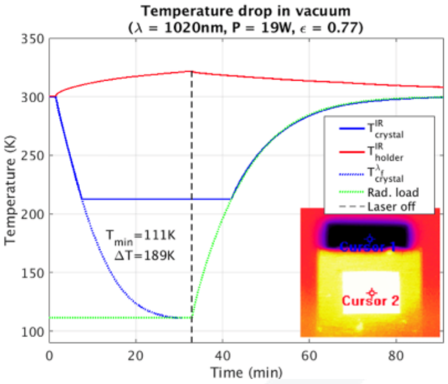
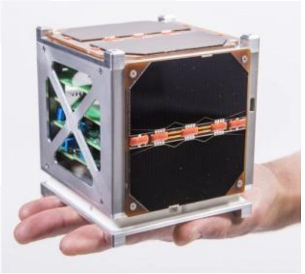
SPACE IS HARD

Lessons from OSS in space

- So many constraints
  - Hardware issues: Extreme Temperature variations, Radiation, Pressure (Vacuum), Vibration
  - Limits on: Power, Physical size, Weight (every gram counts)
  - Requirements: Performance, Fault tolerance, Realtime, Power management
- Extremely high cost per mission
  - Low units: often 1 unit
  - High cost of design, testing, hardware, launch, operations
  - Failure is "not an option" (but a high percentage of cubesats fail)
    - This is why craft often last longer than intended
      - Over-engineered, for robustness





Space missions use LOTS of custom hardware

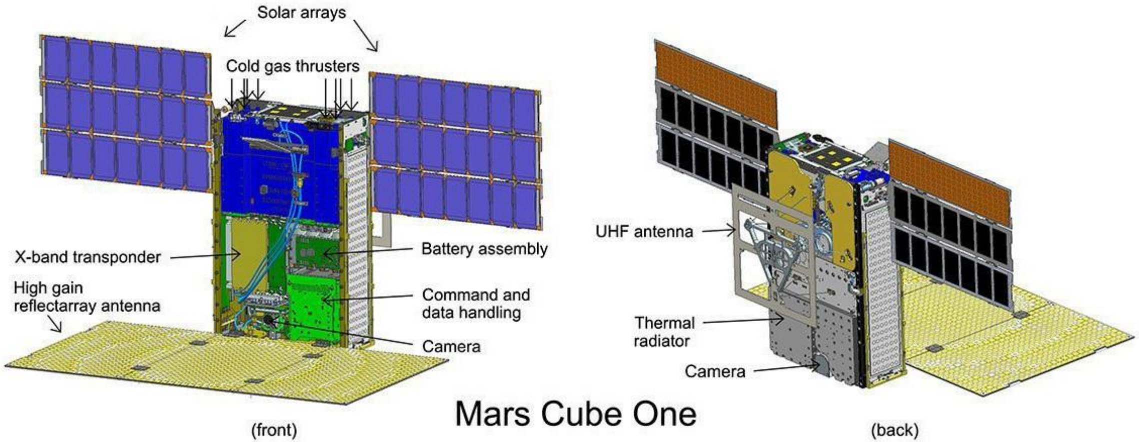
- Focus of mission is specialized science or commercial tasks ('the payload')

  Almost every payload has unique, bespoke hardware

- Even base systems use novel hardware

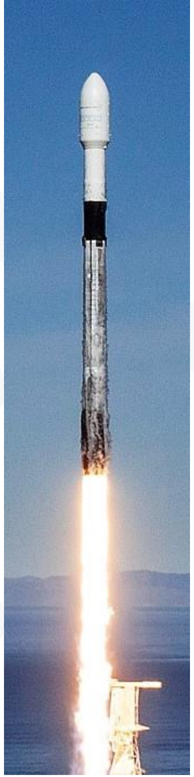
  Thrusters, batteries, stabilizers, power units, sensors, reaction control, etc.

  Every mission seems to want to try something new



Exceptions: COTS hardware and reuse

- SpaceX rockets
  - triple-redundant pairs of COTS x86 processors
- Starlink and Planet satellite constellations
  - x86 processors, not rad-hardened
- Mars Ingenuity helicopter and Perseverance rover and backshell
  - Used some off-the-shelf parts:
    - Qualcomm processor, COTS sensors, USB busses and hubs



Space is embedded in the extreme

- Space sector is "embedded on steroids"
- Emblematic of issues that show up in embedded systems
  - Constraints (power, performance, real-time)
  - Custom-purpose devices and software
  - Hard to find people to collaborate with (for some parts of the stack)

Open Source means collaboration

What defines Open Source?

- Open Source is defined by the ability to use, but also *contribute* to an open code base

- Two effects are key to Open Source

Many Minds Effect

Problem Solver Effect

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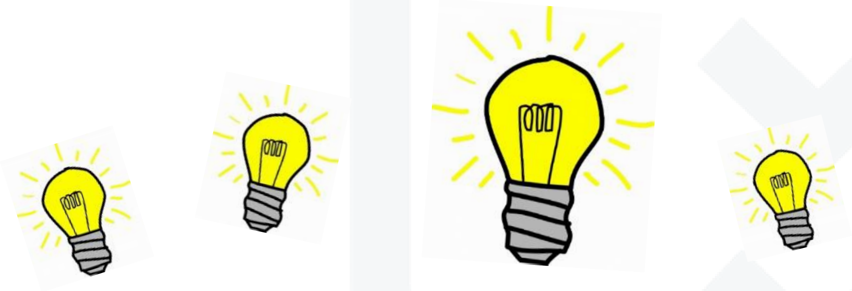
The "Many Minds" Effect

Many Minds Effect

- Variety of experiences and skills results in better ideas

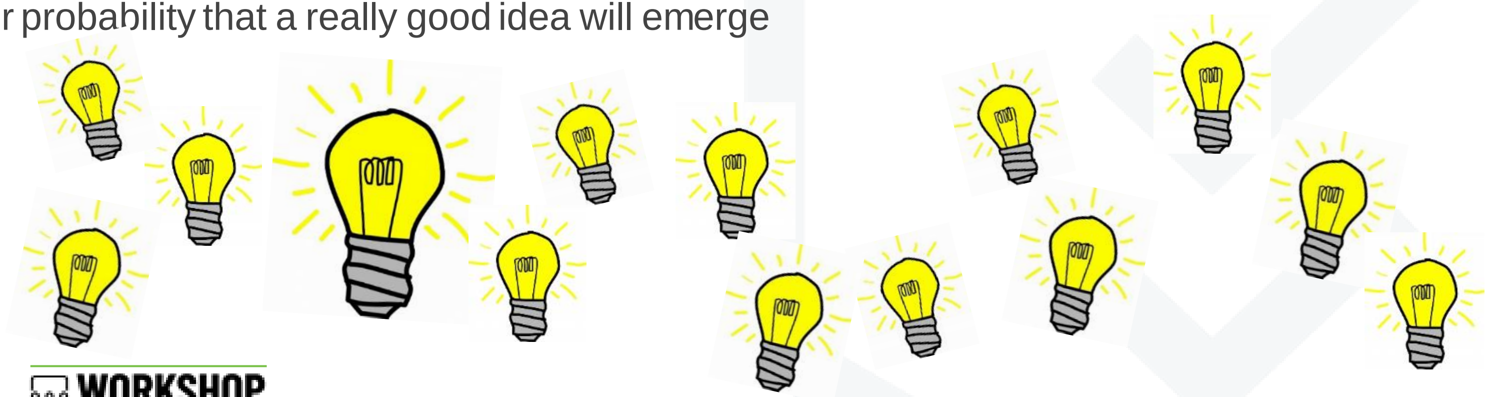
- Open Source strives for a meritocracy, where the best ideas win
- Light bulb analogy:
  - Ideas for a project are like light bulbs...



Open Source effect

- Small community = small number of ideas

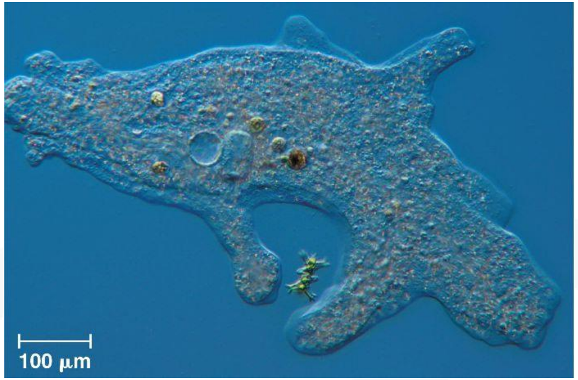
- Bigger community = more ideas
  - Better probability that a really good idea will emerge



Many Minds Effect for bugs

- "Given enough eyeballs, all bugs are shallow"

Problem Solver effect



- Problems are solved as they are encountered

- Software must come “in contact” with a problem space to advance
- Most software is written to solve a specific problem
  - It does not grow outside of it’s original niche
- Openness of OSS allows it to encounter other problem spaces
  - It can adapt and grow in ways different from the original use case

- The OSS virtuous circle: The more problems a piece of software solves, the more users it attracts, and the bigger its community gets

The Paradox of Embedded Open Source

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Embedded OSS Paradox

- How to build an ecosystem, when your projects are unique?

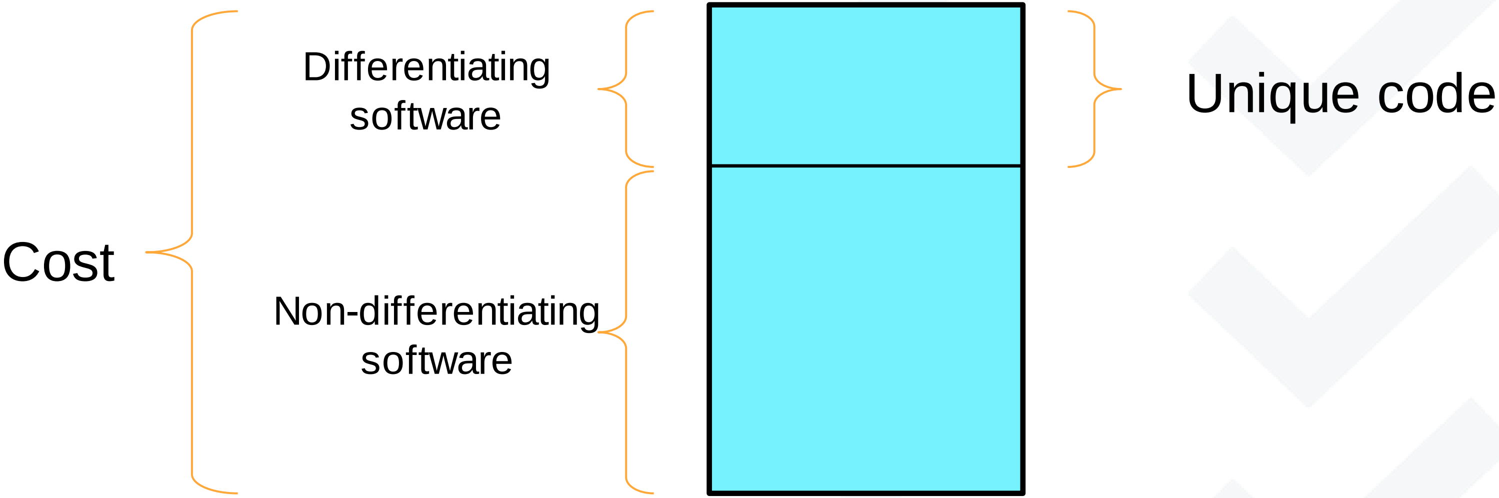
- Other users don't have your use case
- Other users don't use your software
- Other users don't see your bugs
- Your software is not applied to other problem domains

- No Open Source effects!!

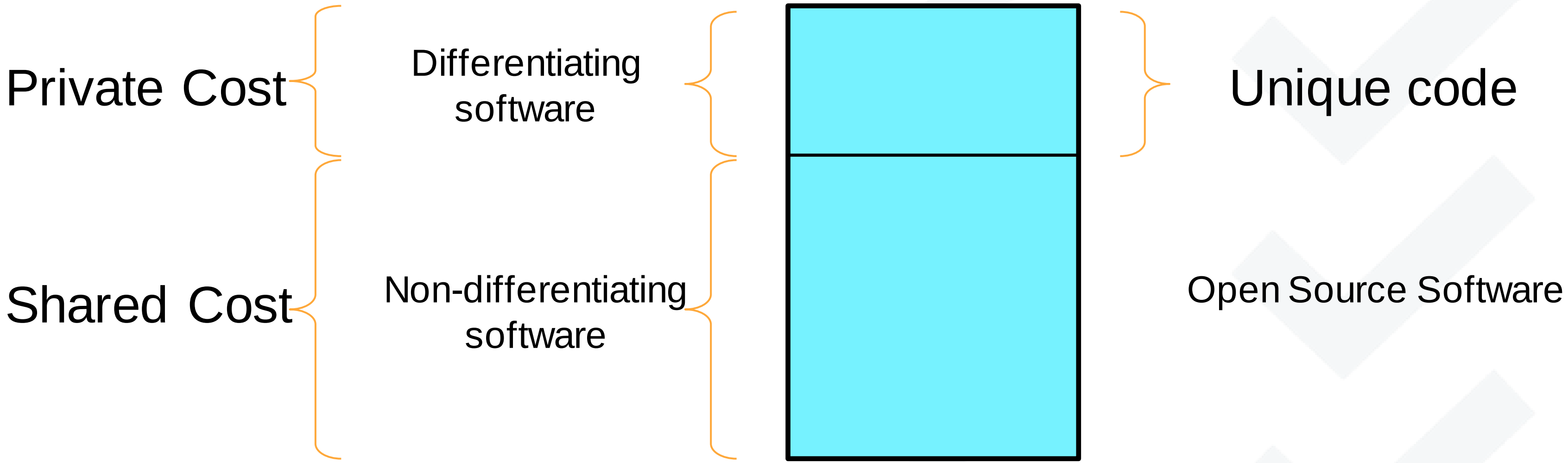
Divide the stack!

- Separate stack into custom solutions and shared code

Differentiating vs. non-differentiating software



Software stack – cheaper way to develop



Private Cost

Differentiating software

Unique code

Shared Cost

Non-differentiating software

Open Source Software

Generalization vs. Specialization

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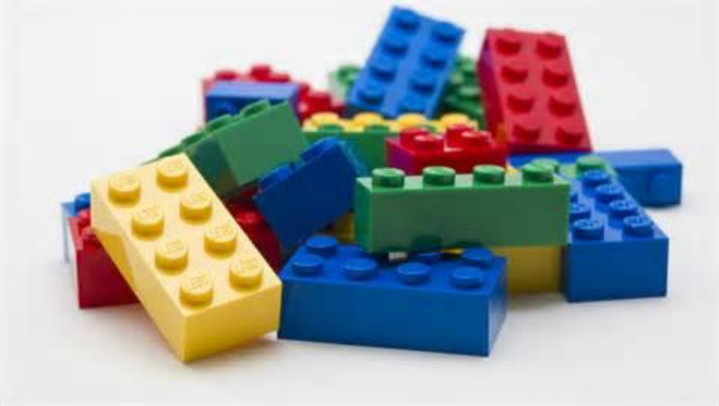
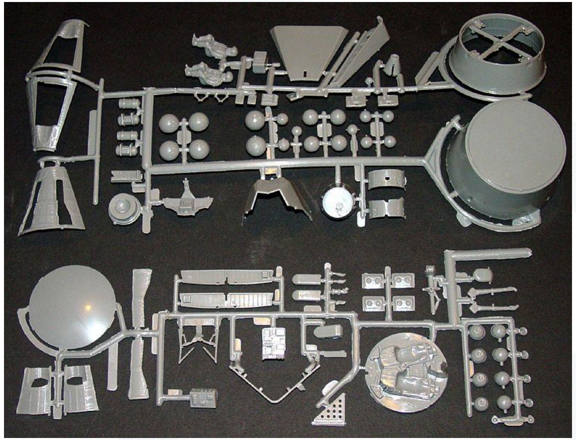
Generalization vs. specialization



Legos

- Modular
- Interchangeable
- Reusable



Parts for a model space capsule

- Custom
- Specific
- Fit-for-purpose

Generalization vs. specialization (cont).

- Spaceship pieces are really good for making a spaceship
- With Lego pieces, you can make also make a spaceship
  - But you can also make a boat, or a car, or a house
- Admittedly, a spaceship made of spaceship pieces will be better
- But the Lego pieces are more general and versatile

Open Source prefer "legos"

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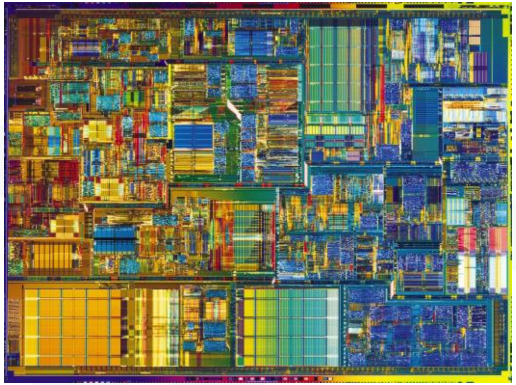
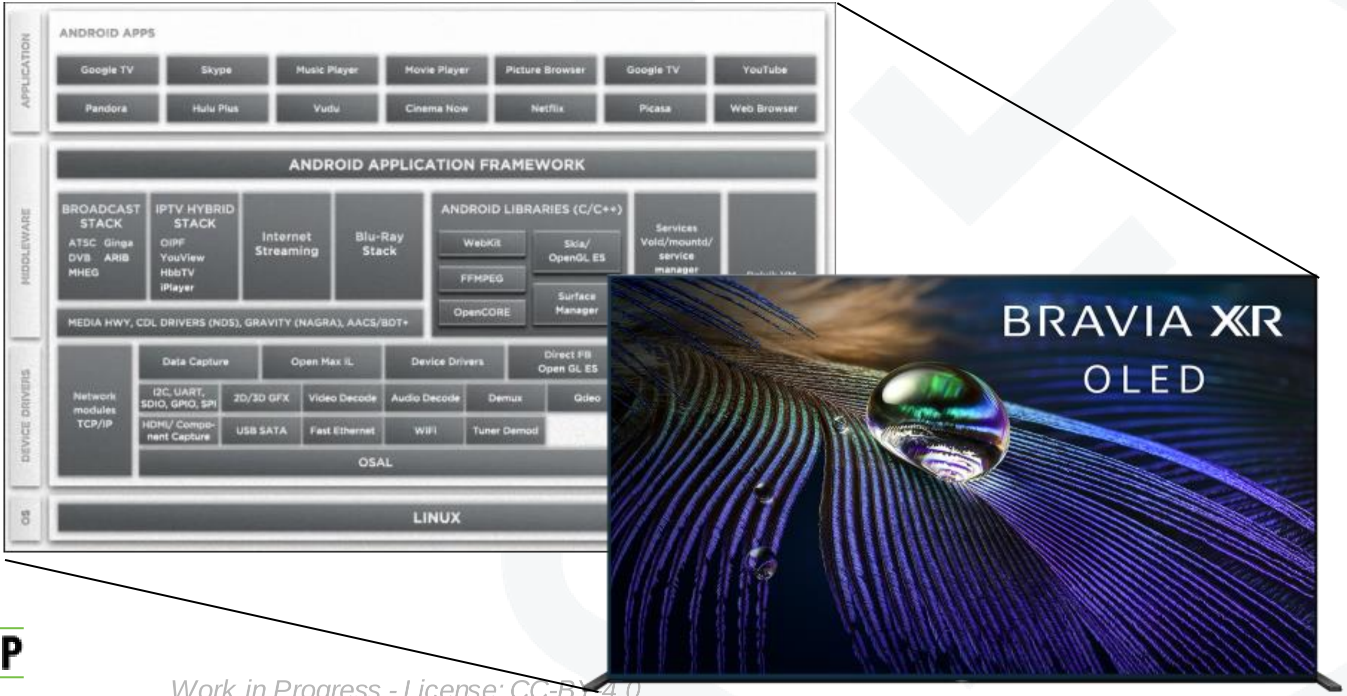
The same is true of modern hardware



- A modern processor has "too much" stuff on it
- Why? – because the processors have been generalized so they can support a wide variety of tasks
  - Commoditization of mobile phone hardware has made processors and hardware features for embedded very cheap
  - There is now a processor that can run Linux, that costs 15 cents
- Your embedded app is unlikely to use every IP block on a modern processor
  - Those are like the rough edges and extra "nubs" on a lego model

Modern software stacks are also complex

- Bravia TV has about 56 million lines of code
- 80 to 90% is open source



Overbuilding, tight margins, and functional safety

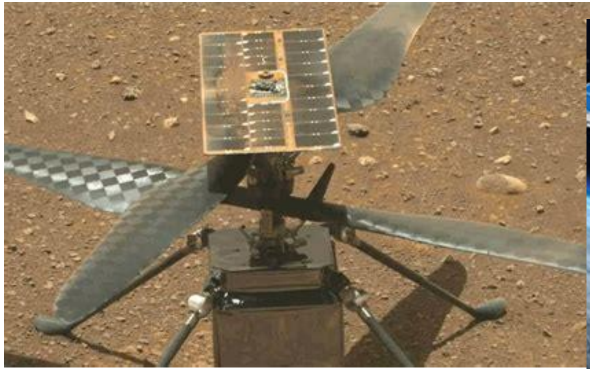
- Does Bravia TV need all that code? (NO)
- Does any embedded product need everything on the SoC? (NO)
- We accept waste (overbuilding) in the processor space but not in the software space

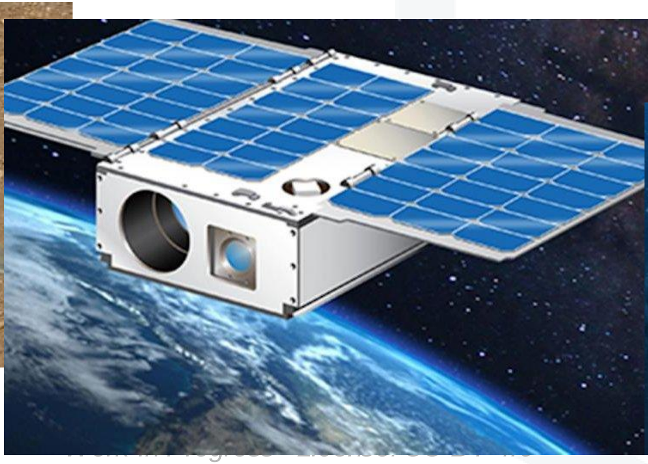
- Functional Safety often means trying to minimize the software to reduce complexity and increase testability

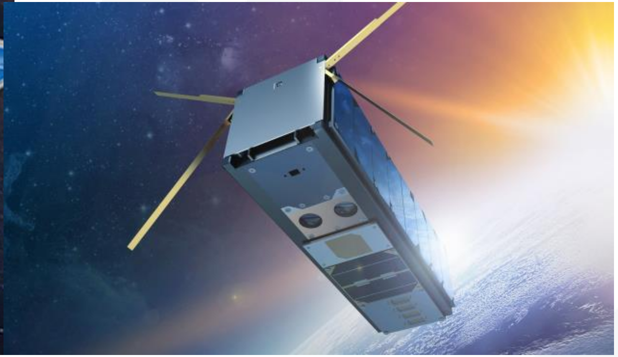
Examples of overbuilding

- Some space missions used shell scripts and Linux distro features to extend capabilities or resolve issues
- Ingenuity used compression to solve a problem, when not in the original plan

  Possible because gzip was in the distribution anyway
- Asteria and Aalto cubesats provided shell callouts







Tips to build an ecosystem

Tips to build an ecosystem

- Increase the community
- Create opportunities for non-experts
- Improve generalization
- Avoid unnecessary specialization
- Find allies

Increase the community

- Actively invite others
- Do something to make the community more interesting or valuable
    - Space has built-in interest factor
    - Gamification
- Reduce barriers to participation
    - Lots of documentation
    - Automation (e.g. project setup tools)
- Contributors come from users

  You have to have users in order to increase the pool of contributors

Create opportunities for contribution by non-experts

- Contributions can be in many forms

  Usage reports

  Bug reports

  Documentation

  Infrastructure management

  Testing

  Reviewing

  Marketing and advocacy

  Code

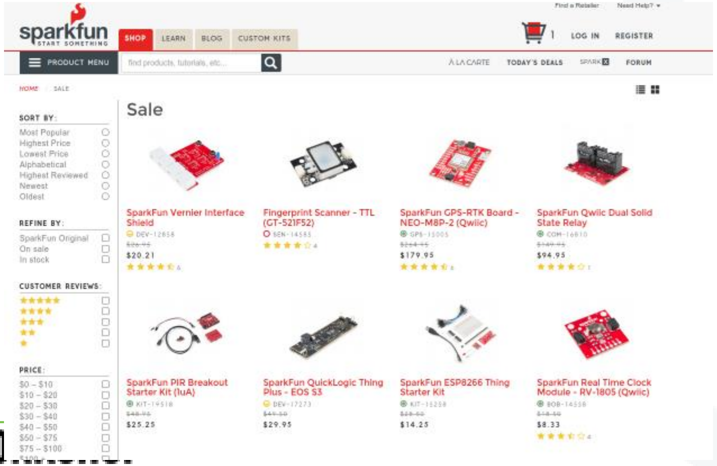
Improve generalization

- Extend existing mechanisms rather than add new ones
  - Candidate: Use a Linux IPC instead of your own message bus
- Make sure your contributions handle other people's use cases

Avoid unnecessary specialization

- Use the same hardware that others are using
- Use the same sub-systems and software technologies as others
- Don't over-reduce

Ship with more than the absolute minimum you need



Sale

SORT BY:
- Most Popular ○
- Highest Price ○
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- Alphabetical ○
- Highest Reviewed ○
- Newest ○
- Oldest ○

REFINE BY:
- SparkFun Original □
- On sale □
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CUSTOMER REVIEWS:
- ★★★★★ □
- ★★★★ □
- ★★★ □
- ★★ □
- ★ □

PRICE:
- $0 – $10 □
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- $40 – $50 □
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SparkFun Vernier Interface Shield
DEV-12858
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★★★★☆ 6

Fingerprint Scanner - TTL (GT-521F52)
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SparkFun GPS-RTK Board - NEO-M8P-2 (Qwiic)
GPS-15005
~~$264.95~~
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SparkFun Qwiic Dual Solid State Relay
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★★★★☆ 1

SparkFun PIR Breakout Starter Kit (1uA)
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$14.25

SparkFun Real Time Clock Module - RV-1805 (Qwiic)
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$8.33
★★★☆☆ 4

Find technical allies

- Find people who care about your issues, and work with them
- Sometimes, it's not who you expect:
  - Small system size
    - Security researchers interested in reduced attack surface
    - Cloud service companies (for low-footprint VMs)
  - Low power usage
    - Mobile phone developers, IOT developers
    - Data Center Linux developers
  - Fault Tolerance
    - Banking, Routers

Technical Allies – boot time example

- Recently started a Boot Time Special Interest Group (SIG)
- Found lots of people from different sectors interested:
  - Automotive, Consumer Electronics, Desktop, Mobile
  - Some unexpected: Cloud Servers, Supercomputers
    - For quick service spinup, initialization of chips with high CPU count
  - Lots of developers with limited kernel development experience
    - I created automated tools and a wiki for people to contribute data and docs

Conclusion

Let's work together on

a bright and interesting future!

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Thanks!

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